

The Role of Small Mammals in Post-fire Establishment of Invasive Plant Species

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Prepared for The Center of Invasive Plant Management
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Introduction

Coastal sage scrub (CSS) occurs in the Mediterranean-type climate of coastal southern California and supports ~100 rare, sensitive, threatened, or endangered plants and animals. CSS habitat is disappearing rapidly due to human and agricultural development (O'Leary et al. 1994) and perhaps only 10-15% of the original extent of CSS habitat remains intact (Westman 1981). As a result, CSS is of primary conservation concern in southern California. Because CSS is a fire-prone community, general patterns of post-fire plant succession have been well documented (Westman 1981, Keeley and Keeley 1984, O'Leary 1990). However, despite the potential for fire to increase non-native plant invasions in CSS (Zedler et al. 1983, Haidinger and Keeley 1993), very few studies have explicitly examined the impact of fire on non-native species invasion in CSS or the mechanisms allowing invasion during post-fire succession. Understanding which factors influence invasion dynamics within a community and mechanisms by which they do so is essential for effective management of native CSS diversity.

A number of studies have documented the potential of small mammal foraging decisions to cause shifts in vegetation succession (Batzli and Pitelka 1970, Mills 1983, Brown and Heske 1990, Ostfeld and Canham 1993, Ostfeld et al. 1997). One striking example by Brown and Heske (1990) demonstrated a dramatic change in habitat, from desert shrubland to grassland, 12 years after the removal of 3 species of granivorous small mammals. Short-term changes in habitat were explained by increases in large-seeded grasses in response to release from rodent predation, as well as decreases in small-seeded shrubs in response to increased competition with grasses. Additional long-term changes in habitat occurred when a reduction in soil disturbance following small mammal removal resulted in decreased litter decomposition, the establishment and persistence of tall grasses, and colonization by specialized grassland rodent species.

In this study, we investigate the role of small mammals in post-fire establishment of invasive plant species in CSS by experimentally excluding small mammals from burned habitat spanning a gradient of pre-fire invasion by non-native grasses and forbs. We expect small mammals to preferentially forage on large-seeded non-native grasses, rather than small-seeded native shrubs. Therefore, we predict greater cover of non-native grasses inside exclosures, where small mammal granivory is removed, relative to control areas where small mammals are present on study grids.

Materials and Methods

We are conducting this ongoing study on the Rancho Jamul Ecological Reserve (RJER) in southeastern San Diego County, California. In October of 2003 an intense wildfire

burned large portions of RJER. We have pre-fire vegetation and small mammal data from 9 CSS study plots, spanning a gradient of invasion by non-native grasses and forbs that burned in the 2003 fire (Figure 1). During summer 2004, we established three 4 x 4 m grids on or near each of these 9 CSS study plots. The three 4 x 4 m study grids include: 1) an enclosure (with trenching and fencing) and 2) a pseudo-enclosure (with trenching, but no fencing) immediately adjacent to each study plot, as well as 3) a control grid (without trenching or fencing) placed on each study plot (Figure 2). Enclosures consist of hardware cloth fencing placed 0.3 m below ground within trenches and standing 1 m in height above ground. To keep small mammals from climbing into enclosures, 20 cm wide sheet metal flashing is folded over fence tops and secured with rivets (Figure 3). Because trenches themselves may have unexpected effects on nearby vegetation, we dug additional trenches without fencing to act as pseudo-enclosure controls. These trenches were filled with dirt when completed.

After establishing all 4 x 4 m study grids, we set 4 Sherman live-traps within each enclosure for 3 days to trap and remove any small mammals present. Although we did not capture any small mammals within enclosures, in order to remove any invaders, we continued to check for the presence of small mammals within enclosures monthly. We also conducted 3-day trap sessions on the nine 50 x 50 m study plots 4 times throughout each year (Jan., April, July, and Oct.) to estimate small mammal abundances. We opened, set, and baited all traps with sunflower seeds during the afternoon preceding a trap session. Seeds were roasted in ovens at high temperatures to prevent later germination. We checked traps at sunrise each morning thereafter. During each capture we recorded date, location, species, body mass, sex, reproductive status, and a unique toe-clip (assigned on first capture). After examination and marking, animals were released at capture sites.

