Managing for biodiversity in vernal pool grasslands using fire and grazing

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ABSTRACT. California grasslands represent one of the most invaded ecosystems in the United States, with the cover of exotic plant species often exceeding 85 percent. Native species persist in these grasslands despite the high cover of exotics, particularly at sites with extreme edaphic or hydrologic environments (e.g., serpentine, vernal pools). Recent studies have shown that grazing in vernal pool grasslands maintains the diversity and function of the system. In one study, I found that native plant and aquatic species diversity declined and the period of pool inundation was significantly reduced when grazing was removed from the system. I was also interested in determining whether the addition of fire to a grazed system promotes native plant species diversity in and around vernal pools while reducing exotic species cover. In an experiment across four sites (Vina Plains, Valensin Ranch, Cosumnes Foothills and Jepson Prairie) in the Central Valley of California, I found that fire reduced exotic grass cover but promoted the growth of exotic forbs, suggesting that fire cannot be used to control exotics across the board. At all sites one year after spring prescribed burn treatments, exotic grass cover was lower in burned versus unburned plots. In contrast, exotic forb cover was higher in the burned plots than the unburned plots across all sites. Native species richness was 15 percent higher in burned versus unburned treatments across all sites. Fire effects were undetectable across all sites by the second year following the burn treatment. Only one site, the Jepson Prairie Preserve, showed positive fire effects that lasted for up to three years. Although these results provide compelling evidence for using fire in combination with grazing to enhance grassland plant communities at some sites, the ephemeral nature of these effects and difficulty of implementation present serious drawbacks. General control of exotic species likely cannot be achieved using fire without grazing in these heavily invaded systems.

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INTRODUCTION

One of the major objectives for land management in California's vernal pool grasslands is the control of invasive weeds. This is a major challenge given the fact that exotic plant cover at many sites exceeds 85 percent (Marty, unpublished data). Fire and grazing are both effective management tools available to landowners managing vernal pool grassland habitat in California and can be used separately or in combination. We expect that each tool might affect the annual grassland plant community in different ways. While grazing selectively removes plant material based on the preferences of the grazing animal (Huntsinger et al., 2007), fire consumes all of the flammable material in its path. Additionally, grazing can occur in any season while fire only occurs when there is sufficient dry plant material to burn.

Marty (2005) found that the removal of cattle grazing in vernal pool grasslands had a number of detrimental effects on diversity and hydrology of the pools. Native plant species richness declined after three years of grazing removal as grasses began dominating the plant community in and around the vernal pools. Vernal pool hydrology was also negatively affected by removing cattle from the system. Ungrazed pools held continuous water on average 50 days less than pools grazed at historic levels. While grazing clearly plays a role in maintaining the diversity and function in vernal pool grasslands, significant cover of exotic grasses and invasive forbs persist. Can fire further improve the condition of vernal pool grasslands?

Land managers often rely on fire to control invasive species that degrade the value of the grassland habitat. The target species include a number of exotic grass species (e.g., *Taeniatherum caput-medusae*, *Aegilops triuncialis*) and some exotic forbs like yellow starthistle (*Centaurea solstitialis*). Studies that focus on the effects of fire on California grassland communities generally show a temporary increase in native species diversity and exotic grass cover decline following fires (Harrison et al., 2003; Meyer and Schiffman, 1999; Parsons and Stohlgren, 1989; Pollak and Kan, 1998). A recent meta-analysis assessing fire effects in California grasslands analyzed the results of 28 studies and could not find a straightforward effect of fire on native or exotic species (D'Antonio et al., 2001). The authors concluded that a small sample size and high variability in study design and execution made it difficult to develop clear conclusions about the benefits of fire to grassland plant communities, especially with regard to effects on species richness.

Here, I explore the use of fire as a management tool for restoring native vegetation in grazed grasslands associated with vernal pools in California. The main purpose of the study was to generate more general conclusions about fire effects in these grasslands rather than specific fire prescriptions for these sites. I implemented prescribed fire treatments at four sites spanning over 200 kilometers and representing a wide range of geologic formations, soil types and climatic variation in the Central Valley of California.

METHODS

Study Sites

I selected four vernal pool grassland sites in the Central Valley of California where fire management was actively being used (Figure 1). The Valensin Ranch and Cosumnes Foothills sites (Sacramento County) are part of the 18,600-hectare Cosumnes River Preserve. Prescribed fire has been an active management tool used at these sites since 1999. Cattle graze all vernal pool grassland habitat on the Preserve.

The grasslands at the Valensin Ranch occur on the Riverbank Geologic Formation and have relatively fertile soils with a subsurface claypan layer restricting rapid water infiltration. The productivity of this site is relatively high with average forage production estimated at 2,800 kg/ha (NRCS, 2007). I selected three pastures at this site for fire treatment in June 2000. One pasture was treated in 2000 and the other two were treated in June 2001.

The Cosumnes Foothills site is located in eastern Sacramento County, and has been managed using fire since 2002. The vernal pool grasslands at this site occur on Valley Springs and Laguna Formations and the surface soils are relatively infertile (average productivity = 1,100 kg/ha, NRCS, 2007). A combination of bedrock and cemented hardpan restricts water drainage on this site. Three plots within two pastures received fire treatment in June 2003.

