# Effects of Burning and Grazing on a Coastal California Grassland

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**Abstract**

**We tested the effects of fall burning and protection from livestock grazing as management to enhance native grasses on a coastal grassland in central California. Plants from the Mediterranean, introduced beginning in the late 1700s, have invaded and now dominate most of California's grasslands. Coastal grasslands are generally less degraded than those inland and have higher potential for restoration and conservation. Productivity of the experimental plots varied annually and declined over the course of the study because of rainfall patterns. Foliar cover of the native *Danthonia californica* (California oatgrass) increased more under grazing than grazing exclusion and did not respond to burning. Two other natives, *Nassella pulchra* (purple needlegrass) and *Nassella lepida* (foothill needlegrass), responded variably to treatments. The response of *N. pulchra* differed from that reported on more inland sites in California. Restoring these grasslands is complicated by differing responses of target species to protection from grazing and burning. The current practice of managing to enhance single species of native plants (e.g., *N. pulchra*) may be detrimental to other equally important native species.**

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## Introduction

California's Mediterranean grassland covers approximately 10 million ha in the foothills of the inland central valley and along the coast (Heady et al. 1991). This grassland has undergone an extensive and permanent change in floristic composition over the past 250 years. Since the mid-1800s, introduced species have spread widely, and replaced natives with annuals (Elliott & Wehausen 1974; Heady et al. 1991) or weedy perennials (Peart & Foin 1985). The current flora is dominated mostly by introduced Mediterranean annuals, but the original vegetation probably was dominated by perennial bunchgrasses (Bartolome et al. 1986). These bunchgrasses are moderately tolerant of grazing (Bartolome & Gemmill 1981; Edwards 1996) and dry season (summer and fall) fires (Heady 1968), but are sensitive to heavy livestock use (Heady et al. 1991). Removal of livestock does not result in succession to a native-dominated community, but some native perennial grasses typically are present even with heavy livestock grazing (Heady et al. 1991). This is especially true on coastal sites (Bartolome 1994) that have never been tilled (Stromberg & Griffin 1996). Studies of practices that enhance or restore native perennials have generally occurred on inland sites (Hatch et al. 1991; Dyer et al. 1996).

Grasslands along California's coast differ considerably from the more-studied inland types (Bartolome 1994). Thus, two major vegetation types are recognized within California's Mediterranean grassland: the annual-dominated Valley Grassland in the foothills of the Central Valley, and the Coastal Prairie (Heady 1977). The putative original Californian Coastal Prairie was dominated by native perennial bunchgrasses (Heady et al. 1977) such as *Danthonia californica* (California oatgrass) and *Deschampsia caespitosa* var. *holciformis* Beauv. (tufted hairgrass). Although coastal grasslands in northern and central California have been largely invaded by annual plants from the Mediterranean, native perennial species are more common (Heady et al. 1991), and successful invaders are more likely to include perennial species (Hektner & Foin 1977) than in inland grasslands. The coastal grassland represents a valuable resource as a remnant California grassland often dominated by native perennial plants.

Cooper (1960) reported increased foliar cover of *D. californica* after 1 year of reduced stocking and rotation grazing in a deteriorated Coastal Prairie. A management change from heavy year-round grazing to more moderate deferred-rotation grazing seems sensible, but experiments investigating restoring native grasslands with grazing or burning are lacking and Edwards (1996) has observed that *D. californica* may increase with heavy grazing. Research on Valley Grassland and Oak Savannas in the Sacramento Valley, more than 75 km inland and 150 km northeast of our site, has shown that burning and seasonal grazing can enhance establishment of *Nassella pulchra* (purple needlegrass) (Hatch et al. 1991; Dyer et al. 1996). However, the coastal climate has cooler summers and warmer winters with frequent fog. The response of plants on the coast could be different from that on inland locations and coastal *N. pulchra* has been shown to have different phenology and defoliation response compared to inland individuals (Huntsinger et al. 1996).

This study has examined the effects of grazing exclusion and fall burning on species composition of a grazed Coastal Prairie. It investigated the potential of management strategies that are successful on inland grasslands. We hypothesized that burning and/or grazing would benefit native perennial grasses and we expected the effects to be additive rather than interactive. Also, we hypothesized that position along the slope (upper, middle, lower) of our study site would have no effect.