We sampled vegetation from late Feb. through mid-May of 2005 using a point intercept method within each of the 4 x 4 m grids (i.e., enclosures, pseudo-enclosures, and controls) to estimate vegetation cover by species, origin (native or non-native), and growth form (shrub or herb) for each grid. Within each 4 x 4 m grid we sampled three 3 m long transects with a point every 0.25 m. Points began at 0.25 m and ended at 2.75 m, resulting in a total of 11 regularly spaced points per transect. We combined point-intercept data across transects on each 4 x 4 m grid to calculate absolute cover of vegetation, i.e. the spread of a vegetation type across space. Absolute cover was calculated as the number of individual sample points with at least one hit of a particular type of vegetation recorded (e.g. native, exotic, shrub, etc.), divided by the total number of points sampled. We also estimated native species richness for each grid by recording all unique native species found alive and rooted within the grid area.

We used repeated measures ANOVA to examine whether vegetation cover or richness differed inside the enclosures relative to controls or pseudo-enclosures. We performed separate analyses for absolute exotic cover, absolute native cover, and total native species richness. Because each grid served as its own control, these analyses tested for differences across treatments while controlling for the fact that both pre-fire invasion and post-fire small mammal activity differed across the plots. However, we performed follow-up linear regression analyses to explicitly examine how average cover and richness of vegetation on treatment plots (controls and pseudo-enclosures only) were related to pre-fire invasion and post-fire small mammal activity. In particular, we examined how the activity of heteromyid small mammals (i.e., pocket mice and kangaroo rats) related to vegetation cover and richness. Heteromyids in CSS are typically associated with open grassy patches (Meserve 1976a),

prefer foraging on grass seeds to shrub seeds (Meserve 1976b), and are thus expected to have the greatest impact on exotic plant cover. We estimated heteromyid activity as the total number of heteromyid captures in April. We used April captures because both CSS small mammals and vegetation typically peak in abundance/growth in spring.

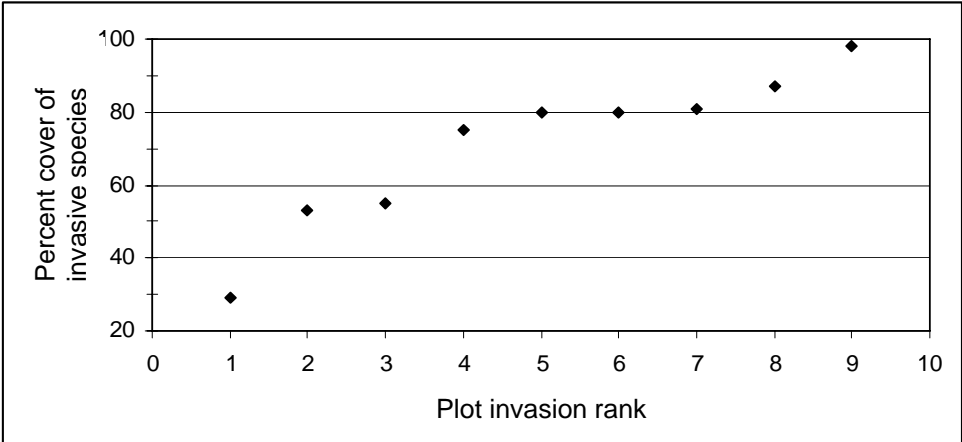


Figure 1. Gradient of invasion covered by 9 burned study plots at RJER. Absolute cover of invasive species (y-axis) is based on 2003 vegetation data.