The Vina Plains Preserve is owned and managed by The Nature Conservancy as part of the Lassen Foothills Project in Tehama County. The site has 854 ha of vernal pool grassland habitat on relatively unproductive (average productivity = 680 kg/ha, NRCS, 2007) soils derived from the Tuscan Geologic Formation. Prescribed burning has been used for two decades at this site to manage exotic species infestations. The site is also managed with seasonal cattle grazing. I selected two pastures for treatment at Vina Plains. One was burned in 2002 and two macroplots within the second pasture were burned in 2003.

The Jepson Prairie Preserve (Solano County) is one of California's best remaining examples of claypan vernal pools and native bunchgrass prairie. The 630-hectare property is owned and managed by the Solano Land Trust. Prescribed burning was used as a management tool on this site for two decades. The soils are associated with the Modesto Formation and are relatively productive in the study pasture (productivity = 2,400 kg/ha, NRCS, 2007). The entire site is lightly grazed by sheep. We burned three large macroplots in June 2003.

Within each treatment block or pasture at each site, I delineated two large (~ 2 ha) macroplots and randomly assigned a burn treatment (burned or unburned) to each. I collected pre-treatment data on five randomly-selected vernal pools within each burned and unburned macroplot (5 in the burned area and 5 in the unburned area). At each site, a single burn treatment was conducted in late spring (late May—late June). Late spring burning was used because it has been shown to be effective in reducing the cover of certain exotic grass species while promoting several native species (Meyer and Schiffman, 1999; Pollak and Kan, 1998). In addition, burning at that time of year is logistically more feasible because of air quality and fire safety concerns. The size of the prescribed fires varied between treatments (~ 6—200 ha). The sampling area (macroplot) within the burned and unburned treatments was similar at each site (~ 2 ha).

I collected plant species composition data in the preburn year and for three years following the burn treatment in randomly-located 35 x 70 cm quadrats after the pools had dried and the majority of the