## Site

Investigations were conducted in a 150-ha area of Pomponio Beach State Park in central coastal California, about 75 km south of San Francisco. The climate is typical for the central California coast with 65 cm mean annual precipitation, mostly falling in winter with frequent fog. The dry season lasts from May through October, producing a November-through-June growing season, and fires are common during late summer and early fall. The area is near sea level on a coastal terrace a few hundred meters from the ocean. It extends 1 km inland to an elevation of approximately 150 m. The land has been grazed for approximately 150 years and was purchased by the state in the 1970s, with lifetime use and occupancy rights to the historic owner.

During the study, the area exclusive of experimental exclosures was grazed yearlong by approximately 15 dairy cows and 200 sheep. The study plots were in a section of the park seldom grazed by cattle and unevenly grazed by sheep. This grazing pattern has had a continuous tenure of at least several decades.

The soils in the upper slope were mapped as Tierra loams, which are classified as fine, montmorillonitic, thermic mollic paleoxeralfs (Wagner & Nelson 1961). Soils in the middle and lower slope were mapped as Colma sandy loams, which are classified as fine, loamy, mixed mesic typic argixerolls.

The vegetation was dominated by Mediterranean annual grasses with scattered perennial grass stands dominated by *D. californica, N. pulchra*, and *Nassella lepida.* These natives were the most abundant plants in the study area with an average of 17.3, 19.4, and 7.4% foliar cover, respectively (see Methods). The most intensively studied nonserpentine coastal grasslands in California, located at Bodega Head and Sea Ranch north of San Francisco, contain much less *D. californica* and *Nassella* spp. and many more exotic perennials than our site at Pomponio Beach (Hektner & Foin 1977; Peart & Foin 1985). *N. lepida* had the patchiest distribution. Annuals of Mediterranean origin, including *Vulpia bromoides* S.F. Gray (foxtail fescue), *Lolium multiflorum* Lam. (annual ryegrass), *Bromus hordeacous* L. (soft chess), and *Aira caryophyllea* L. (silver hairgrass), contributed 17.6, 8.6, 7.1, and 3.7% foliar cover, respectively. Forbs were not abundant. Only *Plantago* spp. (*Plantago. maritima* L., *Plantago lanceolata* L., and *Plantago erecta* E. Morris) at 6.5%, and *Hypochoeris glabra* L. (smooth cat's ear) at 1.4%, exceeded 1% cover.

## Methods

Three study areas of approximately 0.25 ha each were established in native perennial stands on the upper, middle, and lower slope of the park. Grazing exclusion and burning treatments were applied in a randomized complete block design. Fences constructed in late summer of 1989 excluded livestock from the ungrazed treatments (Fig. 1). The burning treatment was applied 3 November 1990, which is within the summer-fall historic window of natural fire in the region, and precedes the area's late fall though spring growing season.

Percent foliar cover, frequency of perennial grasses, and standing crop were measured in the springs of 1989 and 1991. Percent foliar cover was determined from 50 points on each of the two permanent 10-m transects established in late summer of 1988 at random locations within each study unit. The transects were averaged for each study unit. The change between 1989 and 1991 was used for the analysis. Frequency was estimated from four 50 $\times$ 50-cm plots, located randomly and permanently established along each transect. The presence or absence of native perennials in the 100 5 $\times$ 5-cm contiguous subplots within each were recorded. The eight plots in each study unit were averaged to determine the number of occupied subplots, and the frequency per $m^2$ was calculated. The percent change in frequency between 1989 and 1991 was used for analysis. Peak standing crop (Kg/ha) dry weight per unit was estimated from two randomly located, clipped 0.06-$m^2$ quadrats each year. Clipped material was oven dried at 70°C for 48 hr.

Estimating frequency using the method described, similar to Kershaw (1957) and Thompson (1958), has practical advantages: it requires less labor than counting, and it obviates the need to determine which plants are separate individuals. For grasses, determining separate individuals may not be possible without genetic analysis.

Dependent variables were analyzed using analysis of variance (ANOVA) with grazing as the main plot treatment and burning as a split on main plots. Results were considered statistically significant if $P < 0.10$, and means were separated by the Least Significant Difference method. Because the design does not include replications of the experiment at the landscape level, results are limited to the population on the specific site we studied.

