MANAGEMENT OF SMALL MAMMALS IN A RELICT GRASSLAND IN CALIFORNIA'S CENTRAL VALLEY

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ABSTRACT: Populations of many small mammals in the western United States have declined as a consequence of changes in land-use patterns over the past century. In California's Central Valley these changes have resulted in replacement of native grassland vegetation by non-native annual grasses. Jepson Prairie is a natural reserve that has been set aside to preserve native vernal pool and bunchgrass habitats. Jepson Prairie also provides habitat for several state and federally listed threatened or endangered species, including plants insects, and vertebrates. Current management of the reserve includes prescribed burning and grazing by domestic sheep to foster restoration of native grasses. We examined the effects of prescribed burning on small mammals by censusing small mammal communities inhabiting burned and unburned habitats over a one-year period. Nine censuses (6720 trap-nights) resulted in a total of 215 captures of five species. Three of these species (deer mouse, *Peromyscus maniculatus*, California vole, *Microtus californicus*, and Botta's gopher, *Thomomys bottae*) are common in many parts of California. The remaining two are either reduced in numbers (California kangaroo rat, *Dipodomys californicus*) or listed as Federal Special Concern (FSC) species by the state of California (San Joaquin pocket mouse, *Perognathus inornatus inornatus*); it is worth noting that only one capture was made of the latter species. In general, extremely low and varying capture rates suggest that Jepson Prairie may be poorly suited to supporting populations of small mammals, although habitat management could substantially improve conditions for these species.

For sites such as Jepson Prairie to be managed to maintain small mammal populations, we recommend 1) acquisition of upland habitat to provide refuge from seasonal flooding; 2) control of domestic and feral cats; and 3) a comprehensive prescribed burning program to restore native plant species, reducing the need for grazing.

Key Words: Jepson Prairie Natural Reserve, prescribed burning, small mammal

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INTRODUCTION

Native bunchgrass prairies historically covered one-fourth of California's Central Valley (Barry 1972, Griggs 1981, Morris 1988). Since the arrival of European settlers, much of this 100-km wide alluvial floodplain has been converted to agricultural lands, leaving only fragmented patches of vernal pool habitat and native bunchgrass prairies. Jepson Prairie Natural Reserve (JPNR), a 634-ha reserve, is managed jointly by the University of California, Davis (UCD) and The Nature Conservancy (TNC). The reserve contains much of the remaining vernal pool and perennial bunchgrass habitats where several native species occur. Species of concern include Solano grass (*Tuctoria mucronata*; a federally-listed endangered species), the Delta green ground beetle (*Elaphrus viridis*; a federally-listed threatened species), the San Joaquin pocket mouse (*Perognathus inornatus inornatus*; a state-designated species of special concern) and the California tiger salamander (*Ambystoma tigrinum californiense*); a state-designated species of special concern). Native rodents such as the California vole (*Microtus californicus*) and the California Kangaroo rat (*Dipodomys californicus*) rely heavily on native vegetation for food and shelter, and serve as important prey to a variety of mammalian, reptilian and avian predators (Morris 1988).

Prescribed burning was employed at Jepson Prairie in 1996 to remove exotic plant species and to foster native vegetation. Although a number of studies have focused on plant communities and changes in soil structure in response to fire (Baker 1940, Beck and Vogl 1972, Kozlowski and Ahlgren 1974, Omi and Laven 1982, Ostfeld and Klosterman 1986), few studies directly address the effects of fire on fauna.

This study attempted to assess the effects of prescribed burning on the small mammal community at Jepson Prairie. We compared small mammal community structure in fields subjected to prescribed burns with that of fields which have not experienced recent fires to address the following questions: 1) does rodent species composition differ between burned and unburned areas and, if so 2) does this difference reflect changes in resource availability as a result of prescribed burning?

