

Potential Impacts of Emergency Seeding on Cover and Diversity Patterns of Californian Shrubland Communities

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Abstract. Chaparral and coastal sage scrub comprise two major shrubland types in mediterranean climate areas of California whose structure and function are profoundly influenced by fire. Since the 1940's, land managers in southern California have sown seeds of native shrubs and introduced grasses and forbs onto postburn shrubland slopes in an attempt to reduce sediment yield resulting from late fall and winter rains. This paper explores possible influences of emergency rye grass seeding upon postburn shrubland components of species richness and cover. Native herbs constituted the great bulk of ground surface coverage on sample sites stratified by aspect and substrate type. The herb flora mainly consisted of native annual dicots of which a few dominant species contributed the great bulk of cover. The majority of all the 168 plant species encountered in the study displayed aspect and/or substrate preferences. Correlations between rye grass cover and herb species richness, native species richness, and native species cover were all weakly negative. Correlations between rye grass cover and seedling densities of both *Ceanothus megacarpus* and *C. oliganthus*, both obligate seeding shrubs, were also weakly negative. With the exception of sites or portions thereof where rye grass cover was locally heavy, it appears unlikely that dominant elements of the postburn flora were impacted by the emergency seeding. However, even light to moderate rye grass cover may negatively impact uncommon elements of the postburn flora which constitute most of the species present. Competitive interactions between rye grass and diverse assemblages of species associated with different habitat types could lead to disproportionately large negative impacts upon overall species diversity. Further, such impacts would not be mitigated by substitution of native for non-native species for the emergency reseeding since the competitive interaction would likely produce similar results.

Keywords: Chaparral; coastal sage scrub; emergency seeding; *Lolium multiflorum*; southern California; species diversity; vegetative recovery.

Introduction

Chaparral and coastal sage scrub comprise the two major shrubland types in mediterranean climate regions of California, and their structure and function are profoundly influenced by fire (Keeley and Keeley 1988, Mooney 1988). Chaparral, the more widespread and better understood type, usually occupies higher elevation, moister sites and is composed of deep-rooted woody shrubs averaging 2-4 m in height with sclerophyllous, evergreen leaves. Coastal sage scrub, which is typical on drier, lower-elevation sites than chaparral, is characterized by malacophyllous, drought deciduous subshrubs with comparatively open canopies and shallow roots. The more open nature of coastal sage scrub permits the occurrence of a greater herb component than is usually associated with mature chaparral (Westman 1979).

High density of shrub cover, extreme summer drought characteristic of a Mediterranean-type climate, and accumulation of volatile fuels result in periodic fires in California's shrubland vegetation. Fires occur every 20-50 years (McPherson and Muller 1969, Keeley 1986) with unburned stands over 50 years being uncommon (Bauer 1936, Hanes 1977, Keeley 1992a,b). However, Keeley and Zedler (1978) suggest that pre-settlement chaparral is adapted to both short and long fire-free periods, the latter occurring in the southern, coastal portions of the state and being fire-free for up to a century. The various adaptations of shrubland dominants (Wells 1962, Keeley and Zedler 1978) and occurrence of fossil charcoal in offshore ocean sediments suggest that fire has long exerted a strong selective force within shrubland communities (Byrne et al. 1977, Johnson 1977, Berger 1980).

Keeley and Zedler (1978) and Keeley (1986) characterized sprouting and non-sprouting as two ends of a regeneration strategy continuum for chaparral shrubs, many of which reproduce almost exclusively by one means or another (obligate sprouters vs obligate seed-

ers). Facultative resprouting represents another regeneration strategy that occurs at an intermediate position on the regeneration strategy continuum, and is characterized by species that both resprout and produce seedlings the first postburn year. Coastal sage shrubs, like several chaparral shrubs, occur at an intermediate location on this continuum but fundamentally differ by being capable of more vigorous seedling recruitment during inter-fire periods (Malanson and O'Leary 1982, Keeley 1992a,b, Keeley and Keeley 1984).