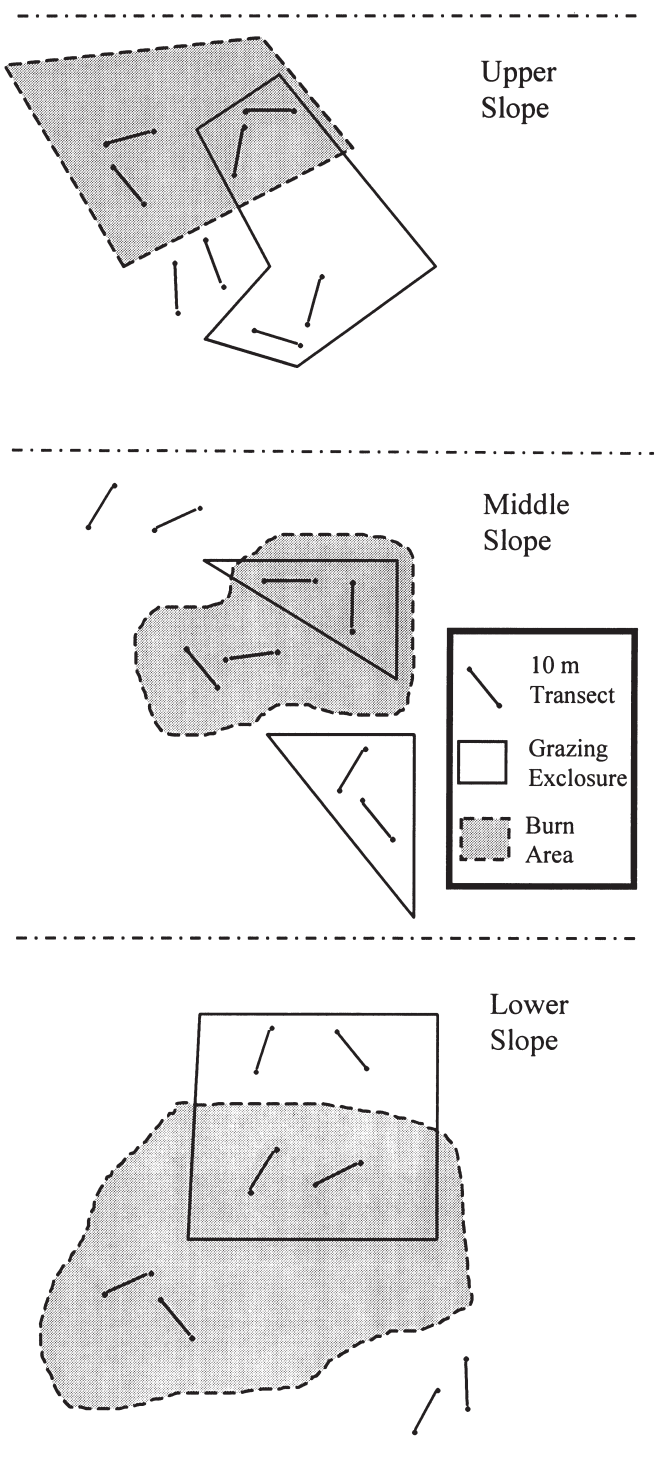


Figure 1. Schematic layout of experiment, not drawn to scale. The experiment was conducted in three non-contiguous pastures along a slope gradient.

**Results**

Forage productivity differed along the observed elevation gradient from the upper slope to the lower slope (Fig. 2). Grazing and burning did not affect standing crop, and apparent utilization (obtained by comparing standing crop in grazed and ungrazed treatments) varied considerably between years and among slope positions. Standing crop was lower on all plots in 1991 (the season after the burn).

Neither foliar cover nor frequency of any of the native grasses or their combination showed a significant difference due to the burning treatment (Fig. 3). There were no ungrazed plots in 1989.