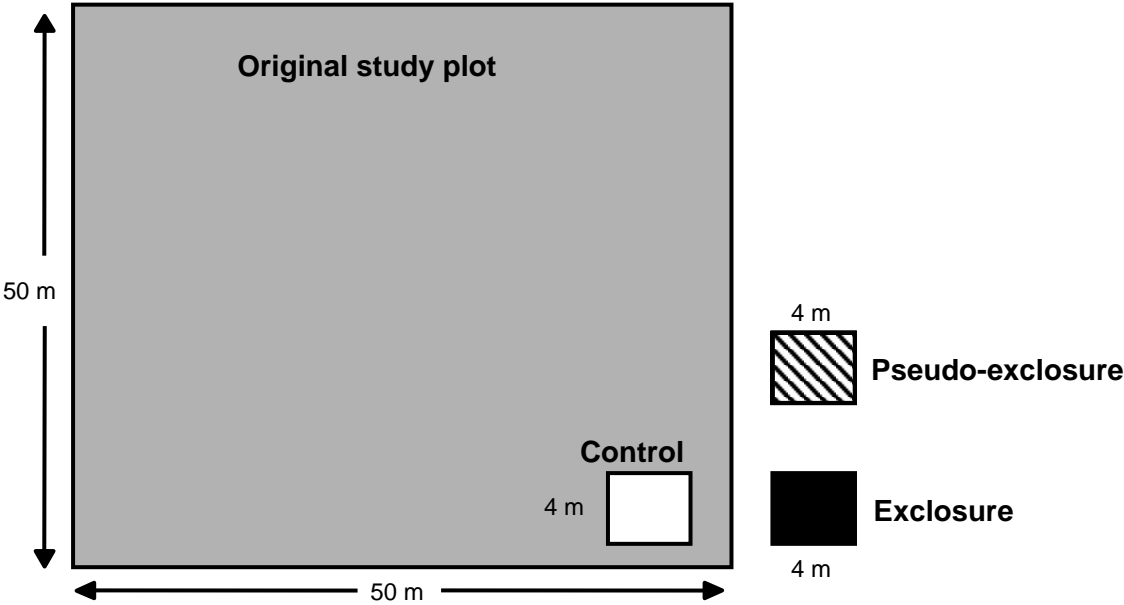


Figure 2. Study design includes: 1) an enclosure (trenching and fencing) and 2) a pseudo-exclosure (trenching without fencing) adjacent to each study plot, as well as 3) a control grid (without trenching or fencing) randomly placed on each study plot. Figure is not to scale.



Figure 3. A 4 x 4 m enclosure consisting of hardware cloth fencing placed 0.3 m below ground within trenches and standing 1 m in height above ground. To keep small mammals from climbing into enclosures, 20 cm wide sheet metal flashing is folded over fence tops and secured with rivets.

Results

Abundant rainfall during winter of 2004-2005 produced generally high levels of vegetation cover, but cover and richness were highly variable across all grids (Table 1). We detected no significant differences in vegetation cover (exotic or native) or native richness among treatment types within grids (repeated measures ANOVA, Table 1; Figures 4-6). However, across grids we did find a significant negative influence of heteromyid activity on the average exotic cover seen on controls and pseudo-exlosures (linear regression, Table 2). In addition, the overall influence of heteromyid activity on average exotic cover was stronger than the positive influence of pre-fire invasion. Heteromyid activity uniquely explained 32%

of the variability in average exotic cover across treatment plots (based on semipartial r^2 values), compared to 11% uniquely explained by pre-fire invasion. Nonetheless, the influence of heteromyid activity was moderated by pre-fire invasion. In particular, heteromyids showed a greater negative influence on exotic cover on grids with lower levels ($< 55\%$) of pre-fire invasion than grids with high ($\geq 75\%$) pre-fire invasion (Figure 7). We did not detect any influence of heteromyid activity on average absolute native cover or total native richness across treatment plots. Average total native richness across treatment plots was negatively related to pre-fire invasion (linear regression, Table 2; Figure 8).

