Carrizo Plain Ecosystem Project
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Summary

Understanding relationships among giant kangaroo rats (GKR), plant dynamics, and cattle grazing is necessary to optimize conservation of upland species in the Carrizo Plain National Monument. We completed the seventh year of the Carrizo Plain Ecosystem Project (CPEP), a long-term study to quantify these relationships using replicated cattle and GKR exclosures. 2013 was the second consecutive dry year in the Carrizo, vegetation levels were low and consequently no cattle were grazed for the second year in a row. There was no discernable precipitation during the growing season in 2013. GKR abundance was the lowest ever recorded in Center Well pasture and the second lowest in Swain pasture. Summer apparent survival of GKR was also the lowest recorded in this study and reproduction remained at the record low seen in 2012. Blunt-nosed leopard lizard (BNLL) numbers were at a record low after record highs in 2011 and 2012. *Uta* lizards showed some gains but densities were still lower than the earlier dry years (2007-2009). Invertebrate biomass reached a record low this year in all but the cattle exclosures. San Joaquin antelope squirrels (SJAS) seem to be weathering the dry years somewhat better than many of the other species with densities about average and apparent survival the highest yet recorded. Plant richness reached record lows in Center Well pasture and was the second lowest recorded in Swain pasture. A decrease in native plant richness is the primary cause for this decline as non-native richness remained fairly steady across years. Vegetation percent cover reached a new recorded low this year and peak residual dry matter was half of what it was in 2011, the record high for percent cover. Although no cattle were grazed this year, overall invertebrate richness and abundance as well as beetle abundance were higher on grazed plots. GKR exclosures also had significant effects on invertebrates in 2013 with overall richness, abundance, and arachnid abundance all higher where GKR were present. In both Center Well and Swain pastures, non-native plants were present more often when GKR were absent. As seen in previous years, bunchgrasses were positively affected by GKR presence and exotic grasses were negatively affected, suggesting that GKR foraging may limit the dominance of exotics they prefer to eat, such as large-seeded grasses. There was no new gopher activity on vegetation plots, but gopher activity did continue on all sites with the highest activity still occurring where GKR were absent. Kit fox den surveys were conducted this year with twelve active dens found on plots and most dens were found on cattle exclosure plots. We did not conduct bird surveys or spotlighting surveys this year.

Prepared by Rachel Endicott, 2014

Background

The Carrizo Plain National Monument, located in the southern San Joaquin Valley of California, is the largest (810 km^2) of the few remaining San Joaquin grassland ecosystem remnants and is a "hotspot" of species endangerment (Dunn et al. 1997). The federally endangered giant kangaroo rat (*Dipodomys ingens*, hereafter "GKR") is a keystone species in this system; it modifies the soil extensively with burrow systems and is important prey for many predators, such as the federally endangered San Joaquin kit fox (*Vulpes macrotis mutica*). Managing for endangered species conservation is a mandate of the monument (B. Stafford, pers. comm.), and this is a particularly challenging task because endangered species occur at every trophic level in the Carrizo Plain. Additionally, the Carrizo Plain is now dominated by annual grasses from Europe. Thus, sound management in the Carrizo Plain requires an understanding of the interactions between the many endangered and exotic species that occur there.

Previous research in the Carrizo by D. Williams provided basic demographic and life history information for GKR and compared a population in a grazed area to one in an ungrazed area. Additionally, monitoring data for a variety of species (including GKR) in relation to grazing was carried out for nine years and is currently being analyzed by Dr. C. Christian. These studies and others have provided conflicting evidence as to the effect of grazing on upland species and their habitats. Additionally, they cannot establish causal relationships between invasive plant dynamics and factors such as GKR abundance because they were observational rather than experimental.

In 2007, we initiated the Carrizo Plain Ecosystem Project (CPEP) to examine the relationships between cattle, GKR, plants, and other species in the Carrizo Plain using replicated exclosures (Prugh 2007). We gathered baseline data on the flora and fauna on our experimental plots, and we constructed 10 cattle exclosures in the annually-grazed Center Well pasture and 20 kangaroo rat exclosures in the Center Well and Swain (ungrazed) pastures. In 2013, we continued monitoring the flora and fauna on these plots.

Long-term project goals

1. To determine how giant kangaroo rats affect the distribution and abundance of native and invasive plants in the Carrizo Plain National Monument

2. To determine how livestock grazing directly and indirectly affects native species in the Carrizo Plain, especially giant kangaroo rats and plants.