Percent foliar cover of *D. californica* decreased an average of 12% on ungrazed plots and increased 10% on grazed plots (Fig. 4A). Foliar cover on the upper slope increased 12%, did not change on the middle slope, and decreased 5% on the lower slope. There was no *Danthonia* foliar cover slope by grazing interaction. *Danthonia*

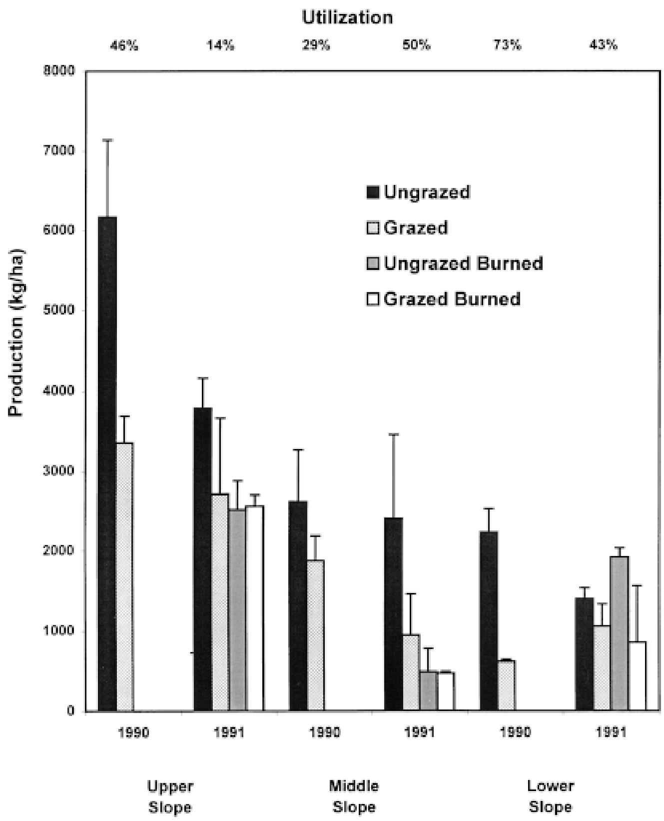


Figure 2. Production and apparent utilization by site. Production was measured as peak standing crop in the springs of 1990 and 1991. Utilization was measured as the difference between ungrazed and grazed peak standing crop, divided by ungrazed standing crop, expressed as percentage. The plots were burned in the fall between the 1990 and 1991 samples. Error bars are standard errors of the mean.