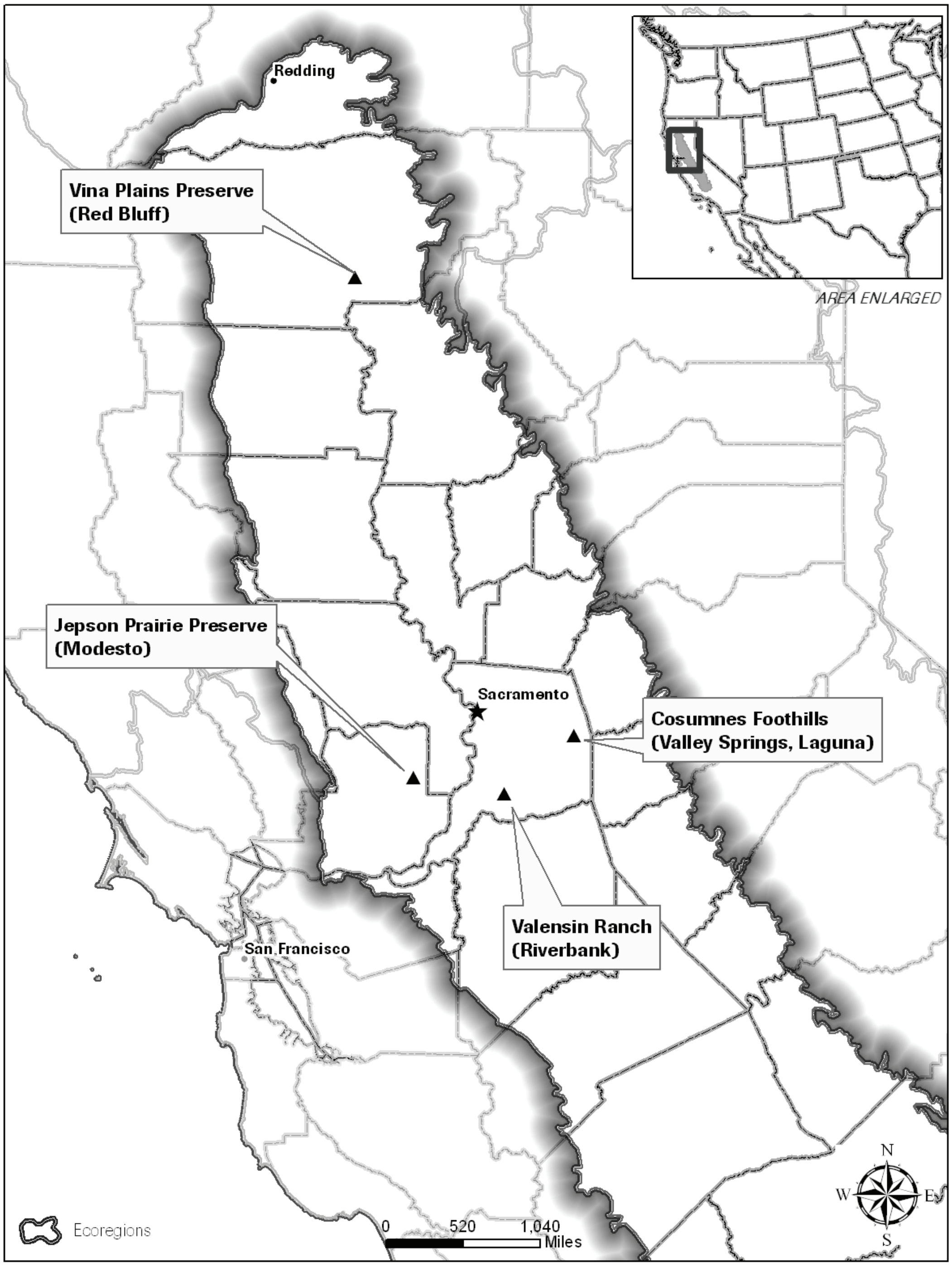

FIGURE 1. Study site locations including geologic formation of the vernal pool complexes.

plant species were flowering (April—May). Quadrats were randomly located and sampled along three transects for each pool in three different pool zones (3 quadrats x 3 zones = 9 quadrats per pool). The three zones were the (1) deepest part of the pool, (2) edge of the pool (selected each year based on the high-water mark of the pool), and (3) upland area (5 m from the adjacent edge quadrat). Each plant species occurring in the quadrat was identified using Hickman (1993) and given a modified Daubenmire cover class value (Barbour et al., 1987). I pooled quadrat data for each zone in each pool. Cover class values were converted to midpoint cover values to calculate percent cover.

Data Analysis

I tested for burn treatment effects across all four treatment sites using an analysis of variance (ANOVA) model with experimental site, burn treatment and quadrat location as main effects and included an interaction term of burning treatment by quadrat location (n = 72). I used repeated-measures analysis of variance (MANOVA) to test for treatment effects across years. I tested for burn treatment effects at each site using pasture, burn treatment and quadrat location (plus the burn x quadrat interaction, n = 18). I also tested for burn effects within each pool zone separately. Pairwise comparisons were made using Tukey's Honestly Significant Difference (HSD) test (Sokal and Rohlf, 1994). Diversity is reported as species or taxa richness (s). All analyses were conducted using JMP statistical software, version 5.1 (SAS Institute, 2004).

RESULTS

I recorded 246 species of plants (Appendix) across all sites in the four years of this study (168 natives and 78 exotic; 208 forbs and 38 grasses). The Vina Plains Preserve had the most species, at 170. The Cosumnes Foothills had 157, Valensin Ranch had 155 and Jepson Prairie had 152 species total. Absolute cover of exotic grasses in unburned upland plots in all years was the highest at the Jepson Prairie Preserve (mean = 33% ± 1.6%) and Valensin Ranch (28% ± 1.3%) and the lowest at the Cosumnes Foothills (mean = 20% ± 1.4%) and Vina Plains sites (mean = 19% ± 0.9%). Consequently, thatch cover was highest in unburned units at Jepson (18% ± 2%) and Valensin (14% ± 1.7%) and lowest at the Cosumnes Foothills (8% ± 1.6%) and Vina Plains (3% ± 0.6%). Average native species richness was highest at the Vina Plains (10 species per quadrat) and lowest at the Jepson Prairie Preserve (6.5 species per quadrat).

I found no significant effect of burning on total exotic species cover across all sites after one, two or three years, even though fire significantly affected exotic species composition at all of these sites. Exotic annual forb cover nearly doubled in burned plots one year following the fire across all study sites ($F = 17.64$, $p < 0.0001$, Figure 2a). This effect was only significant in the upland plots ($F = 6.51$, $p < 0.01$) at these sites and was no longer detectable two or three years following the burn. One year after the fire, I recorded a threefold increase in exotic annual forb cover at the Jepson Prairie Preserve ($F = 39.7$, $p < 0.0001$). This effect was reduced but still significant two years following the fire ($F = 8.82$, $p = 0.01$). Burned plots had higher exotic annual forb cover compared to unburned plots one year after the fire at Vina Plains ($F = 4.75$, $p = 0.05$), and the Cosumnes Foothills site ($F = 6.78$, $p = 0.01$). This effect was only marginally significant at the Valensin Ranch ($F = 4.42$, $p = 0.06$) and was absent at these three sites by two years post burn.

Exotic annual grass cover was reduced by 35% across all sites one year following the burn ($F = 18.30$, $p < 0.0001$, Figure 2b). As was the case with exotic annual forbs, grass cover returned to pretreatment levels by the second year post burn. At the site level, I found significant reductions in exotic grass cover in the pool, edge and upland zones at the Jepson Prairie Preserve (all zones: unburned = 41.5% ± 2.8%, burned = 15.1% ± 1.45%; $F = 75.5$, $p < 0.0001$) and only in the upland zone at the Cosumnes Foothills site (unburned = 20.2% ± 2.3%, burned = 14.7% ± 1.6%; $F = 7.24$, $p < 0.01$).

Burning did not increase native annual forb cover consistently across all sites in any year following the burn treatment, but native annual forb richness increased across all sites by 15% with the addition of burning for the first year after the fire ($F = 6.6$, $p = 0.01$, Figure 2c). Cover of native annual forbs increased by 25% and richness increased by 40% in burned versus unburned plots at the Valensin Ranch site one year following the fire (n = 18 for both, $F = 4.72$, $p = 0.05$; $F = 20.62$, $p = 0.001$). There was no detectable fire effect two or three years following the burn at this site. Native forb cover was not significantly increased with the addition of fire at Vina Plains or the Cosumnes Foothills site.