3. To assess the potential impacts of climate change on the distribution, abundance, dynamics and interactions of native and invasive species in the Carrizo Plain National Monument.

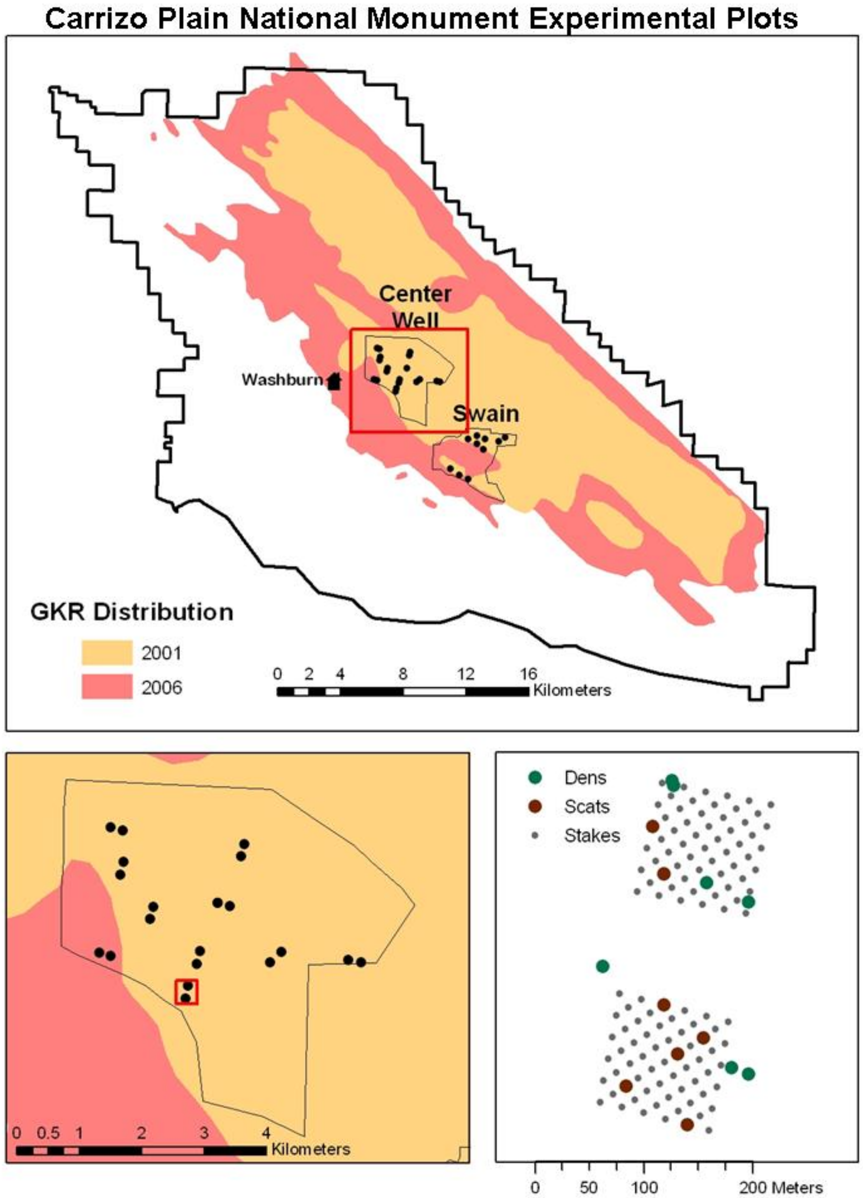


Figure 1. Map of study sites in the Carrizo Plain National Monument. Details are shown for the Center Well pasture and site CW 7. Kit fox dens and scats, as well as trap stakes, are shown for site 7.

Methods

Experimental design

We are using the Before-After-Control-Impact design with Paired sampling (BACIP; Osenberg et al. 1994) to determine the effect of GKR and cattle removal treatments on plant biomass and composition. BACIP is a powerful statistical framework that requires baseline surveys to control for pre-existing differences between control and treatment sites. To determine the effect of GKR on plants, we are using a randomized block split-plot design with three fully-crossed factorial treatments: pasture, GKR presence, and soil disturbance (Figure 2). The effect of cattle on GKR, plants, and other species is added as a partial fourth treatment (Figure 2). Because there is no cattle grazing in the Swain pasture and because it is not feasible to exclude GKR while allowing access to cattle, we were not able to add livestock presence as a fully factorial treatment. Thus, we have used structural equation modeling to estimate the strength of interactions and indirect effects of cattle (Wootton 1994).