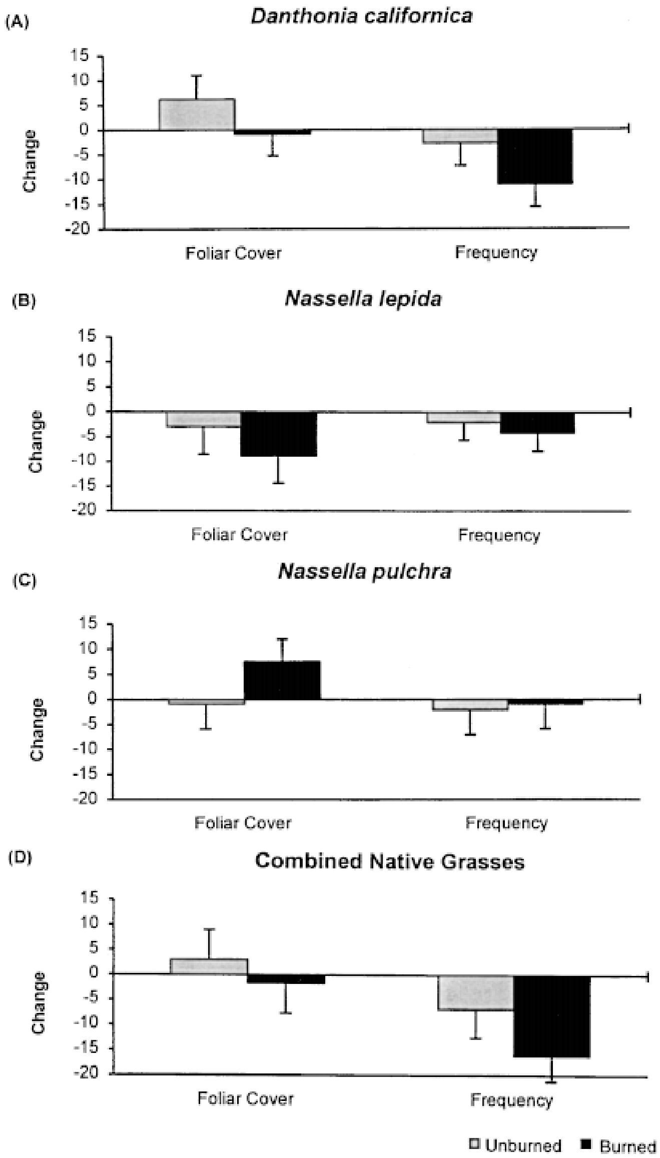


Figure 3. Changes in foliar cover and frequency of perennial grasses between 1989 and 1991 due to burning. None of the comparisons was significant ($P < 0.10$). Statistical comparisons between foliar cover and frequency are inappropriate.

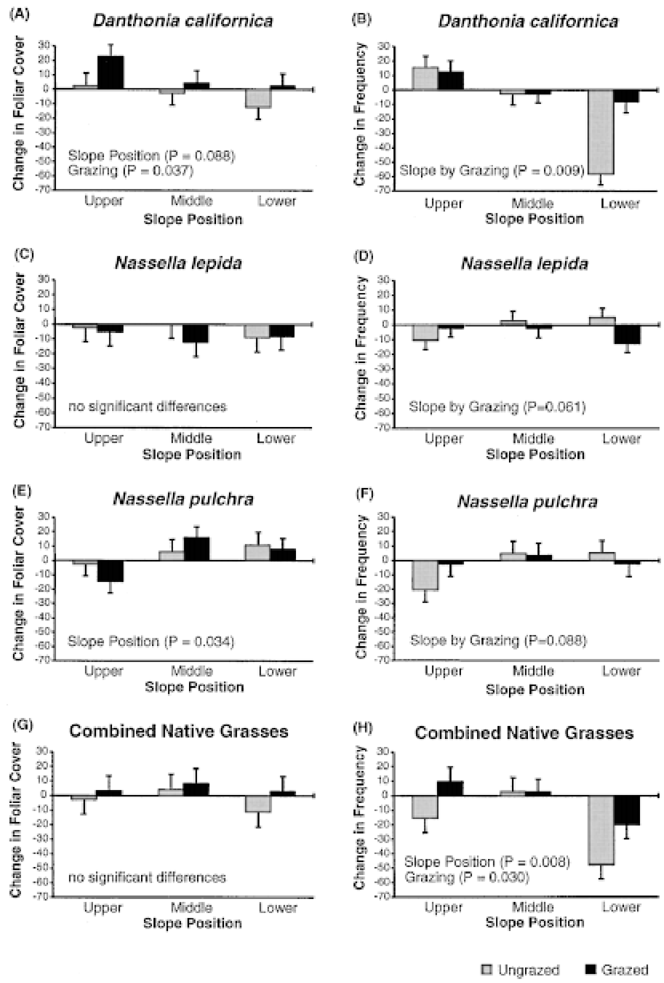


Figure 4. Changes in foliar cover and frequency of perennial grasses between 1989 and 1991 due to slope position and grazing. Error bars shown are the standard error of mean change for the slope by grazing interaction. Significant differences for main effects are noted on the graph.

frequency showed an interaction between slope and grazing (Fig. 4B). The *Danthonia* upper slope frequency increased in both ungrazed and grazed treatments (16 and 12%), compared with little change on the middle slope (ungrazed 3%, grazed 1%), and decreased on the lower slope (ungrazed 58%, grazed 8%). The burning treatment had no significant effect (Fig. 3A) with an average frequency decrease of 3% in unburned and 11% in burned plots.

*N. lepida* foliar cover changes because of slope position or the burning and grazing treatments were not significant (Figs. 3B & 4C). However, *N. lepida* foliar cover decreased an average of 5% in all plots. Slope and grazing interacted significantly for *N. lepida* frequency (Fig. 4D). Upper slope frequency decreased (10%) for the ungrazed treatment, whereas grazed treatments did not change. Change in *N. lepida* frequency on the middle slope averaged less than 1%. The lower slope ungrazed frequency increased 5% and decreased 13% in the grazed treatment.