A profusion of short-lived herbs termed "pyrophyte endemics" (Hanes 1977) usually dominate the ground cover of chaparral during the first growing season after fire and are greatly reduced in number and diversity the following year (Hanes 1977, Keeley et al. 1981). After fire most of these same species commonly occur in coastal sage scrub though sometimes in reduced abundance owing to the presence of perennial herbs (Keeley and Keeley 1984, O'Leary 1990, O'Leary and Westman 1988). The vast majority of these herbs are annuals which are believed to arise from a dormant seed pool whose germination requires the stimulatory effect of heat, charred wood and light in varying combinations (Keeley 1991). Apparently these ephemeral herbs are prominent in stabilization of postburn nutrient losses in chamise chaparral (Rundel and Parsons 1984).

Since the 1940's, land managers in southern California have sown seeds of native shrubs and introduced grasses and forbs onto postburn shrubland slopes in an attempt to reduce sediment yield resulting from late fall and winter storms (Beyers et al. 1994). During the past several decades the non-native annual ryegrass (*Lolium multiflorum*) emerged as the most commonly used species for postburn emergency seeding owing to its rapid germination, extensive root system, inexpensive cost, and availability (Department of Forester and Fire Warden 1985, Beyers et al. 1994). However, there is much controversy over the efficacy of emergency seeding in reducing slope erosion and over the potentially negative impact of emergency seeding upon postburn biotic processes (e.g., Keeley et al. 1981, Gautier 1983, Nadkarni and Odion 1986, Taskey et al. 1989, Conrad and Beyers, these proceedings). Unfortunately few quantitatively rigorous studies, utilizing appropriate experimental design, have been conducted that adequately address postburn effects of emergency seeding (Barro and Conrad 1987). Indeed, results from all studies are complicated by external factors such as year-to-year variability in timing and amounts of precipitation, soil type, topography (e.g., slope steepness and aspect), fire history, and vegetation composition.

In this paper, I explore possible influences of emergency ryegrass seeding upon postburn shrubland components of species richness and cover. I will focus

on patterns recorded after a fire in 1978, some of which has previously been reported on (O'Leary 1984, 1988).

Study Area

The study area was located on coastal slopes of the western Santa Monica Mountains, 55 km west of central Los Angeles (Fig. 1). It was within a 9500 ha area of chaparral and coastal sage scrub that burned in late October, 1978. Shortly after the fire, the entire area was aerially seeded with ryegrass as an emergency erosion prevention measure.

The region has a Mediterranean-type climate, with nearly 93% of the average annual precipitation falling from November through April. Average precipitation values range from about 380 mm on coastal terraces near Pt. Dume to about 520 mm at the crests of the range. Precipitation totals for hydrologic year 1978-79 were about 38% above normal for the area (Los Angeles County Flood Control 1979). The area's rugged topography is underlain by sedimentary and volcanic rocks of Eocene to Miocene age, which have been severely folded and faulted (Wilson 1955, Bass 1960, Campbell et al. 1968). All volcanic sample sites were located on andesitic rock of the Conejo formation, and all sedimentary sample sites were located on Sespe sandstone, except those near Castro Peak, which were on sandstones of the Vaqueros and Topanga formations.

Methods

In the spring after the fire of October 1978, 22 sample sites were selected and categorized by substrate, andesite or sandstone; slope aspect, north and south; and elevation at 150-m intervals between 100 and 850 m (however, no andesitic slopes in the study area extended above 750 m). Thus, there were six replicate sites each on north- and south-facing sandstone slopes and five replicate sites each on north- and south-facing andesitic slopes. North and south aspects were selected so that aspect-caused differences in vegetation owing to differences in evapotranspirative stress would be highlighted. All study sites supported chaparral prior to burning, except the three lowest sites which supported coastal sage scrub. Sites selected had slope inclines of 20-32°. Prior to the 1978 fire, all sample sites apparently had been burned in a single conflagration in late 1956 (Los Angeles County Fire Department, unpublished fire maps).

