

The Use of Prescribed Fire to Control Invasive Exotic Weeds at Jepson Prairie Preserve

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ABSTRACT. Jepson Prairie in Solano County, an outstanding example of remnant California Central Valley vernal pool and grassland habitats, is threatened by invasive exotic species. This paper describes the results of a 200-acre late-spring prescribed fire conducted at Jepson Prairie in June of 1995 and aimed at reducing the cover of an extensive infestation of Medusahead (*Taeniatherum caput-medusae*). Burned and unburned control plots are compared with respect to changes in community composition within three habitat types. The habitat types - mound, intermound, and swale - correspond to three topographic/hydrologic regimes within vernal pool complexes. Ocular estimates of percent cover (using Daubenmire cover classes) were recorded for six species guilds: native grasses, exotic grasses, native early forbs, exotic early forbs, native late forbs, and exotic late forbs. Cover of thatch, bare ground and residual dry matter was also measured. Results show significant decreases in the cover of exotic annual grasses (including Medusahead) and thatch in burned mound and intermound habitats. Cover of native grasses and native early forbs increased on burned mound and intermound habitats. However, exotic early forbs also increased on burned mounds and intermounds, due mainly to an increase in cover of *Erodium* spp. The results provide strong evidence that late-spring burning reduces the cover of non-native annual grasses, such as Medusahead, while increasing the dominance of native species and the cover of native grasses and forbs. Prescriptions for management of vernal pool and grassland habitats in California should include late-spring prescribed fire in areas that have heavy infestations of Medusahead or an accumulated thatch layer.

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INTRODUCTION

Invasive Weeds in Vernal Pool Complexes

Vernal pools have been described as among the most pristine of California's vegetation types (Holland and Griggs, 1976). However, recent surveys of several vernal pool preserves have revealed heavy infestations of Medusahead (*Taeniatherum caput-medusae*), an exotic annual grass, encroaching into vernal pools and swales in both grazed and ungrazed pastures (The Nature Conservancy, 1995a; 1996). The exotic annual grasses, most commonly *Bromus* spp., *Lolium* spp., *Avena* spp., and *Taeniatherum caput-medusae*, which typically dominate the uplands surrounding vernal pools, are strong competitors for light and water (Heady, 1956; Bartolome, 1979). The rapid soil moisture depletion by most annual grasses occurs earlier than that of native perennial species (Sampson and McCarty, 1930). Once these species become established within a vernal pool complex, competitive and hydrologic regimes are altered (Harris, 1977; Hull and Muller, 1977; Gordon et al., 1989) and native plant species diversity declines.

Long-term protection of California's vernal pool complexes will depend on the ability to reduce the competitive edge of these exotic annual grasses. The Nature Conservancy, working with several other organizations, has been investigating the use of prescribed burning and grazing as management tools for the maintenance of the structure, function, and diversity of native grasslands within vernal pool complexes.

This paper presents the results of a study to determine the effects of a late-spring prescribed fire on vernal pool and grassland community composition at Jepson Prairie in Solano County (see Figure 1). Based on a fifteen-year history of prescribed burning at Jepson Prairie, we expected a spring burn to reduce the cover of non-native annual grasses while increasing the cover of native grasses and forbs. The specific management objective of the prescribed fire was to reduce the dominance of Medusahead and to reduce the overall cover of exotic annual grasses.

Medusahead

Taeniatherum caput-medusae (formerly *Elymus caput-medusae*) or Medusahead is a late-blooming annual grass of Medi-

terranean origin. This introduced species has recently spread rapidly in grazed pastures throughout California. As recently as 1950, the species was reported from only six counties in northwestern California (Sampson et al., 1950). Today, it occurs in more than twenty counties (Pollak, pers. obs.), and has been reported for the first time in 1996 on the Santa Rosa Plateau Preserve in western Riverside County (R. Wills, pers. comm.). Dense infestations of Medusahead appear to suppress most native plant species by reducing germination or survivorship. Medusahead continues to grow, extract soil moisture and produce large numbers of seed after most other annual grasses have turned brown.

Medusahead, with its high silica content, is largely unpalatable to livestock except very early in the growing season; it also produces a heavy, persistent residue of silica-rich thatch (Bovey et al., 1961). Some grazing regimes appear to reduce but not eliminate its cover, largely through trampling effects. Removal of cattle grazing has not reduced exotic species cover in a number of studies (Heady, 1988; White, 1966; Stromberg and Griffin, 1996). Pastures that have had grazing excluded for more than ten years at the Jepson Prairie and Vina Plains preserves have heavy infestations of Medusahead and other annual weeds, such as Yellow Starthistle (*Centaurea solstitialis*).