In contrast, fire had a dramatic, positive effect on native species cover and richness at the Jepson Prairie Preserve and this effect lasted for up to three years post burn. Native annual forb cover was 67%, 34% and 32% higher in burned versus unburned plots one ($F = 27.0$, $p < 0.001$), two ($F = 8.6$, $p = 0.01$) and three ($F = 9.8$, $p = 0.01$) years post burn, respectively (Figure 3). These positive effects were significant in all three pool zones. One year after burning, native cover was 2.6 times higher in burned versus unburned upland quadrats ($F = 9.7$, $p = 0.004$), 2 times higher on the edge ($F = 22.3$, $p < 0.0001$) and 35% higher in the pool zone ($F = 6.5$, $p = 0.02$). By the second year post burn, native cover was 50% higher on the edge ($F = 4.2$, $p = 0.05$) and 38% higher in the pool in burned versus unburned treatments ($F= 10.4$, $p = 0.003$). By the third year following the burn the pool quadrat maintained 50% higher native cover in the burned plots compared to the unburned plots ($F = 6.8$, $p = 0.01$). Native annual forb richness was 75% higher in burned versus

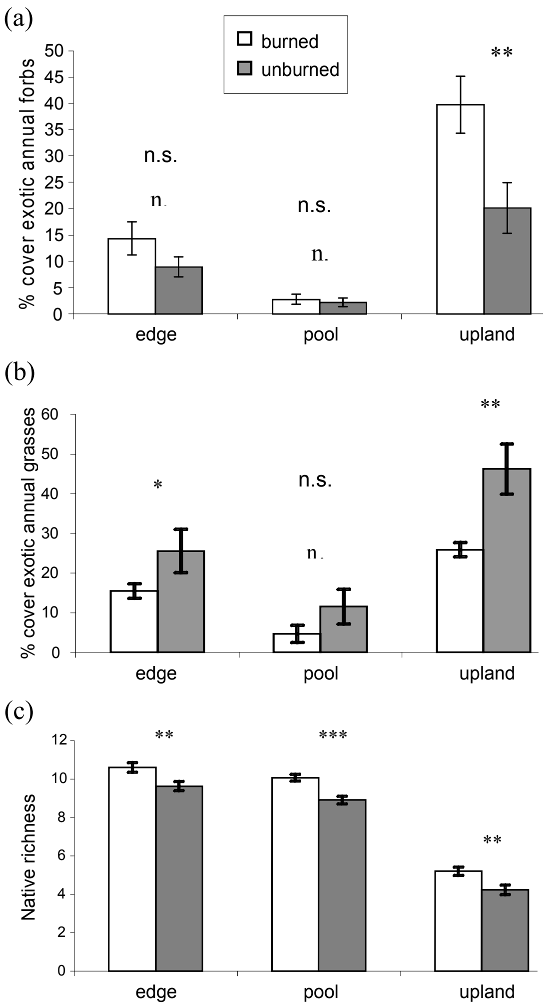

FIGURE 2. One year post-burn effect of fire on (a) exotic annual forb cover, (b) exotic annual grass species cover, and (c) native species richness across all study sites by burn treatment. Values shown are mean ± SE. n.s., not significant; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

unburned upland plots one year post burn ($F = 9.9$, $p = 0.004$) and 34% higher in the pool zone ($F = 6.7$, $p = 0.01$). These effects were not significant two years following the fire. Native perennial grass cover was increased by burning one year following the fire with cover in burned plots 1.8 times higher than in unburned plots ($F = 7.65$, $p = 0.01$).

DISCUSSION

The results of this study highlight the tradeoffs associated with the use of fire in grazed California vernal pool grasslands. Although I recorded a significant reduction in the cover of exotic annual grasses across all sites, I measured a concomitant increase in exotic annual forb cover in the upland habitats surrounding the vernal pools. This tradeoff of exotic grasses for forbs may be worthwhile in these grasslands where exotic grasses clearly dominate. Annual grasses have been shown to be formidable competitors for resources in these systems and may be limiting the germination and growth of some of the native species (Barbour et al., 1993; Dyer and Rice, 1999; Marty et al., 2005). Additionally, excessive grass cover may have negative impacts on vernal pool hydrology by drawing the soil moisture down early (Marty, 2005).

Fire effects are clearly ephemeral in these annual-grass dominated habitats. The positive effects of fire (e.g. increased native diversity, decreased annual grass cover) were found to last for only one year after burning at all sites except the Jepson Prairie Preserve. The annual grasses that dominate California grasslands quickly re-invade most burned sites within one to two years following a spring fire (D'Antonio et al., 2001). For some native forbs, this short-term effect may be ecologically important if the species is able to germinate and increase seed production the year following the fire.