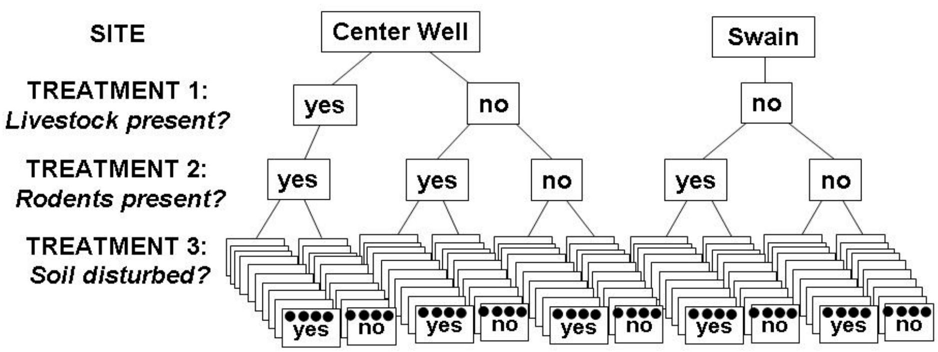


Figure 2. Experimental design of the project. There are ten blocks of each treatment combination and four nested vegetation plots (filled circles) within each block.

Exclosures

We constructed 20 20x20-m GKR exclosures, 10 in Center Well and 10 in Swain. Exclosures were placed in the center of each randomly chosen sub-block. Cattle exclosures were constructed around each GKR exclosure in Center Well. Cattle exclosures are 140x140-m (1.96 ha), large enough to have a population of roughly 20-100 GKR occurring within each exclosure. Paired 1.96-ha control plots are located 60 m from each cattle exclosure in Center Well in a random compass direction. Plants were sampled in each GKR exclosure, in a paired 400-m^2 area 20 m away from the GKR exclosure, and in Center Well, at the center of each paired control plot (Figure 3).

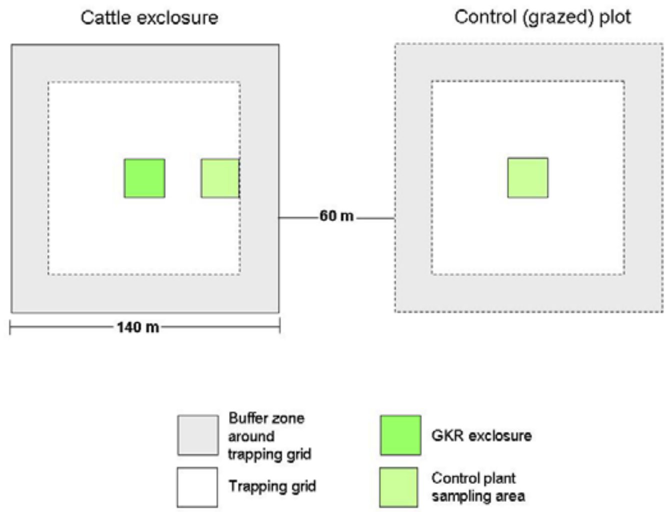


Figure 3. Nested exclosure design to separate livestock and GKR effects on plants, with paired control plot. A buffer zone around each GKR trapping grid ensured that the surveyed population was comprised of individuals living within the plot. This shows the design in Center Well; in Swain each plot is identical to the cattle exclosure but does not have cattle fencing.

Plant and soil sampling

We established 8 1-m^2 permanent plant sampling quadrats in each of the 50 400-m^2 plant sampling areas, for a total of 400 quadrats. Half of the quadrats were placed on GKR precincts and half were placed off precincts. The pinframe sampling method was used to determine plant cover and composition in each 1-m^2 plot, in which all species intercepted by 81 crossing points were recorded (Figure 4; Kimball and Schiffman 2003, Seabloom et al. 2003). Species occurring in the plot but not in the crosshairs were also noted. Biomass samples were obtained from 1/16-m^2 plots adjacent to each 1-m^2 plot to estimate biomass in April and September (expected peak and minimum biomass). Since cattle were not grazed this year the July, post-grazing biomass samples were not collected. Clip plots are surveyed in a different location each sampling session. Plant height was also measured prior to clipping.