Two transects, 25 m apart, each consisting of 25 1-m² quadrats, were used for floristic sampling of each

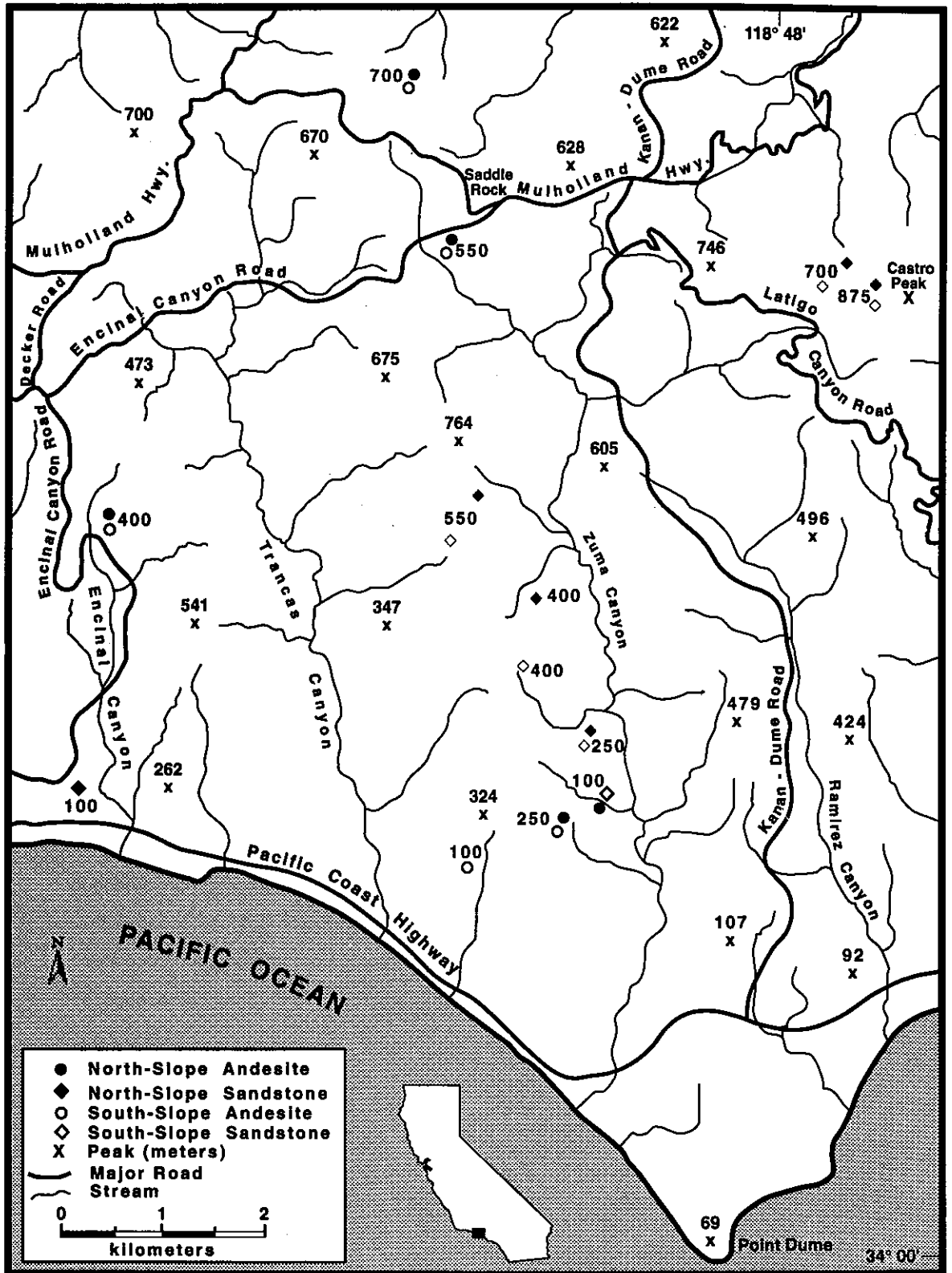


Figure 1. Location and elevation of the 22 sample sites (indicated by solid and hollow circles and diamonds) stratified by substrate type and aspect in the central Santa Monica Mountains.