*N. pulchra* foliar cover and frequency did not change significantly because of burning (Fig. 3C) or grazing treatments (Figs. 4E & 4F). *N. pulchra* foliar cover decreased by 9% on the upper slope and increased by 11% and 9% on the middle slope and lower slopes, respectively. *N. pulchra* frequency decreased by 11% on the upper slope, increased 4% on the middle and 3% on the lower slope. Slope by grazing interaction weakly affected *N. pulchra* frequency, with a decrease in frequency on the upper ungrazed slope (Fig. 4F).

The combined data for the three native grasses showed no significant change in foliar cover from the treatments or the slope positions (Figs. 3D & 4G). The combined frequency (Fig. 4H) was relatively unchanged on the upper (decreasing 3%) and middle slopes (increasing 2%). The lower slope combined frequency decreased 34%. The combined frequency decreased 20% on the ungrazed plots and 3% on the grazed plots. Combined foliar cover decreased an average of 1% and frequency by 11% across all plots. There were no slope by grazing interactions.

## Discussion and Conclusions

Forage productivity differed from the upper slope to the lower slope (Fig. 2), likely because of soil type. Both soils are rated as fair in range productivity, but the Tierra loam has a higher water-holding capacity than the Colma sandy loam (Wagner & Nelson 1961), which may have contributed to observed higher forage levels on the upper slope. Standing crop was lower on all plots in 1991 owing to the cumulative effects of below average rainfall in 1989–90 (43 cm) and 1990–91 (46 cm), 66 and 71%, respectively, of the long-term average of 65 cm. This observed decline in standing crop because of weather is consistent with reports from other California grassland sites (Heady et al. 1991).

Grazing has many effects on plant communities. The removal of senescent material and/or competing neighbors, the addition of nutrients, the mixing of seeds and soil, and the reduction of transpiration area can change the competitive balance, benefiting some plants over others (Noy-Meir et al. 1989). Damage to plants from grazing and trampling can vary from undetectable to severe (Noy-Meir et al. 1989) and over-grazing is thought to be at least partially responsible for the shift away from native grass dominance in California (Bartolome & Gemmill 1981). However, perennials may benefit from litter removal, both of competitors and their own (Huntsinger et al. 1996). Moderate trampling from grazing may prevent encroachment by shrubs, which is common on ungrazed coastal grasslands (Edwards 1995). Litter removal also improves perennial grass seedling establishment (Bartolome & Gemmill 1981).

In this study, increased *D. californica* foliar cover under continued grazing, and decreased cover and frequency with grazing cessation are consistent with the observations of Heady et al. (1963) and Edwards (1996). They noted that moderate or even heavy grazing stimulated vegetative growth in *D. californica* and reduced competing annuals.

A species favored by grazing might be expected to respond positively to fire, but *D. californica* was unaffected by fire. The lack of a consistent response by *N. pulchra* to grazing or burning is puzzling because, on a Valley Grassland site with a similar treatment, this species responded positively to burning and grazing exclusion (Hatch et al. 1991). Plants from another coastal *N. pulchra* population seemed tolerant of fall burning and moderate grazing (Huntsinger et al. 1996).

Developing an appropriate strategy to increase *D. californica* and *Nassella* spp. in coastal grasslands presents the manager with the dilemma observed by Dennis (1989)-management that favors one native grass species may damage other, equally desirable ones. *D. californica* decreased in cover and apparent density with grazing exclusion, without a significant response to fire. *N. lepida* and *N. pulchra* did not show a consistent response to either grazing protection or fire, and performance varied unpredictably with slope position. The differing site-specific responses of these desirable plants, even in this relatively small area with similar species composition, compound the management dilemma. Differing responses by native grasses to soil type, plant productivity, and grazing pressure merit further research.

Our results demonstrate that fire and grazing exclusion have limited value for restoring a *Danthonia/Nassella* Coastal Prairie. This finding contrasts with most grassland restoration research in California, which has keyed on studies of *N. pulchra*, with management recommendations based on results from that one species. We believe that restoration efforts should focus on a greater diversity of native perennial grasses. Unfortunately, a mix of native and non-native species with conflicting responses to management is likely to be typical, and the common simple prescription to "burn and graze seasonally" will not achieve restoration goals.

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