Several studies designed to evaluate the use of fire for Medusahead control have yielded mixed results (Hilken and Miller, 1980). Reductions of greater than 98% have been reported with prescribed burns carried out in June in Solano County (McKell et al., 1962), whereas other researchers report increases in Medusahead following burns in August in Alturas, California. (Young et al., 1972).

Surveys conducted at Jepson Prairie Preserve in 1995 indicated extensive areas of the preserve (including vernal pools) were dominated by Medusahead (The Nature Conservancy, 1996). At the Vina Plains Preserve in Tehama County, Medusahead exhibited a frequency of 89% and 50% of quadrats placed in ungrazed and grazed pastures respectively in 1995 (The Nature Conservancy, 1995a).

Prescribed Burning as a Management Tool

Prescribed burning and grazing are the primary tools available for management of grasslands and vernal pool complexes. Many native bunchgrasses are known to respond favorably to fires, with vigorous re-sprouting and flower production after fire (Keeley, 1981; Young and Miller, 1985; Glenn-Lewin et al., 1990), and numerous authors have noted that fires can reduce competition from annual grasses (Hervey, 1949; Zavon, 1982; Ahmed, 1983; Keeley, 1990; George et al., 1992). Burn prescriptions should include a consideration of the specific management objectives for the site, fuel loads, seasonality,

dimensions of burn units, and likely fire behavior (Martin and Sapsis, 1991).

A ten-year study at Jepson Prairie on the effects of summer burning and short-duration spring grazing have indicated that a reduction in thatch and competition from exotic annual grasses is required to maintain and foster the establishment of native grasses and forbs (Dyer et al., 1996). Summer prescribed burns have not, however, been effective at reducing the seed bank of some undesirable exotic species.

Starting in 1994, a series of management burns was conducted at Jepson Prairie that focused on comparing the effectiveness of using fall and late-spring prescribed burns for Medusahead control. Fall burns (conducted after the first rains) have the advantage of moderate fire behavior due to higher fuel moisture and can be conducted when fire suppression resources are readily available. Fall burns provide some reduction in thatch, and kill some weed seedlings. The effects, however, appear to be relatively indiscriminate - many native species are as vulnerable as exotic species. Late-spring burns (e.g. conducted after seed set and dispersal of most species, but prior to seed dispersal of Medusahead) appeared to provide significant thatch reduction and to selectively kill seeds not yet dispersed (primarily exotics). The disadvantages of late-spring burning include more intense fire behavior and the need for fire suppression equipment during the wildfire season.

METHODS

Study Site

Jepson Prairie, in Solano County, supports one of the best remaining examples of California Central Valley native grassland and vernal pool complexes (The Nature Conservancy 1995b). A rich flora and fauna are known from the 1,566-acre preserve, including eighteen special-status species and extensive stands of Purple Needlegrass (*Nassella pulchra* formerly *Stipa pulchra*) and other native grasses in a mosaic with claypan vernal pools. The preserve is cooperatively managed by The Nature Conservancy, The University of California, Davis and the Solano County Farmlands and Open Space Foundation. Ongoing ecological management activities include sheep grazing, periodic prescribed burns, control of invasive exotic plant species, and monitoring of rare species. Based on its high density of exotic weed species and dense thatch layer, a 200-acre pasture on the preserve was selected for burn treatment in June of 1995 (Figure 1).

Topographic Classification

Although the origin of the mima mounds found in many vernal pool complexes is still debated, it is clear that this undulating topographic pattern establishes strong environmental gradients,