Table 1. Descriptive statistics for exotic cover, native cover, and native richness on treatment plots. Averages are computed for each treatment type across grids, but the standard deviations (s.d.) reveal high variability in all measures among grids. F-statistics are shown from repeated measure analyses examining differences in cover and richness among treatments within plots. No significant differences were found.

Dependent Variable	Descriptives				Repeated measures ANOVA outcome		
	Min	Max	Mean	s.d.	F-value	df1, df2	p-value
<i>Absolute Exotic cover</i>					1.75	2, 16	0.206
Control	30.3	100.0	82.2	21.9			
Pseudo-exclosure	42.4	100.0	82.5	21.0			
Exclosure	69.7	100.0	90.2	13.2			
<i>Absolute Native cover</i>					0.51	2, 16	0.610
Control	24.2	87.9	50.2	20.8			
Pseudo-exclosure	6.1	93.9	42.8	30.7			
Exclosure	3.0	93.9	43.5	33.6			
<i>Total native richness</i>					0.39	2, 16	0.684
Control	5	17	10.9	4.0			
Pseudo-exclosure	6	18	11.6	3.9			
Exclosure	6	22	11.9	5.4			

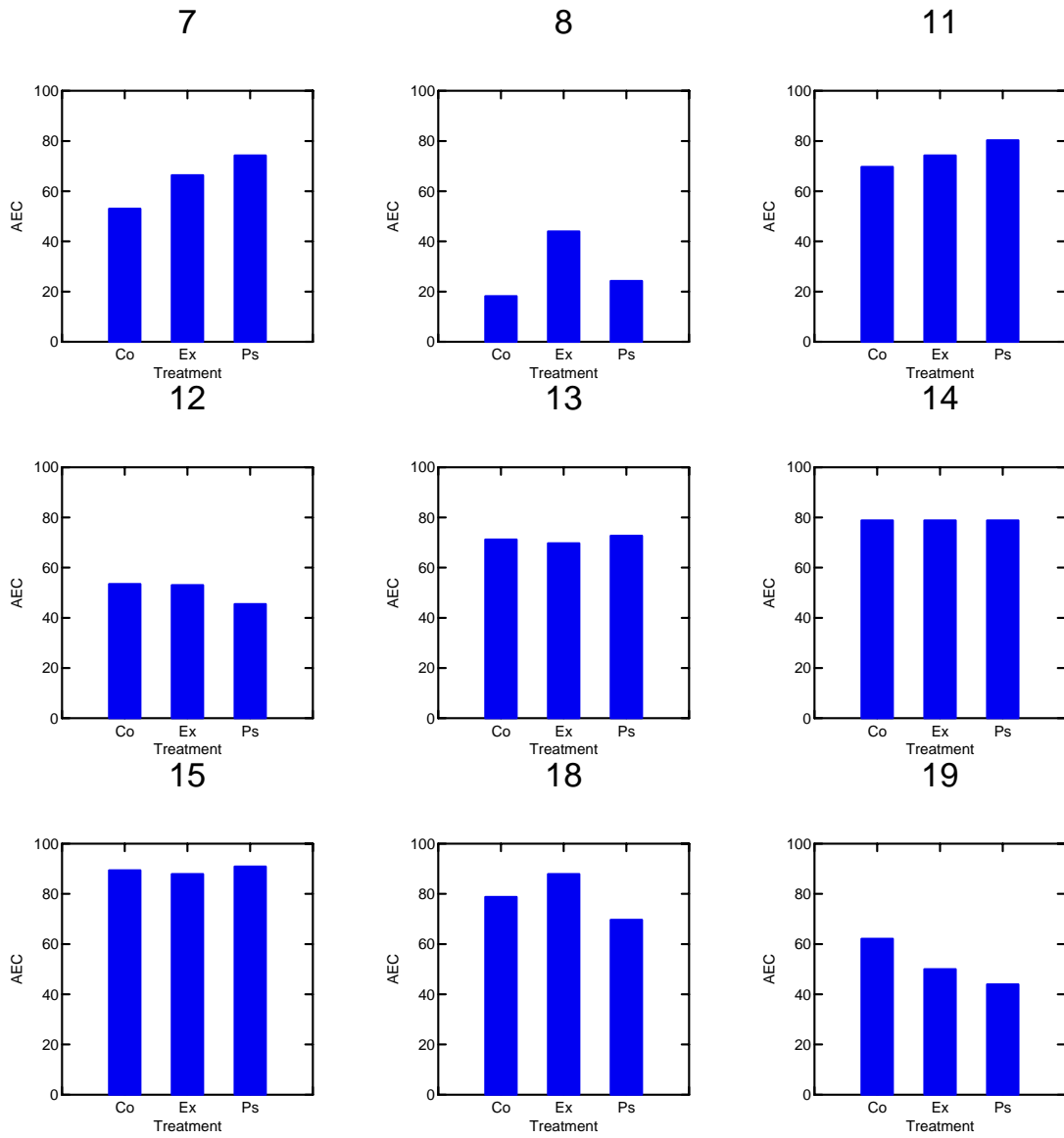


Figure 4. Differences in absolute exotic plant cover among treatment types on 9 study grids. Numbers above each graph are grid numbers. Co = control, Ex = exclosure, Ps = pseudo-exclosure.