At the Jepson Prairie Preserve, fire appears to have a much more positive, longer-term effect on the native plant community, at least in the pasture that I studied. Jepson Prairie is the only study site grazed by sheep and the thatch levels indicate that it has been grazed relatively lightly compared to the other study sites. Jepson Prairie also has the highest cover of exotic grasses of all of the sites, possibly due to the fact that sheep prefer to eat forbs over grasses (Parsons et al., 1994). It seems likely then that the native plant community at the Jepson Prairie Preserve would be the most dramatically affected by the reduction of exotic grasses.

The two sites that had the most positive effects from burning (Jepson and Valensin) are also, ironically, the most difficult places to implement a prescribed fire program. Both sites are closer to major urban centers than the other two sites (Vina Plains and Cosumnes Foothills) and thus air quality and fire liability issues are much more prominent. In fact, prescribed fire has not been used at the Jepson Prairie Preserve since this study was conducted in 2003 because of the lack of capacity from the local fire-fighting agencies and the landowner.

Exotic species are part of the fabric of our vernal pool grasslands, like it or not. Prescribed grazing will continue to play an important role in the annual

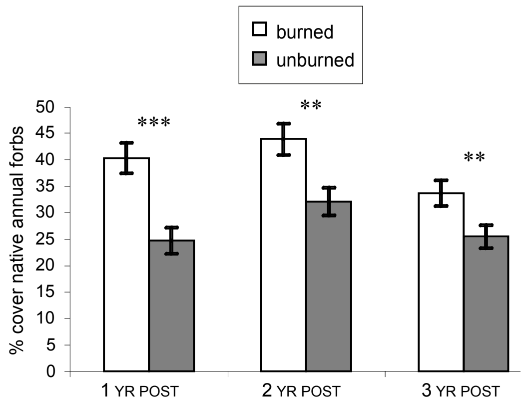

FIGURE 3. Mean native annual forb (naf) cover at the Jepson Prairie Preserve. Values shown are mean ± SE. n.s., not significant; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

management of these grasslands particularly to reduce exotic annual grass cover. Fire in addition to grazing may only be useful to give a short-term boost of native richness and temporarily reduce exotic grass cover.

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Appendix. List of plant species identified at each site during the study. CF = Cosumnes Foothills; JP = Jepson Prairie; VP = Vina Plains; VR = Valensin Ranch. * denotes exotic species.

FERNS AND FERN ALLIES	LOCATION			
Isoetaceae				
Isoetes howellii (Howell's quillwort)	CF		VP	VR
Isoetes nuttallii (Nuttall's quillwort)	CF		VP	
Isoetes orcuttii (Orcutt's quillwort)	CF	JP	VP	VR
Marsileaceae				
Pilularia americana (American pillwort)	CF	JP	VP	VR

DICOTS	LOCATION			
Apiaceae				
Eryngium castrense (Great Valley button celery)			VP	
Eryngium vaseyi (coyote thistle)	CF	JP		VR
Lomatium caruifolium (alkali desert parsley)	CF	JP	VP	VR
Sanicula bipinnatifida (snakeroot)	CF			VR
*Scandix pecten-veneris** (shepherd's needle)		JP		
*Torilis arvensis** (field hedge parsley)		JP		
Torilis nodosa (knotted hedge parsley)		JP		
Asteraceae				
Achillea millefolium (common yarrow)		JP	VP	VR
Achyrachaena mollis (blow wives)	CF	JP	VP	VR
*Anthemis cotula** (dog fennel)		JP		VR
Blennosperma nanum (yellow carpet)	CF	JP	VP	
Calycadenia multiglandulosa (rosin weed)	CF			
*Carduus pycnocephalus** (Italian thistle)		JP		
*Centaurea solstitialis** (yellow star thistle)		JP	VP	VR
Chamomilla suaveolens (pineapple weed)				VR
Conyza canadensis (Canadian horseweed)			VP	
*Cotula coronopifolia** (brass buttons)	CF	JP		VR
*Filago gallica** (narrow-leaved filago)	CF	JP	VP	VR
Gnaphalium luteo-album (everlasting cudweed)			VP	
Hemizonia congesta (hayfield tarweed)		JP	VP	
Hemizonia fitchii (Fitch's tarweed)	CF	JP	VP	VR
Hesperevax caulescens (hogwallow starfish)			VP	
Holocarpha virgata (yellow flower tarweed)	CF	JP	VP	VR
*Hypochaeris glabra** (smooth cat's ear)	CF	JP	VP	VR
*Hypochaeris radicata** (hairy cat's ear)	CF	JP	VP	VR
*Lactuca serriola** (prickly wild lettuce)	CF		VP	VR
Lasthenia californica (California goldfields)	CF	JP	VP	VR
Lasthenia fremontii (Fremont's goldfields)	CF	JP	VP	VR
Lasthenia glaberrima (smooth goldfields)	CF	JP	VP	VR
Lasthenia glabrata (yellow rayed goldfields)		JP		
Lasthenia platycarpha (alkali goldfields)	CF		VP	VR
Layia fremontii (Fremont's tidytips)	CF	JP	VP	VR
*Leontodon taraxacoides** (hawkbit)	CF	JP	VP	VR
Lessingia nana (dwarf lessingia)			VP	
Micropus californicus (Q tips)		JP	VP	
Microseris acuminata (Sierra foothill silverpuffs)		JP	VP	VR
Microseris campestris (San Joaquin silverpuffs)	CF	JP		VR
Microseris douglasii (Douglas' silverpuffs)		JP	VP	VR
Psilocarphus brevissimus (woolly marbles)	CF	JP	VP	VR
Psilocarphus oregonus (Oregon woolly marbles)	CF	JP	VP	VR
Psilocarphus tenellus (slender woolly marbles)	CF	JP	VP	VR
*Senecio vulgaris** (old man of spring)			VP	VR
Silybum marianum (milk thistle)		JP		
*Soliva sessilis** (field burrweed)	CF	JP		VR
*Sonchus asper** (prickly sow thistle)		JP	VP	VR
Sonchus oleraceus (common sow thistle)		JP	VP	
Boraginaceae				
Amsinckia menziesii (Menzies' fiddleneck)	CF			
Plagiobothrys acanthocarpus (adobe popcornflower)	CF		VP	VR
Plagiobothrys austiniae (Austin's popcornflower)	CF	JP		