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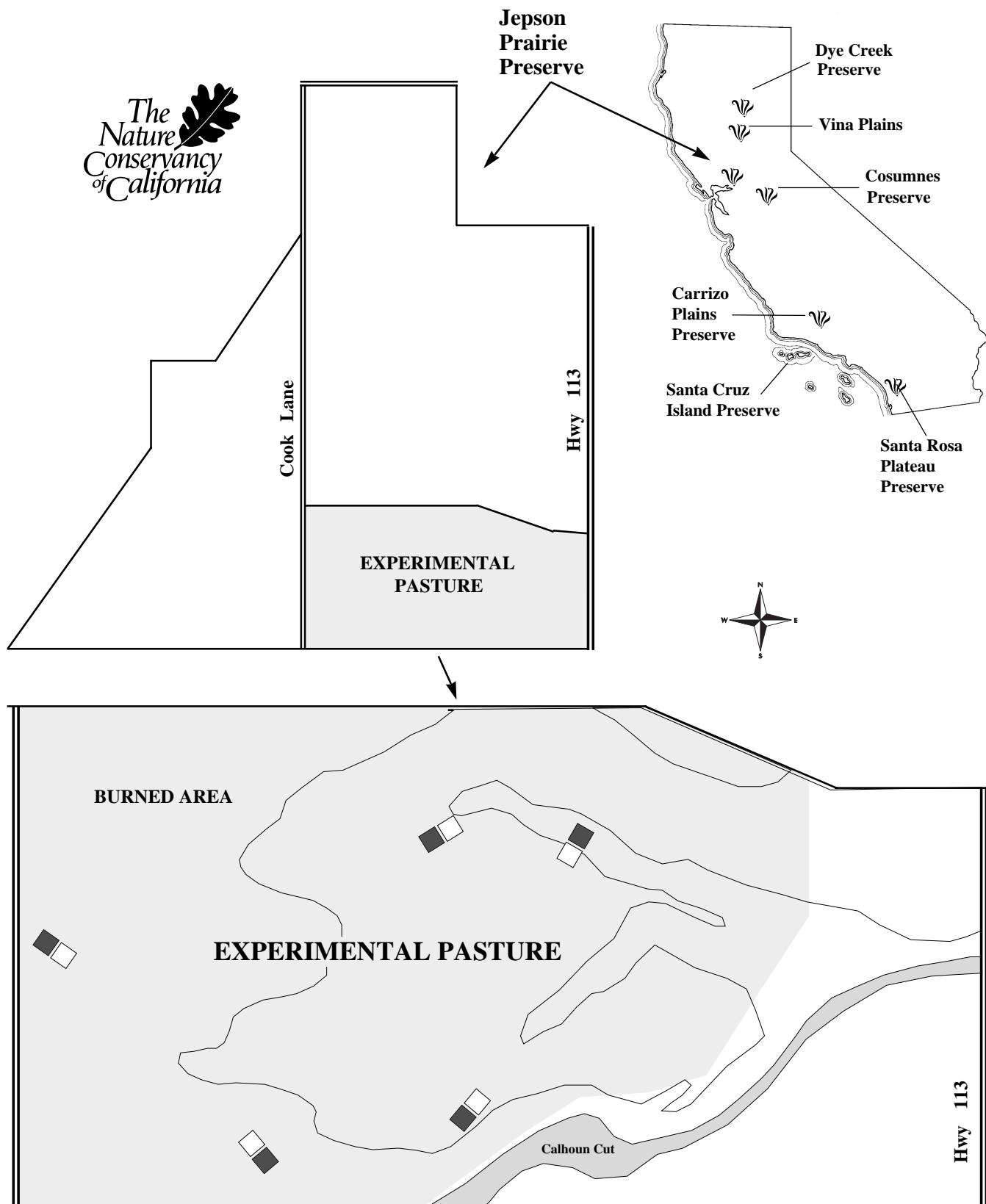


FIGURE 1. Map of The Nature Conservancy's grassland restoration research sites in California, Jepson Prairie Preserve and the 200-acre prescribed burn pasture with experimental plot locations. The ten plots are 35m x 35m. Burned plots are indicated by dark shading. The unburned control plots are unshaded.

which result in corresponding patterns of species diversity (Holland and Griggs, 1976). We established a subjective classification in order to stratify sampling among these "habitats." This stratification reduces the variance among samples (making sampling more efficient) and allows the detection of differential responses among habitats. Upland areas (classified as "mounds") have deeper soils and tend to be dominated by exotic annual grasses. At the low end of the hydrologic and topographic gradient, ephemeral swales or vernal pools (classified as "swales"), with their underlying hardpan and perched water tables, support a primarily native flora of annual grasses and forbs adapted to the seasonally wet conditions (Holland and Jain, 1988). We classified the intermediate range of the hydrologic and topographic gradient as "intermounds," the region below mound tops, but above the seasonally inundated swales. This habitat is floristically intermediate, containing species found in each of the more extreme habitats.

Sampling Design

A pilot sampling was conducted and data were analyzed (T. Holmes, pers. comm.) in April of 1995 to determine appropriate plot, transect, and quadrat numbers (Thompson, 1992; SAS, 1988). Five paired plots (for a total of ten 35- x 35-meter plots) were established within the study pasture from randomly located points, with randomly selected compass directions used to establish plot baselines (Figure 1). To spatially stratify quadrat sampling within plots, four parallel 35-meter transects (with randomly selected starting points), were marked with rebar. The three habitat types (mound, intermound, and swale) were subjectively located and marked along each transect with colored pin-flags. Four sample locations of mound and intermound habitat were regularly spaced within the available habitat along each transect. Swale habitat was determined in the pilot sample to be less variable than the other habitats and thus four sample locations for swale were selected along only two transects per plot.