STUDY AREA

Jepson Prairie Natural Reserve (Solano County), is located in the Central Valley of California (38 16' N, 121 49' W), approximately 20 miles SW of the University of California, Davis. At 2-9 m in elevation, the topography is level, with scattered mima mounds, numerous small vernal pools and one large vernal pool, Olcott Lake, measuring ca. 800 m wide. Vernal pools cover more than 75% of the reserve, with the remainder consisting of grasslands, freshwater marshes, and stands of introduced gum trees (Eucalyptus).

Burned areas (2 years post-fire) were dominated by native plants, including fragrant fritillary (*Fritillaria lilliacea*, Liliaceae), colusa grass (*Neostapfia colusana*, Poaceae), and bearded allocarya or bearded popcorn-flower (*Allocarya (=Plagiobothrys) hystriculus*, Boraginaceae), all of which are declining nationally, and are currently under review for federal endangered species status. Unburned areas were dominated by non-native invasive grass species such as wild oat (*Avena fatua*, Poaceae) and Iberian star thistle (*Centaurea iberica*, Asteraceae). Unburned grids were located on the west side of the prairie, approximately 1 km SW of the burned grids. Treatments were separated by an access road and sheep fencing.

METHODS

Data were collected during nine censuses between January 1996 and February 1997. Four small-mammal trapping grids were established in January 1996. Two of these were located in areas managed by prescribed burning in 1994, and two were in unburned areas. Trapping grids consisted of 48 stations arranged in a 6 x 8 grid with 10 m between stations. Assuming an effective sampling area of at least one half inter-trap distances, our minimum sampling area covered approximately 0.48 ha. Animals were sampled using single medium-sized Sherman live traps (22.5 x 7.0 x 8.5 cm) at each station. Traps were set for four consecutive nights during each census, and baited with rolled oats, mixed seeds, and peanut butter. In warmer months, traps were closed during daylight hours. During colder months, traps were opened throughout the day, and synthetic fiber filling was provided for insulation. If inundation from flooding became a risk, traps were immediately removed. Animals captured were identified to species and marked with ear tags for identification, and weight, sex, reproductive condition, and age were recorded. Because of concerns about hanta virus, *P. maniculatus* were not ear tagged and were handled minimally. Consequently, no data were recorded and an estimate of density could not be made for this species.

Sheep (*Ovis aries*) grazing has been implemented at Jepson Prairie in an attempt reduce non-native vegetation. Because the sheep could not be removed from our study plots, we assumed that grazing had occurred, and thus sheep grazing equally affected all plots. Plant biomass samples were collected for all census periods except January, February, and August 1996. A frame measuring 12-x 12 cm (144 cm^2) was tossed onto each grid at 16 random points, and all plants rooted within the frame were clipped to 5 cm above ground level. Plants were placed in paper bags, and dried in a convective oven at 110°C for two weeks before weighing.

To assess variation between burn treatments we conducted a two-factor Model I repeated measures analysis of variance (rpANOVA) on the number of animals captured per census. For the present report we excluded census data that were not associated with concurrent plant biomass sampling (e.g., data from Jan., Feb., and Aug. 1996 were excluded). Additionally, because *Peromyscus* were not individually marked and these greatly exceeded other species (especially in March 1996) we conducted two additional rpANOVAs to evaluate the sensitivity of our analyses to this confounding variable. First, Peromyscus was excluded and an analysis with the three species of interest (*M. californicus, D. californicus, P. inornatus*) was conducted. A final rpANOVA was conducted from which we excluded trapping data from March 1996, in order to evaluate the influence that these data had on interpretation. Plant biomass data were pooled from each grid, and plots were treated as random factors in an analysis to determine if differences existed between burned and unburned treatments over time. Because of the lack of replications, results of our biomass analyses are specific to the plots studied and cannot be generalized to random sites.