Boraginaceae (continued)		**Location**		
Plagiobothrys fulvus (common popcorn flower)	CF		VP	VR
Plagiobothrys greenei (Greene's popcornflower)	CF	JP	VP	VR
Plagiobothrys leptocladus (popcornflower)	CF	JP	VP	VR
Plagiobothrys scriptus (scribe's popcornflower)			VP	
Plagiobothrys stipitatus var. *micranthus* (stalked popcornflower)	CF	JP	VP	VR
Plagiobothrys undulatus (coast allocarya)	CF	JP		VR
Brassicaceae				
Cardamine oligosperma (Idaho bittercress)	CF		VP	VR
Lepidium latipes (dwarf pepper grass)		JP	VP	
Lepidium nitidum (shining pepper grass)	CF	JP	VP	VR
Thysanocarpus radians (ribbed fringe pod)	CF			
Callitrichaceae				
Callitriche hermaphroditica (secret starwort)		JP	VP	
Callitriche heterophylla (varied leaved water starwort)	CF			VR
Callitriche marginata (winged water starwort)	CF	JP	VP	VR
Campanulaceae				
Downingia bicornuta (doublehorn downingia)	CF	JP	VP	VR
Downingia concolor (spotted throat downingia)		JP		
Downingia cuspidata (toothed downingia)	CF		VP	VR
Downingia ornatissima (horned downingia)	CF		VP	VR
Downingia pusilla (dwarf downingia)		JP		VR
Legenere limosa (false Venus' looking glass)	CF	JP	VP	VR
Caryophyllaceae				
*Cerastium glomeratum** (mouse eared chickweed)	CF	JP	VP	VR
Minuartia californica (California sandwort)	CF		VP	VR
*Petrorhagia dubia** (windmill pink)	CF	JP		VR
Sagina apetala (dwarf pearlwort)			VP	VR
Sagina decumbens (western pearlwort)	CF		VP	VR
*Silene gallica** (common catchfly)	CF	JP		VR
*Spergula arvensis** (stickwort)			VP	
*Spergularia bocconei** (Boccon's sand spurrey)			VP	
*Spergularia rubra** (red sand spurrey)	CF		VP	
*Spergularia villosa** (hairy sand spurrey)	CF			
*Stellaria media** (common chickweed)		JP		VR
Chenopodiaceae				
Atriplex sp. (saltbush)		JP		
Convolvulaceae				
Cressa truxillensis (alkali weed)		JP		
*Convolvulus arvensis** (field bindweed)	CF	JP		VR
Crassulaceae				
Crassula aquatica (aquatic pygmy weed)	CF	JP	VP	VR
Crassula connata (sand pygmy weed)		JP	VP	
*Crassula tillaea** (moss pygmy weed)	CF	JP	VP	VR
Parvisedum pumilum (Sierra stonecrop)			VP	
Cuscutaceae				
Cuscuta howelliana (Boggs Lake dodder)	CF	JP	VP	VR
Elatinaceae				
Elatine californica (California waterwort)	CF	JP		VR
Elatine chilensis (Chilean waterwort)				VR
Euphorbiaceae				
Chamaesyce sp. (spurge)	CF		VP	
Eremocarpus setigerus (turkey mullein)	CF	JP	VP	VR
Fabaceae				
Astragalus tener (alkali milk vetch)		JP		
Lotus purshianus (Spanish lotus)	CF	JP		
Lotus wrangelianus (Chilean lotus)	CF	JP	VP	VR
Lupinus bicolor (miniature lupine)	CF	JP	VP	VR
Lupinus nanus (Valley sky lupine)		JP		
*Medicago polymorpha** (bur clover)	CF		VP	VR