Sampling was conducted using a 1/4 meter² quadrat frame to ocularly estimate percent cover in Daubenmire cover classes (Mueller-Dombois and Ellenberg, 1974) for each of six species guilds: native grasses, exotic grasses, native early forbs, exotic early forbs, native late forbs, and exotic late forbs. The two grass guilds include the graminoids - grasses, rushes and sedges. Forbs were classified as "early" if they were senescent, in fruit or in full flower at the time of sampling. Representative species of each of the guilds are presented in Table 1. Percent cover of bare ground and thatch, depth of thatch, and the dominant species (defined as the species with greatest cover) were also recorded for each quadrat. Residual dry matter was sampled only in 1996 by harvesting all living and dead vegetation in two randomly placed 1/4 meter² quadrats, one in mound and one in intermound habitat, for each of the ten plots. To avoid harming native species, residual dry matter was not sampled within swale

TABLE 1. The most common representatives of each species guild.

Native Graminoids	Exotic Grasses
<i>Deschampsia danthonioides</i>	<i>Avena fatua</i>
<i>Distichlis spicata</i>	<i>Avena barbata</i>
<i>Eleocharis</i> spp.	<i>Bromus hordeaceus</i>
<i>Juncus bufonius</i>	<i>Bromus diandrus</i>
<i>Nassella pulchra</i>	<i>Hordeum murinum</i> ssp. <i>leporinum</i>
<i>Pleuropogon californicus</i>	<i>Hordeum marinum</i> ssp. <i>gussoneanum</i>
Native Early Forbs	Exotic Early Forbs
<i>Blennosperma nanum</i> var. <i>nanum</i>	<i>Cerastium glomeratum</i>
<i>Claytonia perfoliata</i>	<i>Erodium cicutarium</i>
<i>Dodecatheon clevelandii</i> ssp. <i>patulum</i>	<i>Erodium botrys</i>
<i>Lasthenia</i> spp.	<i>Stellaria media</i>
<i>Layia fremontii</i>	
<i>Limnanthes douglasii</i> ssp. <i>rosea</i>	
<i>Triphysaria eriantha</i> ssp. <i>eriantha</i>	
<i>Viola pedunculata</i>	
Native Late Forbs	Exotic Late Forbs
<i>Achillea millefolium</i>	<i>Hypochaeris glabra</i>
<i>Downingia</i> spp.	<i>Lactuca serriola</i>
<i>Eremocarpus setigerus</i>	
<i>Eryngium</i> spp.	
<i>Psilocarphus</i> spp.	

habitats. The samples were placed in paper bags, dried at 65 degrees C and then weighed.

For each of the paired plots, one randomly chosen plot was protected from burning by mowing and then burning a three-meter-wide protective strip, or "black line," around the plot prior to burning the pasture. Thus, a total of five paired burned and unburned (control) plots were established. The plots were sampled prior to the burn in April and May of 1995. Though scheduled for an earlier date, inclement weather caused the prescribed burn to be repeatedly postponed until June 28, 1995. The plots were re-sampled in April of 1996.

Data Analysis

The species guild data were analyzed as a set of six separate paired-sample experiments, one for each combination of habitat and year. Within each of these experiments, differences in percent cover between burned and unburned plots were examined by guild with t-tests or sign tests. Wherever data could be normalized via logarithmic or power transformation (Box and Cox, 1964; Neter et al., 1985), t-tests were employed. In those few cases where a normalizing transformation could not be

found, sign tests (Daniel, 1990) were employed as a distribution-free alternative. Type I error rate was controlled at $I = 0.10$ within each of the six experiments across all six guilds through sequential Bonferroni adjustment (Rice, 1989). The residual dry matter data were analyzed using ANOVA to determine treatment and habitat effects.

RESULTS

Percent Cover

Pre-burn results of percent cover of each guild within each habitat are shown in Figure 2. The pre-burn data indicate that treatment and control plots had statistically similar cover values for each guild in each habitat with the exception of a significant difference in cover of native late forbs in the swale habitat ($p = 0.0044$). In general, the treatment and control plots were very similar in 1995 in terms of both percent cover of guilds in each habitat and overall frequency of dominant species prior to burning.

The effects of the prescribed burn varied by habitat type. Figure 3 shows post-burn comparisons of percent cover for each guild in unburned vs. burned plots for mound, intermound and swale. Results show a significant decrease in the cover of exotic annual grasses in burned mound and intermound habitats. The cover of all three native species guilds are higher on burned plots across all habitat types. Exotic forbs significantly increased on burned mounds, due mainly to an increase in cover of *Erodium* spp.