site. Cover of each plant species in all 50 quadrats was visually estimated by two observers and averaged before recording. Density counts of all vascular species located in every fifth quadrat of both transects was taken. Any additional species present in the overall 25 x 25 m area between the two transects were recorded as present on site. Each site was sampled during early to late April, the time of peak herbaceous cover. Correlation coefficients were calculated between *Lolium multiflorum* cover and herb species richness, native species richness, native species cover, *Ceanothus megacarpus* seedling density, and *C. oliganthus* seedling density. Cover and richness values used for the analyses were taken from 20 quadrats randomly selected from each sandstone site and 24 quadrats randomly selected from each andesitic site. Nomenclature follows Hickman (1993).

Four randomly located soil samples were removed from the upper 15 cm of each site and analyzed for physical and chemical properties as described by O'Leary (1988).

Results and Discussion

Cover and diversity patterns

Statistically significant differences in physical and chemical soil properties existed between andesite and sandstone samples, but not between north- and south-

facing slopes. Average foliar cover of important growth-forms for the four major habitat-types is summarized in Figure 2. During the peak of the spring growing season, herbs (especially) and vines contributed the great bulk of ground surface coverage on most sites. Andesite had greater herb cover on north- and south-facing slopes yet sandstone showed the reverse. Total herb cover and differences between sites decreased in the later sampling. Taken as a whole, average herb cover of sandstone versus andesitic sites did not differ greatly (22.5% vs 31%).

The herb flora consisted mostly of native annual dicots (Table 1). A few dominant species such as *Eucrypta chrysanthemifolia*, *Phacelia parryi*, *P. grandifolia*, *Lupinus hirsutissimus*, and *Chaenactis artemisiifolia* contributed the great bulk of cover. Most of the dominant species of these "pyrophyte endemics" showed aspect preferences and some had pronounced substrate affinities as well (presented in O'Leary 1988). The two vine species prominent in this study, *Calystegia macrostegia* and *Marah macrocarpus*, also co-dominated the first postburn spring on south-facing sandstone and north-facing andesitic sites, respectively. Indeed, the majority of all 168 plant species encountered in this study displayed aspect and/or substrate preferences (O'Leary 1984), the 30 most important of which are presented in Table 2. *Lolium multiflorum* was the dominant exotic herb, averaging 3.4% ground surface cover (range: 0% - 15%), and comprising 12.6% of the total herb cover. All other exotic herbs accounted for only 1% of the herb cover.