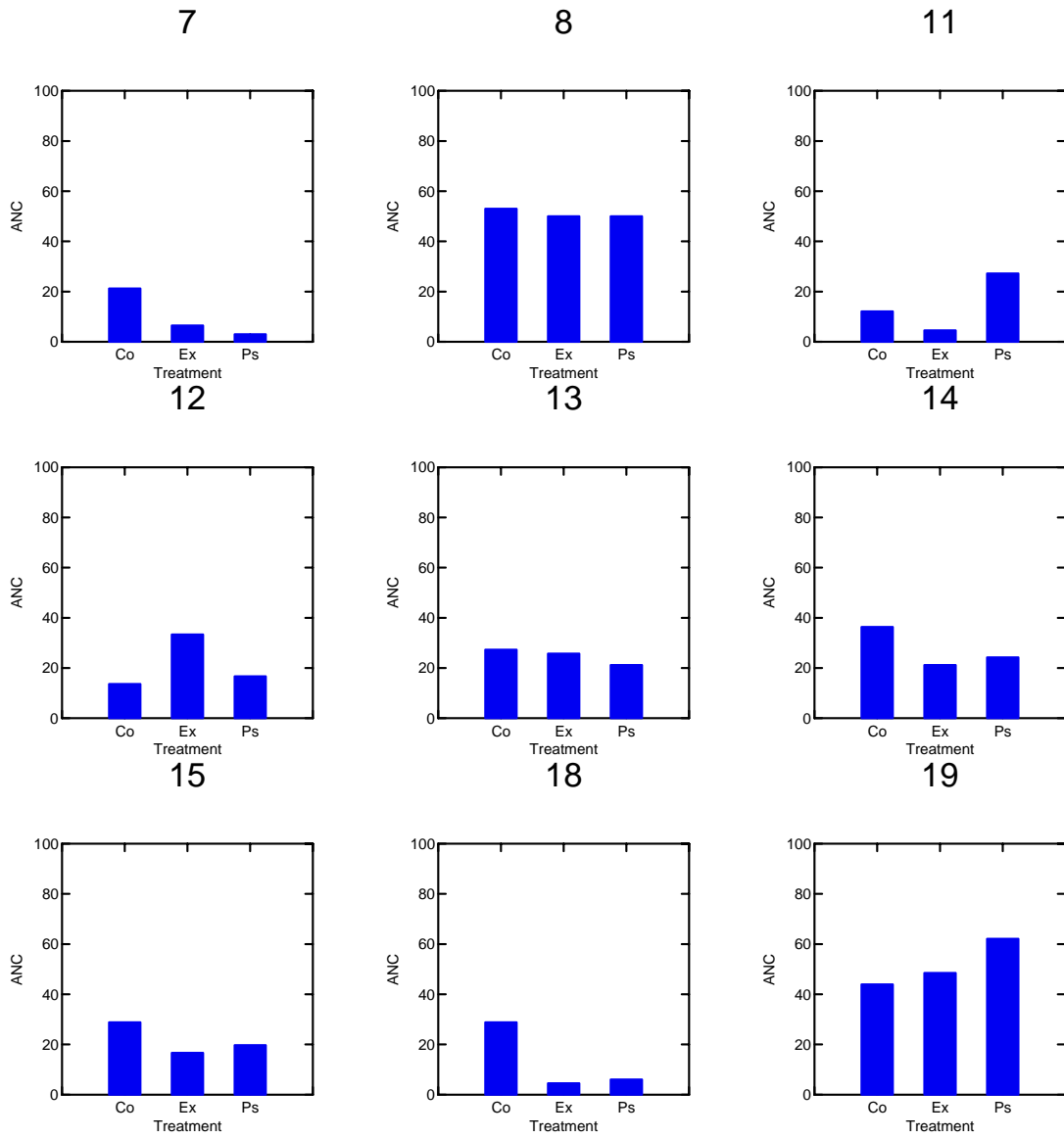


Figure 5. Differences in absolute native plant cover among treatment types on 9 study grids. Numbers above each graph are grid numbers. Co = control, Ex = exclosure, Ps = pseudo-exclosure.