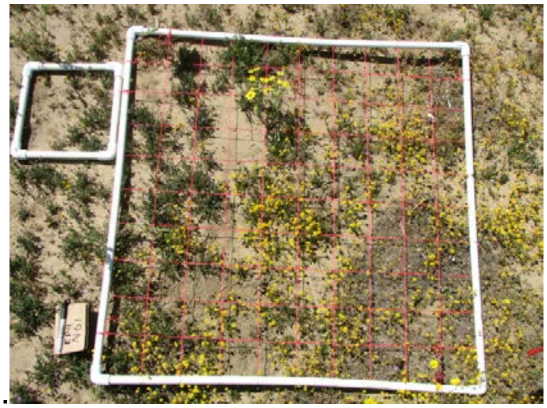
.1.. 

Figure 4. Plant sampling plot in a non-precinct area, showing the 1-m^2 point frame and the 1/16-m^2 clip plot.

GKR surveys

Mark-recapture surveys were conducted on each plot to estimate GKR abundance. Extra-long Sherman traps were placed every 20 meters, with each line offset such that traps were arranged in a checkerboard (Figure 5; n = 60 traps per plot, diagonal trap distance = 14.1 m). Traps were baited with parakeet seed (microwaved to prevent germination) and paper towel, and they were set at dusk and checked approximately 3 hours later. Sessions lasted for 3 nights on each grid in April/May and July/August. All captured animals were marked with an ear and PIT tag, weighed, sexed, a head measurement taken and released. Trapping occurred from April 7-May 2, 2013 (21 trap nights) and July 27-August 20, 2013 (19 trap nights).

To obtain mark-recapture estimates, we used the program R (R Development Core Team 2010) package RMark. We obtained population estimates for each trapping session as well as apparent survival estimates for the period between sessions using the robust design model (Pollock 1982). Death cannot be distinguished from dispersal in this model, so the “survival” rate obtained is referred to as “apparent survival.”

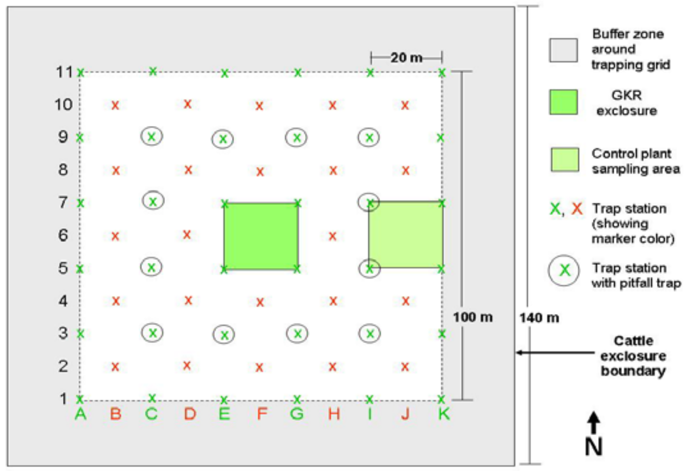


Figure 5. Detailed diagram of a cattle exclosure. Trap stations show trap locations for GKR mark-recapture surveys. Colors correspond to the spray-painted color on the stake marking the location. Letters and numbers identify the grid stakes (A1, B2, etc.).

Graduate student projects

Masters student Camdilla Wirth, CSU Northridge (Supervisor: Tim Karels) is investigating the effect that habitat modification by giant kangaroo rats has on common side-blotched lizards. Giant kangaroo rats may influence the spatial distribution and microhabitat use of these lizards by building extensive burrowing systems that provide structural elements for thermoregulation, refuges from predators, and high quality foraging grounds. Her project seeks to identify which of these mechanisms is behind the association between giant kangaroo rats and common side-blotched lizards.

SJAS surveys

San Joaquin antelope squirrel (*Ammospermophilus nelsoni*, hereafter "SJAS") abundance was determined on each plot using mark-recapture surveys. Tomahawk traps were placed every 40 m in checkerboard spacing, for a total of 18 traps per plot. Traps were baited with oats, set at dawn, and checked every two hours until noon or temperatures rose over 85̊ F. All captured animals were PIT-tagged, weighed, and sexed. Trapping occurred from May 11-May 29, 2013 (13 trap days). The RMark package was used to obtain density estimates on each plot each year.