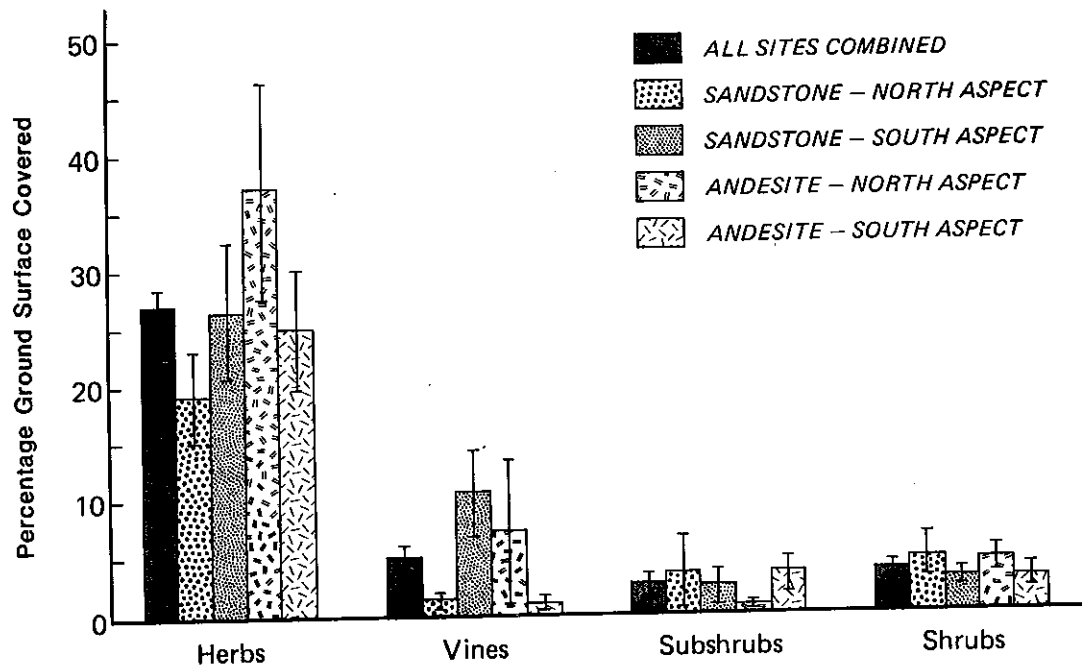


Figure 2. Average foliar cover (\pm SE) of major growth forms for the four habitat-types.

Table 1. Characteristics of postfire herbaceous flora at all 22 sample sites in the Sant Monica Mountains.

Number of Species Present	Life History Type		Class		Origin	
	Annual vs. Perennial		Dicot vs. Monocot		Native vs. Introduced	
	% Species Annual	% Cover Annual	% Species Dicot	% Cover Dicot	% Species Native	% Cover Native
168	59	71	79	88	88	88

Both the chaparral and coastal sage scrub sites exhibited higher species richness in the spring sampling relative to likely preburn values. Average species richness at two sampling scales, 1-m² and 625-m², and individuals per 1-m² quadrat are shown in Figure 3. No significant differences in species richness occurred at either scale between any major habitat types. Richness values at the 1-m² scale reported here are slightly less than those (@ 12 spp./m²) observed on spring postburn sites of coastal sage scrub and chaparral in Orange, Los Angeles, Riverside and San Diego counties in the aftermath of the large wildfires of October, 1993 (John O'Leary and Robin Wills, unpublished data; Jon Keeley, personal communication). Most of the species at either sampling scale were native annual dicots.

Partitioning of foliar cover values is shown clearly by the dominance-diversity curve for north-facing sandstone sites (Fig. 4). The general form of the curve and those for the other three habitat types (not shown) was the same; i.e., lognormal. Clearly, the first few species in the sequence account for the overwhelming bulk of overall foliar cover, and a substantial number of species on an average site are comparatively rare.

North-facing sites averaged nearly twice the density as on south-facing sites (93 vs 49 per 1-m²); and on andesitic sites the discrepancy was even greater. These results agree closely with those of Radtke (1981) who sampled mid- elevation chaparral sites on north and south aspects. Number of *Lolium* individuals per quadrat was fairly even between all major habitat types (\bar{X} = 6.0/m²), except on south slope andesite (\bar{X} = 2.2).

Table 2. Average foliar cover and percentage frequency occurrence (in parentheses) of the 30 most abundant postburn plants (listed in decreasing abundance) found in the 22 sample sites.