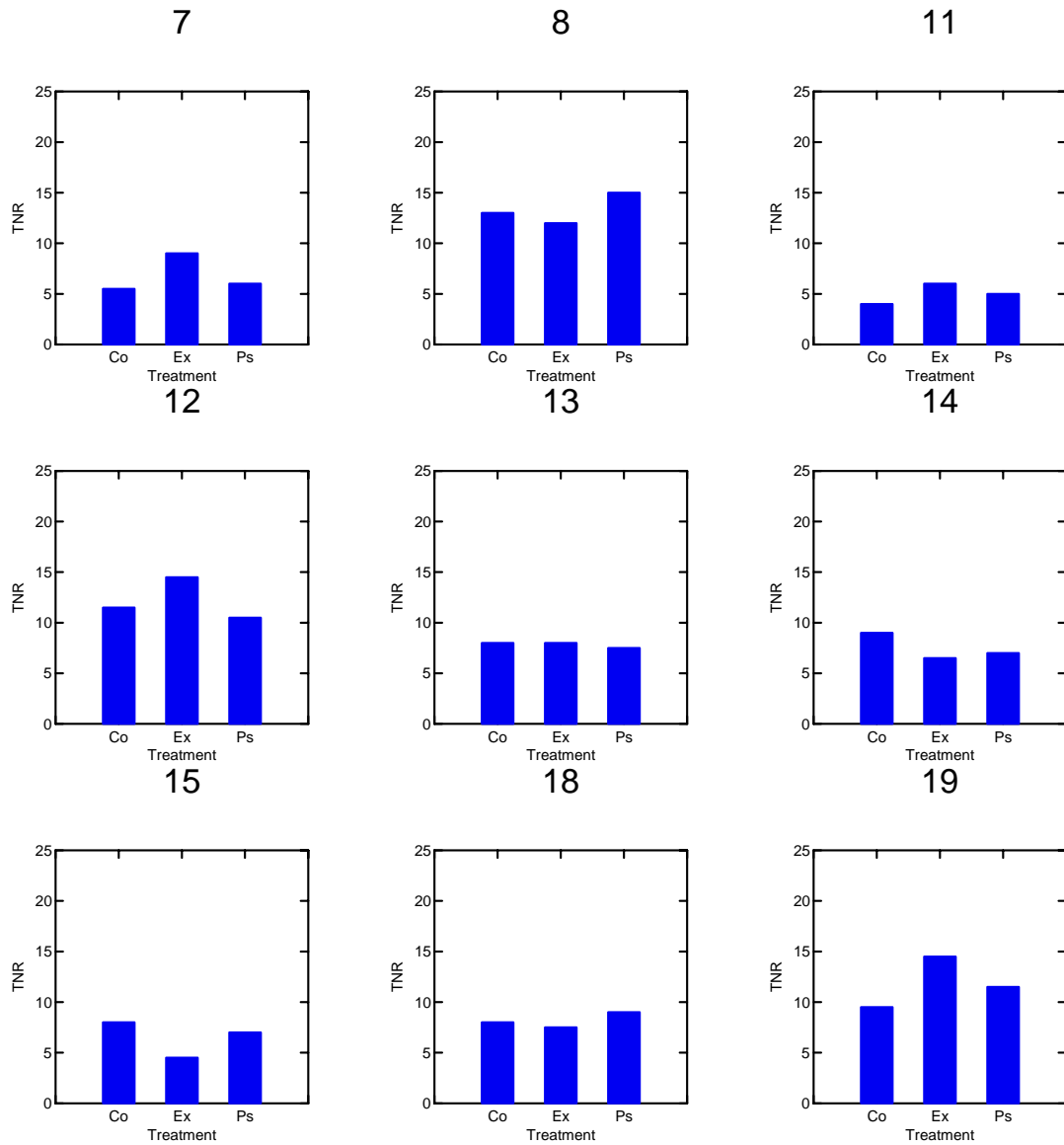


Figure 6. Differences in total native plant species richness among treatment types on 9 study grids. Numbers above each graph are grid numbers. Co = control, Ex = exclosure, Ps = pseudo-exclosure.

Table 2. Results from linear regressions examining the influence of heteromyid activity and pre-fire invasion on exotic cover (AEC) and native species richness (TNR) across study grids. Dependent variables are the average values for controls and pseudo-exlosures across study grids.

<i>DV = Average AEC in exclosure and Pseudo-exlosures</i>							
Model	F (df1,df2)	Sig	R ² adj	B	S.E.	t	Sig.
	9.43 (3,5)	0.017	0.76				
(Constant)				87.471	3.808	22.969	<0.001
Pre-fire invasion				0.353	0.186	1.894	0.117
Heteromyid activity				-9.785	3.010	-3.251	0.023
Pre-fire invasion x Heteromyids				0.463	0.180	2.580	0.049
<i>DV = Average TNR in exclosure and Pseudo-exlosures</i>							
Model	F (df1,df2)	Sig	R ² adj	B	S.E.	t	Sig.
	6.20 (1,7)	0.042	0.394				
(Constant)				11.222	0.973	11.529	<0.001
Pre-fire invasion				-0.119	0.048	-2.490	0.042