Residual dry matter and percent cover of thatch were significantly reduced on burned plots (Figures 4 and 5). Conversely, percent cover of bare ground was significantly higher on burned plots in mound and intermound plots (Figure 5).

Frequency of Dominant Species

The pre- and post-burn comparisons for the frequency of dominant species in unburned vs. burned plots is shown in Figure 6 for all habitats combined. In 1996, the burned mounds experienced a major decrease in dominance of *Bromus* spp., *Lolium* spp., and *Taeniatherum caput-medusae*, and an increase in *Erodium* spp. and *Trifolium* spp. Burning resulted in a shift in dominance in intermound areas from *Lolium* spp., *Bromus* spp., and *Taeniatherum caput-medusae* to *Erodium* spp. and *Juncus bufonius*. The intended reduction in Medusahead by burning was striking - no Medusahead was observed in any of the burned plots (both inside and outside of quadrats). Dominance of *Lasthenia* spp. was greater in burned swale habitats and the native annual grass *Pleuropogon californicus* was largely replaced by another native annual grass *Deschampsia danthonioides*. Overall, the proportion of quadrats that were dominated

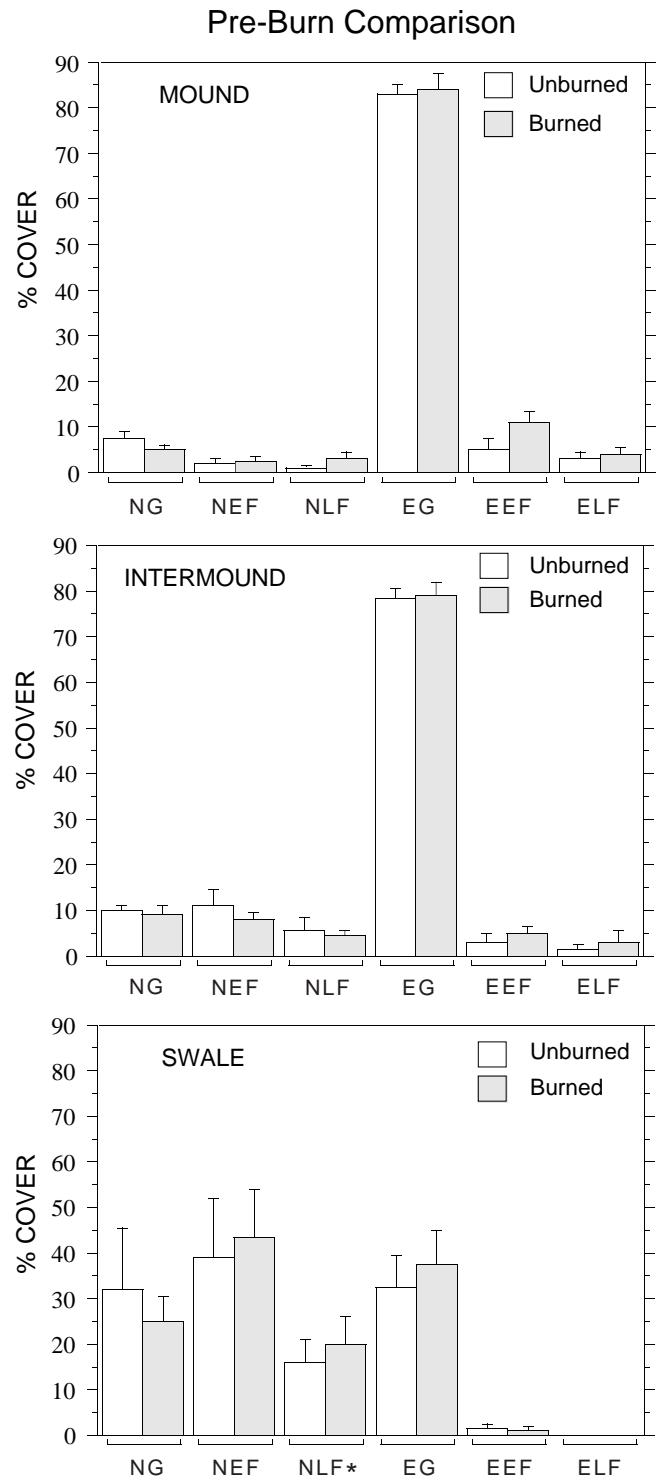


FIGURE 2. Pre-burn comparison of mean percent cover of guilds in mound, intermound and swale habitats from five paired treatment and control plots in 1995. Error bars represent one standard error. NG = Native grasses, NEF = native early forbs, NLF = native late forbs, EG = exotic grasses, EEF = exotic early forbs, ELF = exotic late forbs. An asterisk indicates a significant difference at $\alpha = 0.10$.