Species	Sandstone		Andesite	
	North	South	North	South
	(n=6, 300)	(n=6, 300)	(n=5, 250)	(n=5, 250)
<i>Eucrypta chrysanthemifolia</i>	4.9 (35)	0	25.5 (80)	0.2 (9)
<i>Chaenactis artemisiifolia</i>	0.1 (13)	4.2 (74)	*(1)	7.4 (62)
<i>Calystegia macrostegia</i>	0.2 (23)	8.8 (66)	0.4 (21)	0.9 (23)
<i>Lupinus hirsutissimus</i>	**	3.8 (23)	**	6.2 (32)
<i>Phacelia parryi</i>	*(2)	6.2 (58)	0	2.2 (46)
<i>Marah macrocarpus</i>	1.2 (25)	1.7 (10)	5.8 (46)	**
<i>Phacelia grandiflora</i>	2.1 (40)	1.3 (25)	0	0.3 (10)
<i>Hazardia squarrosa</i>	2.1 (21)	0.1 (6)	0.2 (11)	0.6 (12)
<i>Malosma laurina</i>	*(3)	1.4 (22)	0.2 (8)	1.4 (14)
<i>Phacelia brachyloba</i>	2.8 (33)	0	0	0
<i>Adenostoma fasciculatum</i>	0.8 (36)	1.1 (36)	0.2 (11)	0.4 (24)
<i>Lotus salsuginosus</i>	0.1 (17)	0.9 (31)	0.1 (15)	1.5 (35)
<i>Quercus berberidifolia</i>	2.2 (13)	0	0	0
<i>Phacelia cicataria</i>	1.0 (12)	0.2 (4)	1.0 (33)	*(2)
<i>Cercocarpus betuloides</i>	0.2 (6)	0.2 (3)	1.9 (36)	0.2 (1)
<i>Eriogonum cinereum</i>	0.7 (13)	0.7 (8)	**	0.5 (10)
<i>Apiastrum angustifolium</i>	0.9 (30)	*(3)	0.9 (38)	0.1 (6)
<i>Venegasia carpesioides</i>	0.4 (40)	0	1.5 (63)	0
<i>Eschscholtzia californica</i>	0	1.3 (12)	0	0
<i>Encelia californica</i>	0	1.0 (12)	0	0.3 (5)
<i>Lotus scoparius</i>	0.2 (41)	0.2 (38)	0.1 (26)	0.9 (57)
<i>Cryptantha muricata</i>	**	0.4 (12)	0	0.8 (15)
<i>Arctostaphylos glandulosa</i>	1.1 (21)	0	0	0
<i>Ceanothus spinosus</i>	0	*(3)	1.2 (46)	0
<i>Yucca whipplei</i>	0	0.4 (5)	**	0.7 (12)
<i>Helianthemum scoparium</i>	0.6 (36)	0.3 (20)	0	0
<i>Lotus strigosus</i>	*(2)	0.8 (21)	0	0.1 (5)
<i>Pholistoma auritum</i>	0	0	1.0 (6)	0
<i>Salvia mellifera</i>	0.1 (3)	0.1 (16)	0.1 (25)	0.6 (57)
<i>Calandrinia breweri</i>	0.5 (24)	0.2 (5)	0.1 (5)	0

* Average cover < 0.1%
 ** Percent frequency < 1 Figures

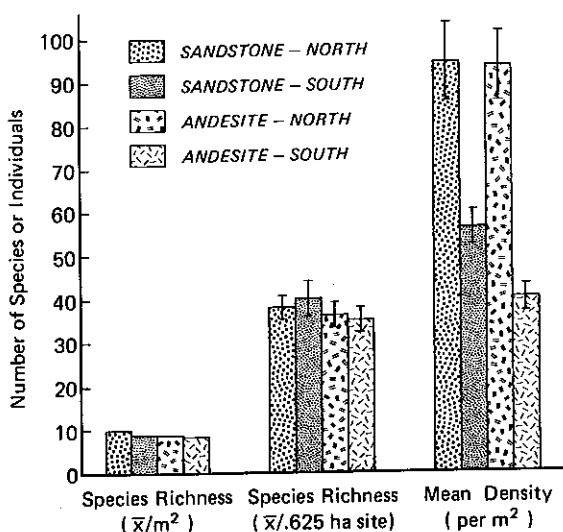


Figure 3. Mean species richness for all species (\pm SE) at the $1\text{-m}^2 \pm 2$ ($N = 120$ for each habitat type) and 625-m^2 ($N = 6, 6, 5, 5$, respectively) sampling scales, and mean density (\pm SE) at the 1-m^2 sampling scale for all major habitat types.