	LOCATION			
Fabaceae (continued)				
Trifolium albopurpureum (Indian clover)			VP	
Trifolium barbigerum (bearded clover)	CF	JP		VR
Trifolium bifidum (notch leaf clover)	CF	JP	VP	VR
Trifolium ciliolatum (foothill clover)	CF	JP	VP	VR
Trifolium depauperatum (cowbag clover)	CF	JP	VP	VR
*Trifolium dubium** (shamrock clover)	CF		VP	VR
Trifolium gracilentum (pinpoint clover)	CF	JP	VP	VR
*Trifolium hirtum** (rose clover)	CF	JP	VP	VR
Trifolium microcephalum (maiden clover)	CF	JP	VP	VR
Trifolium microdon (thimble clover)	CF	JP	VP	VR
*Trifolium subterraneum** (subterranean clover)	CF			VR
Trifolium variegatum (white tipped clover)	CF	JP	VP	VR
Trifolium willdenovii (tomcat clover)	CF	JP	VP	VR
*Vicia benghalensis** (purple vetch)			VP	VR
*Vicia sativa** (spring vetch)				VR
*Vicia villosa** (hairy vetch)				VR
Frankeniaceae				
Frankenia salina (alkali heath)		JP		
Gentianaceae				
Centaurium muehlenbergii (Muhlenberg's centaury)	CF		VP	
Centaurium trichanthum (alkali centaury)	CF			
Centaurium venustum (charming centaury)			VP	
Cicendia quadrangularis (Oregon timwort)	CF	JP	VP	VR
Geraniaceae				
*Erodium botrys** (broad leaf filaree)	CF	JP	VP	VR
*Erodium brachycarpum** (short fruited filaree)	CF	JP		VR
*Erodium cicutarium** (red stemmed filaree)		JP		VR
*Erodium moschatum** (white stemmed filaree)	CF	JP		
*Geranium dissectum** (cut leaved geranium)	CF	JP	VP	VR
*Geranium molle** (dove's foot geranium)		JP	VP	VR
Hypericaceae				
Hypericum anagalloides (tinker's penny)			VP	
Lamiaceae				
Pogogyne douglasii (Douglas' mesamint)		JP	VP	
Pogogyne zizyphoroides (Sacramento mesamint)	CF	JP	VP	VR
Trichostema lanceolatum (vinegarweed)	CF			VR
Limnanthaceae				
Limnanthes alba (white meadowfoam)			VP	
Limnanthes douglasii (Douglas' meadowfoam)		JP	VP	
Lythraceae				
*Lythrum hyssopifolium** (hyssop loosestrife)	CF	JP	VP	VR
*Lythrum portula** (spatula leaf loosestrife)	CF			
Malvaceae				
Malvella leprosa (alkali mallow)		JP		
Sidalcea calycosa (checker mallow)	CF			
Sidalcea diploscypha (fringed checker mallow)			VP	
Sidalcea hirsuta (hairy checkerbloom)		JP	VP	
Onagraceae				
Clarkia purpurea (purple clarkia)			VP	
Epilobium cleistogamum (selfing willowherb)	CF	JP	VP	VR
Epilobium pygmaeum (smooth spike boisduvalia)			VP	
Epilobium torreyi (Torrey's willowherb)	CF	JP	VP	VR
Papaveraceae				
Eschscholzia lobbii (frying pan poppy)	CF		VP	
Plantaginaceae				
Plantago coronopus (buckhorn plantain)			VP	
Plantago elongata (long leaf plantain)	CF	JP	VP	
Plantago erecta (dotseed plantain)	CF		VP	
*Plantago lanceolata** (narrow leaf plantain)			VP	

Polemoniaceae		**LOCATION**		
Linanthus bicolor (true baby stars)			VP	
Navarretia intertexta (needle leaf navarretia)	CF		VP	
Navarretia leucocephala (white headed navarretia)	CF	JP	VP	VR
Navarretia myersii (Myers' pincushionplant)	CF		VP	
Navarretia nigelliformis (adobe navarretia)			VP	
Navarretia pubescens (downy pincushionplant)	CF		VP	
Navarretia tagetina (marigold pincushionplant)	CF	JP	VP	VR
Polygonaceae				
Chorizanthe polygonoides (knotweed spineflower)			VP	
Eriogonum nudum (naked buckwheat)			VP	
*Rumex crispus** (curly dock)	CF	JP		VR
*Rumex pulcher** (fiddle dock)	CF	JP		VR
Rumex salicifolius (willow leaved dock)				VR
Portulacaceae				
Calandrinia ciliata (red maids)		JP		
Montia fontana (water chickweed)	CF	JP	VP	VR
Primulaceae				
*Anagallis arvensis** (scarlet pimpernel)	CF	JP	VP	VR
Centunculus minimus (false pimpernel)	CF	JP		VR
Dodecatheon clevelandii (padre's shooting star)			VP	
Ranunculaceae				
Delphinium variegatum (royal larkspur)			VP	
Myosurus minimus (tiny mousetail)		JP	VP	
Ranunculus aquatilis (white water crowfoot)	CF			VR
Ranunculus bonariensis (Carter's buttercup)	CF	JP		VR
*Ranunculus muricatus** (prickle fruit buttercup)	CF		VP	VR
Rubiaceae				
*Galium parisiense** (wall bedstraw)	CF	JP		VR
Scrophulariaceae				
Castilleja attenuata (narrow leaved owl's clover)	CF	JP	VP	VR
Castilleja campestris (yellow owl's clover)	CF	JP	VP	VR
Castilleja densiflora (dense flowered owl's clover)	CF			VR
Gratiola ebracteata (bractless hedgehyssop)	CF		VP	VR
Mimulus tricolor (tricolor monkeyflower)		JP	VP	VR
*Parentucellia viscosa** (yellow gland weed)	CF			
Triphysaria eriantha ssp. *eriantha* (butter 'n' eggs)	CF	JP	VP	VR
Triphysaria versicolor ssp. *faucibarbata* (yellow owl's	CF	JP		VR
Veronica peregrina (neckweed)	CF	JP	VP	VR
*Veronica persica** (bird's eye speedwell)	CF	JP		VR
Violaceae				
Viola douglasii (Douglas' golden violet)			VP	
Viola pedunculata (Johnny jump up)		JP		