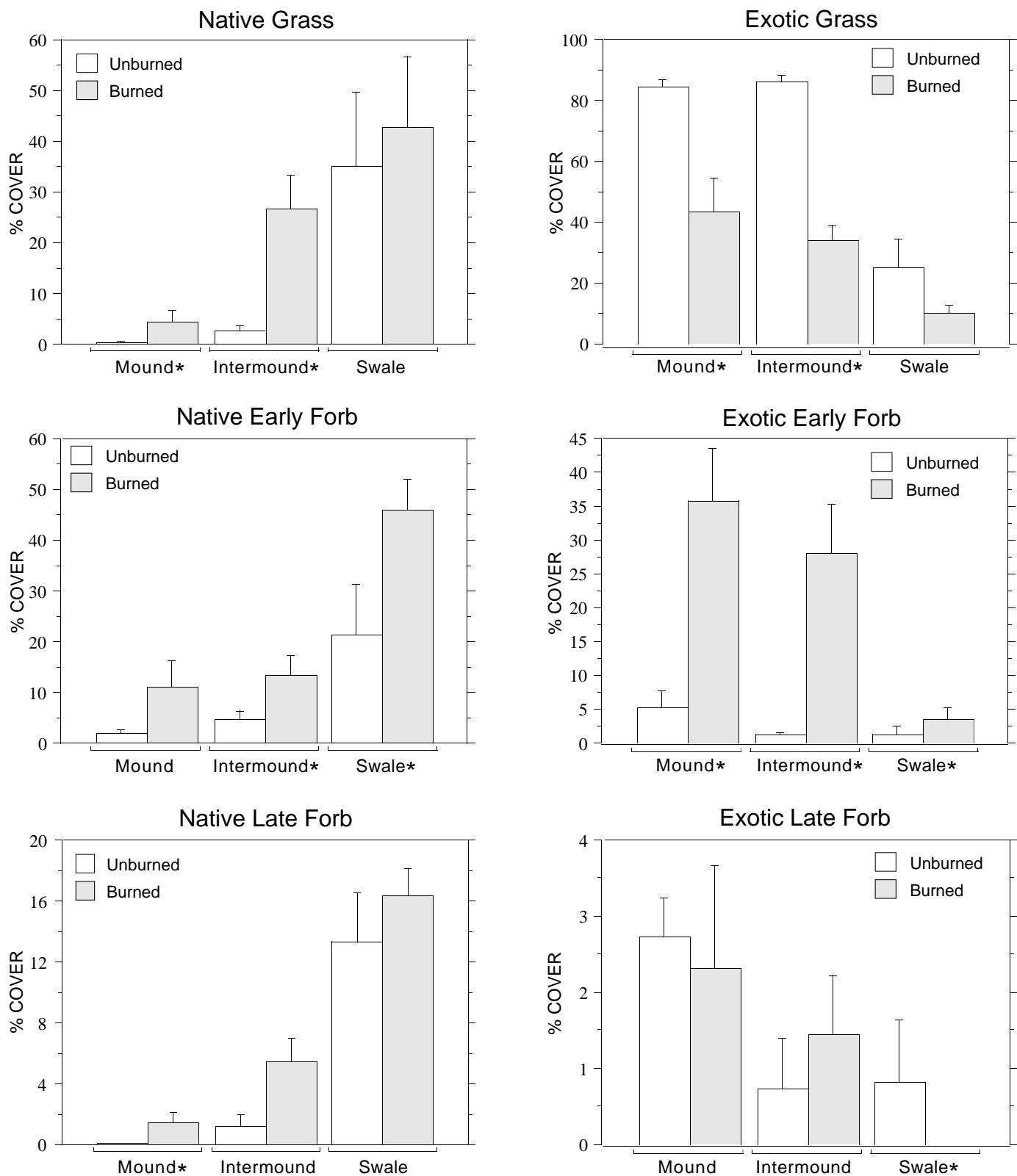


FIGURE 3. Post-burn comparison of mean percent cover of guilds in mound, intermound and swale habitats from five paired burned and unburned plots in 1996. Error bars represent one standard error. An asterisk indicates a significant difference at $\alpha = 0.10$.