Correlation analyses

Correlations between *Lolium multiflorum* cover and herb species richness, native species richness, and native species cover are presented in Table 3. All were weakly negative and, although the correlation between

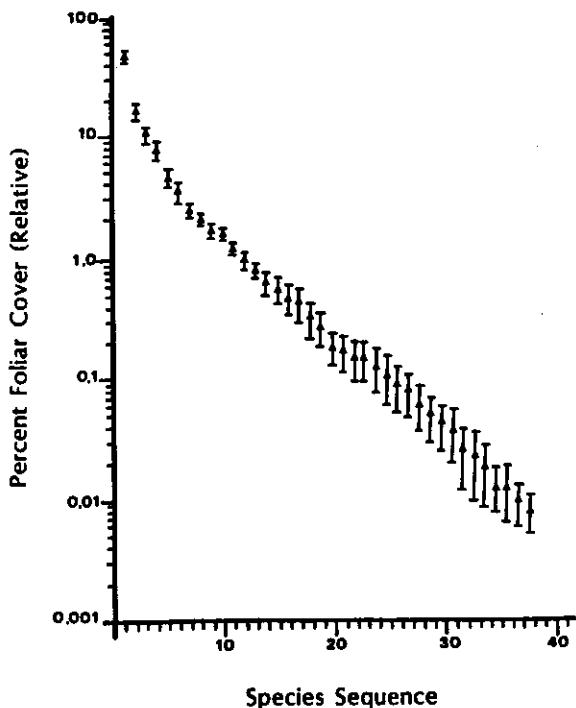


Figure 4. Dominance diversity curve for the six north-facing sites with sandstone substrates. Each value represents the mean cover (\pm SE) for the i th species in the sequence.

Table 3. Correlation coefficients and 95% confidence intervals between *Lolium multiflorum* cover and: 1) herb species richness, 2) native species richness, and 3) native species cover. Population (true) correlation coefficients in the confidence intervals are represented by the letter ρ (rho).

Herb Species Richness	Native Species Richness	Native Species Cover
$r = -0.022$	$r = -0.101$	$r = -0.189$
$-0.471 < \rho < 0.427$	$-0.204 < \rho < -0.018$	$-0.284 < \rho < -0.098$
$n = 22$	$n = 445$	$n = 445$

Lolium cover and native species cover was statistically significant, the strength of the explanatory relationship is extremely low. Correlations between *Lolium* cover and native species richness and native species cover, by habitat type, are presented in Table 4. Though slightly higher than the previous correlations, most were still weakly negative, and are likely of minor biological significance. No clear or strong relationships emerged between the major habitat types for either native species cover or richness. In addition, correlation coefficients were computed between *Lolium* cover and native species cover and native species richness contrasting north vs. south facing sites and andesitic vs. sandstone sites. Again, correlations were weakly negative, ranging from -0.077 (*Lolium* cover vs. native species richness on all andesitic sites) to -0.217 (*Lolium* cover vs. native species richness on all south-facing sites).

Occurrence of heavy rainfall shortly following the aerial seeding of ryegrass likely resulted in much of the *Lolium* seed being washed off of the moderate-to-steep slopes that characterize most of the study area. I observed heavy ryegrass cover in some gullies and small stream channels into which ryegrass seeds had washed. It is unlikely that most of the dominant postburn species encountered in this study were significantly impacted by competition from *Lolium multiflorum*. The generally low negative correlations between *Lolium* cover and native species richness and cover appear to support this contention. However, lack of unseeded control sites prevent testing of differences. Keeley et al (1981) and Beyers et al (1994) have noted that artificial seeding with *Lolium* on postburn chaparral had no apparent effect on total herb cover. *Lolium* success, however, was at the expense of native herb cover, particularly the "fire annual" component. Their results agreed closely with earlier experimental results of Rice and Green (1964) and Corbett and Green (1965) regarding influence of *Lolium* seeding on species composition and cover of postburn chaparral. Beyers et al (1994) also reported significant reductions in native herb richness including some plots where ryegrass cover averaged only 7.4%. Further, Nadkarni and Odion (1986) reported that species richness on

Table 4. Correlation coefficients and 95% confidence intervals between *Lolium multiflorum* cover and native species richness and native species cover, within each major habitat type. Population (true) correlation coefficients by the letter p (rho).