RESULTS

Between January 1996 and February 1997, 9 censuses were distributed over major seasonal changes, and a total of 6720 trap-nights of effort resulted in 215 captures of five species (Table 1). Including all captures in the analysis, all effects were highly significant (Table 2a). The number of captures on burned plots was significantly greater than on unburned plots, and the number of *Peromyscus* captured was significantly greater than that of any other species (Fig. 1a). Additionally, the interaction between treatment and species was significant ($P < 0.05$), indicating that species responded differently to prescribed burning. In particular, *Peromyscus* were more abundant on burned plots (esp. March 1996; recall that data from Jan. and Feb. 1996 were not analyzed here), although exact numbers of animals were not available. Additionally, *Dipodomys* were captured only on burned plots, whereas *Microtus* was found only on unburned plots (Wirtz 1988, 1995) (Fig. 1a). Finally, the treatment x month interaction effect was significant ($P < 0.004$), suggesting that the numbers of captures on each treatment followed different trajectories over time.

When all *Peromyscus* data were excluded from analyses (Table 2b, Fig. 1b), burned and unburned plots did not differ significantly, nor did the number of captures. The significant effect of month ($P < 0.003$) contributed to significant species x month and treatment x species x month interactions. It is notable that the treatment x month interaction was not significant, indicating that these treatments followed similar trajectories over time. Finally, we excluded data for March 1996, when large numbers of Peromyscus were recorded. In this analysis (Table 2c) we observed significant effects for month and interactions with month. These results were therefore similar to those from which all *Peromyscus* data were excluded, except that we also observed a significant burn treatment x month effect.

Plant analyses indicated that prescribed burning had no overall effect on plant biomass (Tables 3 and 4). Additionally, plots within burn treatments were not significantly different from each other ($P > 0.20$). However, there were significant changes over time ($P < 0.0001$), reflecting seasonal patterns of growth. The treatment x time interaction indicates that burn treatments responded differently over time ($P < 0.05$) (Table 4).

DISCUSSION

A common theme to all these analyses was that rodent populations varied across study months, that different species responded differently across months, and that these trajectories were significantly influenced by the burn treatments (three way interactions) (Cooks 1959, Price and Waser 1984, Wirtz 1995). Although there was an apparent difference in community composition and density between the burned and unburned treatments, rodent populations were very low and variable, precluding a detailed seasonal analysis. Nonetheless, these results bear importantly for management of small reserves such as Jepson Prairie. The significant differences in rodent communities at our different sites appear to be attributable largely (but not exclusively) to a single species (*P. maniculatus*), especially at the beginning of the study. Although our analyses were confounded by the unknown number of *Peromyscus* present on our trapping grids, several very interesting patterns, such as month effects and species treatment preference (*Dipodomys* preferred burned plots, whereas *Microtus* preferred unburned plots) were not influenced by the exclusion of this species from our analyses. Most small mammal populations change seasonally, so the significant month effect was not unexpected. Both interactions that involved species were significant, suggesting that

Table 1. Total number of small mammals caught by month, species and treatment at Jepson Prairie Natural Reserve, California from January 1996 to February 1997.[a,b]

Census month	Species					Total
	PEMA	MICA	DICA	PEIN	THBO	
Jan-96	58 / 1	0 / 4	2 / 0	0 / 0	0 / 0	65
Feb-96	56 / 1	1 / 10	2 / 0	0 / 0	0 / 0	70
Mar-96	46 / 3	0 / 4	2 / 0	0 / 0	0 / 0	55
May-96	9 / 1	0 / 1	0 / 0	0 / 1	0 / 0	12
Jul-96	1 / 0	0 / 0	0 / 0	0 / 0	0 / 0	1
Aug-96	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0
Nov-96	2 / 1	0 / 0	0 / 0	0 / 0	0 / 0	3
Jan-97	2 / 0	0 / 0	0 / 0	0 / 0	0 / 1	3
Feb-97	2 / 1	0 / 1	2 / 0	0 / 0	0 / 0	6
Total	176 / 8	1 / 20	8 / 0	0 / 1	0 / 1	215