MONOCOTS		**LOCATION**		
Cyperaceae				
Eleocharis acicularis (needle spikerush)	CF	JP	VP	VR
Eleocharis macrostachya (common spikerush)	CF	JP	VP	VR
Scirpus sp. (bulrush)			VP	
Juncaceae				
Juncus acuminatus (taper tip rush)			VP	
Juncus balticus (wire rush)	CF		VP	VR
Juncus bufonius (toad rush)	CF	JP	VP	VR
*Juncus capitatus** (head rush)	CF	JP	VP	VR
Juncus dubius (dubius rush)			VP	
Juncus effusus (common bog rush)	CF			
Juncus uncialis (inch high dwarf rush)	CF	JP	VP	VR
Juncus xiphioides (iris leaved rush)	CF	JP		VR
Juncaginaceae				
Lilaea scilloides (flowering quillwort)	CF	JP	VP	VR
Liliaceae				
Allium amplectens (narrow leaved onion)			VP	VR

Liliaceae (continued)		LOCATION		
Brodiaea californica (California brodiaea)			VP	
Brodiaea coronaria (early harvest brodiaea)	CF	JP	VP	
Brodiaea elegans (harvest brodiaea)	CF	JP	VP	VR
Brodiaea minor (dwarf brodiaea)	CF	JP	VP	VR
Calochortus luteus (yellow mariposa lily)	CF	JP	VP	VR
Chlorogalum angustifolium (narrow leaved soaproot)	CF		VP	VR
Chlorogalum pomeridianum (wavy leaf soaproot)			VP	
Dichelostemma capitatum (blue dick)	CF	JP	VP	VR
Dichelostemma multiflorum (roundtooth snakelily)			VP	
Fritillaria sp. (checker lily)		JP		
Odontostomum hartwegii (Hartweg's doll's lily)			VP	
Triteleia hyacinthina (white brodiaea)	CF	JP	VP	VR
Poaceae				
*Aegilops triuncialis** (barbed goatgrass)	CF	JP	VP	VR
*Agrostis avenacea** (Pacific bentgrass)	CF	JP		
*Aira caryophyllea** (silver hairgrass)	CF	JP	VP	VR
Alopecurus saccatus (foxtail)	CF	JP	VP	VR
Alopecurus carolinianus (Carolina foxtail)			VP	
*Avena barbata** (slender wild oats)	CF	JP	VP	VR
*Avena fatua** (common wild oats)	CF	JP	VP	VR
*Briza minor** (little quaking grass)	CF	JP	VP	VR
*Bromus diandrus** (ripgut brome)	CF	JP	VP	VR
*Bromus hordeaceus** (soft brome)	CF	JP	VP	VR
*Crypsis schoenoides** (swamp grass)				VR
Deschampsia danthonioides (annual hairgrass)	CF	JP	VP	VR
Distichlis spicata (inland salt grass)	CF	JP		
*Gastridium ventricosum** (nit grass)	CF	JP	VP	VR
Glyceria occidentalis (western mannagrass)	CF		VP	VR
Holcus lanatus (common velvet grass)	CF			
Hordeum brachyantherum (meadow barley)	CF	JP		VR
Hordeum depressum (alkali barley)		JP		
Hordeum marinum ssp. *gussoneanum** (Mediterranean barley)	CF	JP	VP	VR
Hordeum murinum ssp. *leporinum** (foxtail barley)	CF	JP	VP	VR
*Lolium multiflorum** (Italian rye grass)	CF	JP	VP	VR
*Lolium perenne** (perennial rye grass)			VP	
Melica californica (California melicgrass)		JP		
Nassella pulchra (purple needlegrass)		JP		
Phalaris lemmonii (Lemmon's canarygrass)		JP		VR
*Phalaris minor** (little seed canarygrass)	CF			VR
*Phalaris paradoxa** (hood canarygrass)				VR
Pleuropogon californicus (semaphore grass)	CF	JP	VP	VR
*Poa annua** (annual blue grass)	CF	JP	VP	VR
Poa secunda (one sided blue grass)		JP	VP	
*Polypogon maritimus** (Mediterranean rabbit's foot grass)	CF	JP	VP	VR
*Polypogon monspeliensis** (Rabbit's foot grass)	CF			VR
Scribneria bolanderi (Scribner's grass)	CF		VP	
*Taeniatherum caput-medusae** (Medusa head)	CF	JP	VP	VR
*Vulpia bromoides** (six weeks fescue)	CF	JP	VP	VR
Vulpia microstachys (small fescue)	CF		VP	VR
*Vulpia myuros** (rattail fescue)	CF	JP	VP	VR