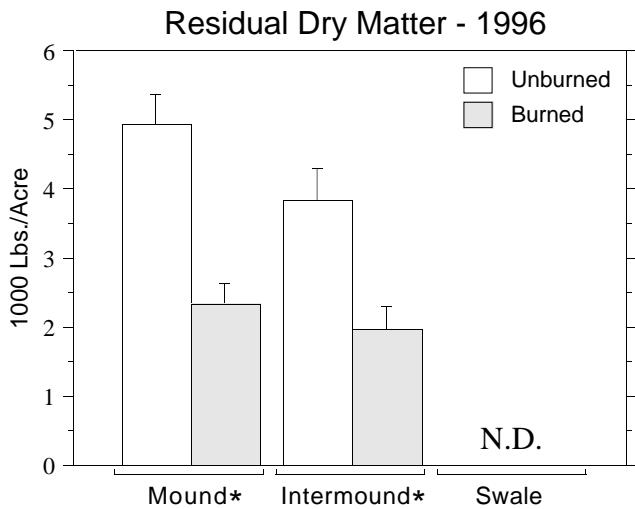


FIGURE 4. Post-burn comparison of mean weight of residual dry matter in mound, intermound and swale habitats from five paired burned and unburned plots in 1996. Error bars represent one standard error. N.D. = no data (to avoid damage to native species, no swale plots were clipped). An asterisk indicates a significant difference at $\alpha = 0.10$.

by native species increased in burned plots across all habitats (Figure 7).

DISCUSSION

Data indicate that a late-spring prescribed burn was effective at reducing Medusahead in this pasture. Further benefits of the fire include a reduction in cover of thatch and residual dry matter, an increase in bare ground in mound and intermound habitats, and a reduction in cover of exotic grasses in mound and intermound habitats. Prescribed burning increased the proportion of quadrats dominated by native species in all habitats.

This study confirms previous observations that prescribed burns, timed to coincide with seed production of Medusahead (after seed set, yet before the seed heads have shattered), are effective at eliminating the current year's seed production. When seed heads are located above ground level, they are subjected to the hottest part of the burn. The effectiveness of this approach for controlling Medusahead is due to its low seed dormancy characteristics. Like most weedy annual grasses, Medusahead has non-dormant seeds with little seed carry-over from one year to the next (Evans and Young, 1989; Young and Evans, 1989). With very few seed reserves in the soil, the abundance of annual grasses can be dramatically reduced if the seed input for even one year can be eliminated. A reduction in seed output due to grazing may similarly explain why grazing may reduce, but not eliminate, Medusahead infestations.

A reduction in thatch due to fire increases light penetration and temperature fluctuations on the soil surface, which stimulate the germination of some native species as well as *Erodium* spp. (Rice, 1985). It is important to note that the response to fire is species specific and the cover of some native species, such as *Pleuropogon californicus*, can be greatly reduced in the season following a burn. The reduced cover of exotic annual grasses after burning may result in increased water availability for both native and exotic forbs. With increased germination, lowered competition, and new bare ground available for establishment, late spring prescribed fires may set the stage for increased establishment of previously suppressed native species.

Implications for Management

Prescribed burning increases the cover of native species in vernal pool and grassland areas. Properly timed fires appear to be an effective tool to control annual species that do not have well-developed seedbanks. Knowledge of the phenology of a species and its seed dormancy characteristics is key to effectively targeting a particular invasive species with a single prescribed burn. Species with longer-lived seed reserves (e.g. Yellow Starthistle) may require repeated treatments to effectively reduce seedbanks. Fire can be used alone or in conjunction with a livestock grazing program. Grazing prior to burning will alter the fuel characteristics and thus reduce fire intensity.

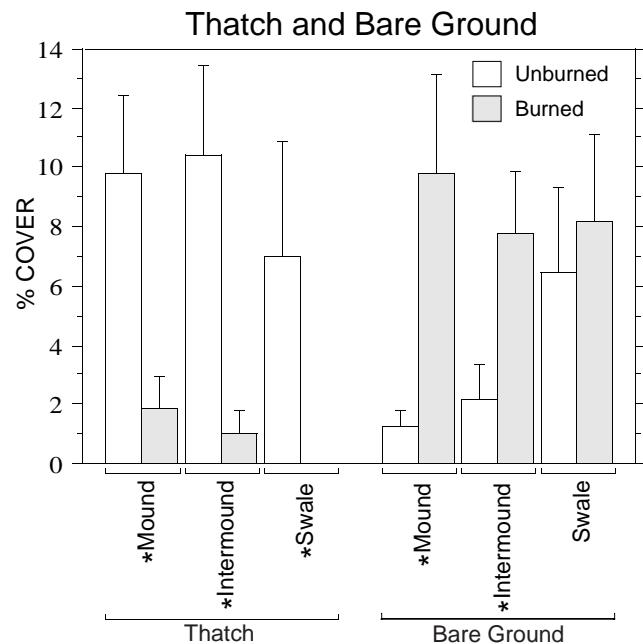


FIGURE 5. Post-burn comparison of mean percent cover of thatch and bare ground in mound, intermound and swale habitats from five paired burned and unburned plots in 1996. Error bars represent one standard error. An asterisk indicates a significant difference at $\alpha = 0.10$.