[a] The first number represents burned plots, the second number represents unburned plots (i.e., 58 caught in burned, 1 caught in unburned for PEMA in Jan-96).
[b] PEMA = *Peromyscus maniculatus* MICA = *Microtus californicus* DICA = *Dipodomys californicus* PEIN = *Perognathus inornatus* THBO = *Thomomys bottae*

these species followed different spatial dynamics. Analysis of the data, however, demonstrated that the principal difference among species was a slight increase in numbers of *Microtus* in February 1996, and that otherwise these species followed very similar seasonal patterns. This likely also resulted in the significant three-way interaction among treatment, species, and month.

Thus, the principal patterns that arose during this study concerned the species composition of burned versus unburned sites. Although both *Dipodomys* and

Table 2. ANOVA results on small mammal captures (*Thomomys* was excluded from all analyses) at Jepson Prairie Natural Reserve, California. a) results with all rodent species; b) results for all species except *Peromyscus*; c) results with data from March 1996 excluded. B = burned UB = unburned Sp = species Mo = month

a) ANOVA with all rodent species.

	Df Effect	MS Effect	Df Error	MS Error	F	p-level
B/UB	1	24.00	8	2.521	9.520	.0149
Sp	3	34.07	8	2.521	13.52	.0016
Mo	5	34.82	40	0.746	46.68	.0001
B/UB * Sp	3	24.97	8	2.521	9.906	.0045
B/UB * Mo	5	16.38	40	0.746	21.96	.0001
Sp * Mo	15	20.18	40	0.746	27.05	.0001
B/UB * Sp * Mo	15	20.28	40	0.746	27.19	.0001

b) ANOVA with Peromyscus excluded.

	Df Effect	MS Effect	Df Error	MS Error	F	p-level
B/UB	1	0.013	6	0.514	0.027	.8748
Sp	2	0.931	6	0.514	1.811	.2425
Mo	5	1.681	30	0.381	4.416	.0039
B/UB * Sp	2	3.431	6	0.514	6.676	.0298
B/UB * Mo	5	0.147	30	0.381	0.387	.8538
Sp * Mo	10	0.597	30	0.381	1.569	.1642
B/UB * Sp * Mo	10	1.364	30	0.381	3.584	.0032

c) ANOVA with March 1996 data excluded.

	Df Effect	MS Effect	Df Error	MS Error	F	p-level
B/UB	1	0.200	8	0.350	0.571	.4713
Sp	3	1.116	8	0.350	3.190	.0841
Mo	4	1.019	32	0.131	7.762	.0001
B/UB * Sp	3	0.400	8	0.350	1.142	.3889
B/UB * Mo	4	0.044	32	0.131	0.333	.8535
Sp * Mo	12	0.710	32	0.131	5.413	.0001
B/UB * Sp * Mo	12	0.119	32	0.131	0.904	.5524

Perognathus were uncommon in this study, it is likely that they would have been completely absent except for the use of prescribed burns (Price and Waser 1984, Wirtz 1982, 1988, 1995). Jepson Prairie is a relatively small reserve, consisting of slightly more than 600 ha. Given the fact that the reserve floods seasonally, the effective area for small mammal populations is much smaller than the actual area of the reserve, and thus may not be sufficient to support viable populations. Several recommendations, if implemented, could improve small mammal conservation. First, Jepson Prairie is characterized by level hardpan soils, which drain poorly, leading to seasonal flooding. Although there are mounds of land higher in elevation (mima mounds) that provide some topographic relief, they are limited in area and probably do not support stable populations. As a result, seasonal flooding could lead to an annual die-off of animals. Acquisition of upland habitat that provides refuge from seasonal flooding would greatly benefit small mammals, most of which rely on burrow systems for shelter. Enhancement of the preserve could allow for the development of a source rodent population, further enhancing