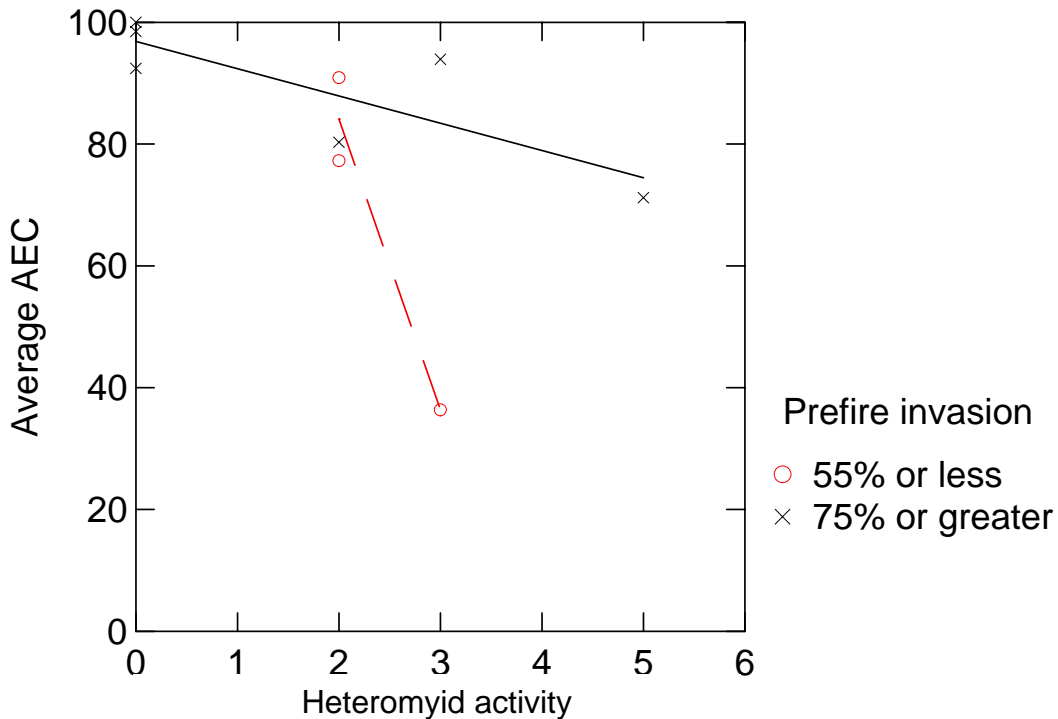


Figure 7. Relationship between April heteromyid activity and average absolute exotic cover on control and pseudo-exlosures across study grids. Separate lines are shown for grids with less than 55% pre-fire invasion and grids with 75% or greater pre-fire invasion.

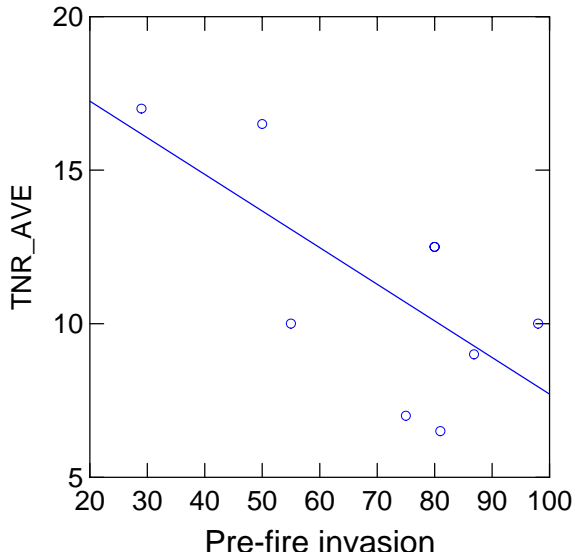


Figure 8. The negative relationship between average post-fire total native species richness (TNR_AVE) on treatment plots and pre-fire invasion.

Conclusions

Although we found no evidence in our experimental treatment plots that small mammals influence post-fire invasive grass establishment 1 year into this study, we expect large effects of small mammals on invasion in native CSS habitat will take longer to appear. It is also possible any small differences among treatments that may have been present were obscured by the prolific vegetation growth that occurred on all grids following abundant rainfall. Our comparison of invasion levels across study plots did show some influence of heteromyid small mammal species. While these results are consistent with our hypotheses regarding how mammals should influence the invasion process in CSS, they should be viewed with caution given the small sample size in this study, especially with respect to the interaction between heteromyid activity and pre-fire invasion. Nonetheless, if the results from the regression are indicative of true effects, we expect the treatment plots will show greater differences over time. Thus, we plan to continue this study and have located further funding with the San Diego Natural History Museum. We hope to eventually determine (1) whether small mammals influence post-fire invasive grass establishment and (2) the strength of any small mammal effects relative to pre-fire invasion levels within the next 2-3 years. We feel understanding which factors influence invasion dynamics within a community and mechanisms by which they do so is essential for effective management of native CSS diversity.

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