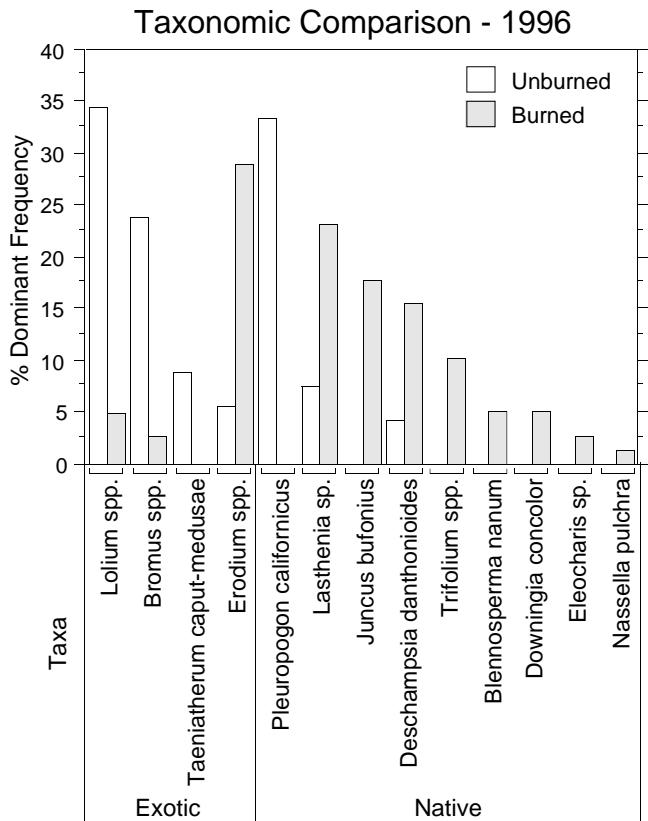


FIGURE 6. Post-burn comparisons of percent of quadrats dominated by selected taxa. Dominance was defined as the taxa that exhibited the greatest cover within a quadrat. Taxa selected are ones that exhibited a change between treatments in post-burn comparisons.

The results reported here are for the first year following a prescribed fire. Observations at Jepson Prairie and elsewhere suggest that the beneficial effects of prescribed burns are observable for at least three years following a burn. Site-specific monitoring of species dominance and thatch levels should guide fire prescriptions. Current management prescriptions for The Nature Conservancy preserves include conducting prescribed burns when thatch buildup becomes excessive and/or Medusahead exceeds 30 percent cover. Further studies will be necessary to determine appropriate frequency and seasonality of burning for particular management objectives in vernal pool and grassland areas.

With the support of partner organizations including the Department of Forestry and Fire Protection, the Bureau of Land Management, the University of California, the Department of Fish and Game and the National Park Service, The Nature Conservancy is also conducting prescribed burns in an adaptive management context on several Nature Conservancy projects (Figure 1). Our long-term goal is the preservation of biodiversity. When carefully planned and implemented, prescribed fire can be an

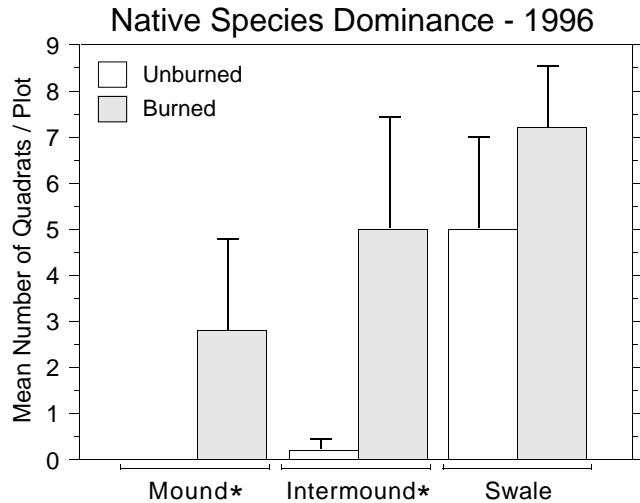


FIGURE 7. Post-burn comparison of mean number of quadrats per plot which were dominated by native species in mound, intermound and swale habitats from five paired burned and unburned plots in 1996. Error bars represent one standard error. An asterisk indicates a significant difference at $\alpha = 0.10$.

effective and efficient management tool for controlling invasive weeds.

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