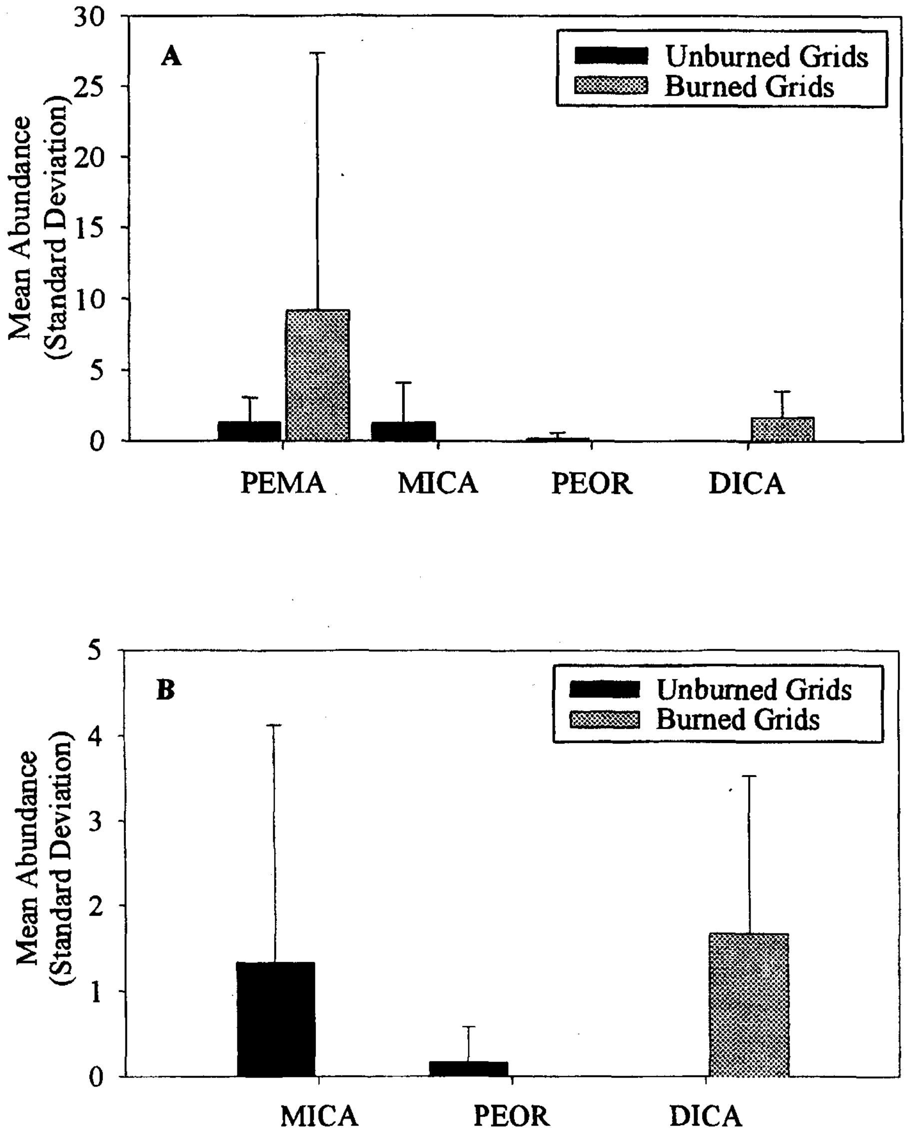

Fig. 1. Mean abundance (+ 1 Standard Deviation) for four species of small mammals at Jepson Prairie Natural Reserve, California. Panel A presents data for all four species, while panel B presents only the three less abundant species to demonstrate treatment effects on these three species. *Thomomys bottae* was excluded from all analyses.

populations of animals that rely on rodents as a primary prey base. Such enhancement would certainly require additional lands, as it would not suit the existing objectives of Jepson Prairie to develop upland habitat over existing vernal pools. Second, the presence of feral cats (*Felis domesticas*) and sheep (*Ovis aries*) grazing may also influence rodent dynamics. Feral cats currently are controlled by periodic removal on Jepson Prairie, but the proximity of farms may provide a constant source of these animals and of anthropogenically supplemented predation. Introduced predators in combination with pronounced seasonal and annual cycles in abundance of small mammals may further explain the low and variable capture rates (Soule et al. 1992). We recommend the control of feral and domestic cats in order to dampen their effects, as well as to stabilize small mammal populations already experiencing annual die-off.