	Sandstone		Andesite	
	North (n = 120)	South (n = 120)	North (n = 120)	South (n = 120)
Native species richness	r = 0.197 -0.348 < ρ < 0.014	r = -0.274 -0.462 < ρ < -0.100	r = -0.187 -0.318 < ρ < -0.044	r = -0.370 -0.370 < ρ < -0.008
Native species cover	r = -0.131 -0.313 < ρ < 0.049	r = -0.181 -0.364 < ρ < -0.002	r = -0.327 -0.521 < ρ < -0.159	r = -0.057 -0.238 < ρ < -0.124

Lolium seeded plots was 40% lower than unseeded plots in Ventura County, California.

The dominant obligate sprouting chaparral shrubs in the study area (*Ceanothus spinosus*, *Cercocarpus betuloides*, and *Quercus beridifolia*) resprouted vigorously after the fire and appear unaffected by the ryegrass seeding. Far more susceptible would be facultatively resprouting shrubs of chaparral (e.g. *Adenostoma fasciculatum* and *Arctostaphylos glandulosa*) and, especially, coastal sage scrub. Most susceptible would be obligate seeding chaparral shrubs such as *Ceanothus megacarpus* and *C. oliganthus* whose regeneration is strictly dependent upon seedling establishment the first postburn year. Schultz et al (1955) reported light to moderate reductions in brush seedling density when seeded grass cover ranged from about 2.5 - 4.5%, and heavy reductions when seeded grass cover ranged from about 15 - 40%. Correlations between *Lolium* cover and seedling densities of *Ceanothus megacarpus* ($\bar{X} = 2.01$ individuals per 1-m²) and *C. oliganthus* ($\bar{X} = 4.08$ individuals per 1-m²) were both weakly negative ($r = -0.028$ and $r = -0.148$, respectively) but statistically insignificant. Again in this study, *Lolium* cover was likely too low to cause a significant repression effect that would lead to compositional and structural shifts comparable to those noted by others (e.g. Schultz et al 1955, Nadkarni and Odion 1986).

Conclusions

With the exception of sites or portions thereof where *Lolium* cover was locally heavy, it would appear unlikely that dominant elements of the native postburn flora were significantly impacted by the emergency seeding. However, this is likely a fortuitous event owing to low average *Lolium* cover, a result that probably disappointed resource managers in charge of the emergency seeding operation. Even so, light to moderate *Lolium* cover may negatively impact establishment of herb species that are naturally uncommon elements of the postburn flora. The lognormal shape of postburn dominance diversity curves for both chaparral and coastal sage scrub clearly indicate that a substantial proportion of postburn species are relatively

rare at the 625-m² sampling scale. Such an element would be put at substantially greater risk of local extirpation if *Lolium* cover ranged from moderate to heavy. *Papaver californicum*, a fire-following annual, represents such an example. It displayed a strong habitat preference for north-facing sandstone sites, occurring in 25% of the 300 quadrats, but averaged only 0.2% ground cover. It occurred in only six of the other 800 quadrats found on the other three major habitat types. Heavy "successful" ryegrass seeding, germination, and growth could easily put uncommon species like *P. californicum* and others at substantial risk.

The species list presented in Table 2 illustrates the fact that the four habitat types sampled in this study support plant assemblages that differ substantially in floristic composition. Consequently, competitive interactions would occur between *Lolium* and diverse assemblages of species associated with each habitat type likely leading to disproportionately large negative impacts upon overall species diversity. Further, such negative impacts would not be mitigated by substituting native species for the emergency seeding since the competitive interaction would likely produce similar results. Emergency seeding of any species, native or non-native, probably serves as little more than a short-term psychological palliative but does have the potential to alter compositional and diversity patterns of these shrubland communities.

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