Grazing was a significant confounding factor in our analysis of plant biomass. Occasional grazing on our study plots (on all grids) may partially explain the lack of a burning effect in most analyses. Although plant species composition was not quantified in our study, direct observations suggested that species composition differed greatly in burned and unburned areas. This difference in species composition may explain the different response on different plots over time (Table 4). Additionally, spatial constraints and age (2 years) post-fire restricted the number of replicate sites we could sample. As a result, the effects of prescribed burning on small mammals were not immediately apparent.

Jepson Prairie is currently being actively managed with a program of prescribed burning and sheep grazing (K. Rice per. comm. 1999). Although much is known about the effects of prescribed burning on flora (Cook

Table 3. Summary of plant biomass collected by census month and treatment at Jepson Prairie Natural Reserve, California from March 1996 to February 1997.[a]

Date	Site	N	Mean (SD) in cm.	Date	Site	N	Mean (SD) in cm.
Mar-96	U1	12	2.00 (0.310)	Nov-96	U1	16	1.44 (0.497)
	U2	12	1.00 (0.111)		U2	16	1.08 (0.317)
	B1	12	1.24 (0.227)		B1	16	1.95 (2.514)
	B2	12	1.44 (0.116)		B2	16	1.52 (0.947)
May-96	U1	16	4.78 (0.601)	Jan-97	U1	16	0.61 (0.694)
	U2	16	4.16 (0.306)		U2	16	0.44 (0.289)
	B1	16	2.98 (0.357)		B1	16	0.63 (0.442)
	B2	16	3.34 (0.304)		B2	16	0.44 (0.247)
Jul-96	U1	16	3.21 (1.983)	Feb-97	U1	16	1.93 (0.522)
	U2	16	1.88 (0.843)		U2	16	2.27 (2.091)
	B1	16	1.28 (0.686)		B1	16	1.74 (0.576)
	B2	16	1.09 (0.849)		B2	16	2.33 (0.533)

a U = unburned B = burned

Table 4. Results of a random effect analysis of variance on the plant biomass collected at four sites at Jepson Prairie Natural Reserve, California between January 1996 and February 1997.

Source	MS	Df	F	P
Model	Residual	23	18.82	0.0001
Burn	Plot (Burn)	1	3.46	0.203
Plot(Burn)	Plot*Time (Burn)	2	2.74	0.113
Time	Plot*Time (Burn)	5	29.37	0.0001
Burn*Time	Plot*Time (Burn)	5	3.58	0.040
Plot*Time(Burn) = Residual error		10	2.32	0.012
Error	365			

1959, Croner and Barrett 1979, Dubis et al. 1988, Biswell 1989), little is known about the effects of trampling on cover dependent species such as *M. californicus*. If a rigorous prescribed burning program can be implemented, it might be possible to reduce the extent of sheep grazing. However, while prescribed burning is a sound management technique, it may not be practical due to the social and political implications of burning a sufficient area of Jepson Prairie to control invasive exotic species. Grazing may have negative impacts on rodents, but because of social considerations, sheep removal is not feasible. Such conflicting management and conservation needs may severely restrict the use of small reserves such as Jepson Prairie for small mammal conservation. However, in the face of continued large-scale habitat fragmentation and the concomitant increase in the number of small habitat patches, it is imperative that further research be conducted to better understand the dynamics of small mammal populations in small reserves (e.g., Clark and Seebeck 1990).

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