Bird surveys

Bird surveys were not conducted this year due to budget limitations. From 2008-2012, point counts were conducted four times on each plot in the spring.

Reptile surveys

Line transect surveys were used to estimate reptile abundance on each 1.96-ha plot. Three surveys were conducted on each plot from May 13–July 26, 2013. Seven 140-m long transects spaced 20 m apart were slowly walked by a single observer, and all reptiles detected within 10 m on either side of the transect were identified and recorded, along with the perpendicular distance from the transect line and age (hatchling or adult). Air temperature was recorded at the start of each survey and wind speed and time of day were recorded at the start and end of each survey. We adopted temperature and wind cutoffs recommended in the blunt-nosed leopard lizard (BNLL) protocol.

Invertebrate surveys

Grasshoppers were counted during reptile surveys. Additionally, pitfall traps were placed on each plot between June 8-9, 2013 and collected 2 weeks later (*n* = 8 traps per plot, 240 total). Traps were made of standard plastic beer cups sunk into the ground such that the top of the cup was level with the ground (Figure 6A). Traps were covered with 10x10" pieces of aluminum flashing with an inch of space between the cover and ground (Figure 6B). Two centimeters of safe antifreeze (propylene glycol) was poured into each cup. A small piece of plastic aviary fencing (¾" mesh) was placed just inside each cup to keep lizards out of the traps (Figure 6A). This probably filtered out larger insects as well. Upon collection, the contents of each trap was rinsed and stored in 50-mL falcon tubes filled with ethanol. Samples were then sorted and all insects were counted and identified to order and morphotype. Each sample was weighed, and key insects (beetles, ants, and orthopterans) were also weighed separately.

A  **B** 

Figure 6. Pitfall trap viewed from above (A) and from the side with the aluminum cover (B).

Spotlight surveys

Spotlighting surveys were not conducted this year due to budget limitations. From 2008-2012, ten spotlight routes along dirt roads in our study pastures ranging in length from 1.9-5.5 km (total distance = 35.4 km for all 10 routes) were surveyed in spring and summer.

Kit fox activity and diet

In 2010, kit fox dens found on plots or opportunistically while walking to plots were geo-referenced. In 2013 a kit fox den survey was conducted on all plots using line transect surveys. In 2013, we continued to collect scats deposited on our traps as kit foxes often marked our traps with urine and feces. We collected 102 kit fox scats. We also recorded all sightings of kit foxes.

Cattle grazing intensity

Cattles were not grazed this year because there was not enough forage and therefore cattle patty counts were not conducted, however cattle patty counts were conducted in all previous years shortly after the cattle were removed.

Results and Discussion

Plants

General plant composition

Plant species richness in both Center Well and Swain dropped in 2012 and this trend continued in 2013 with a record low in Center Well and the second lowest data recorded in Swain (Table 1). Exotic species richness has remained similar across all years (value range: 6-10) but native species richness dropped in both pastures. Native species richness was the lowest ever recorded in Center Well and the second lowest recorded in Swain.

In 2012, percent cover was the lowest yet recorded for this study and it dropped still further in 2013 (Table 1). In Center Well, exotic cover remained the same as in 2012, 16%, and native cover dropped from 5% to 2%. In Swain the opposite trend occurred with native cover remaining the same as in 2012 at 7% and exotic cover dropping from 25% to 23%.

Grass (*Poaceae)* cover was the lowest ever recorded in grazed and ungrazed plots with GKR. Grass cover was the third lowest recorded in kangaroo rat exclosures (Figure 7). *Schismus arabicus* and *Bromus madritensis* remained the dominant grass species in Center Well and Swain, respectively. Similarly, *Bromus* was again the most common grass in GKR exclosures, while in areas with GKR, *Schismus* was the most common grass (Table 2).

In comparing all plots, the most common plant in Center Well was the exotic species *Schismus arabicus*, followed by the native species *Vulpia microstachys* and the exotic *Hordeum murinum*. On all plots in the Swain pasture, the exotic *Erodium circutarium* was the most common species, followed by *Bromus* and *Schismus* (Table 2).

The plants dominating in Center Well 2013 were the same as in 2012 and more similar to those seen in 2011(*Erodium*, *Vulpia microstachys*, *Schismus*) than those seen in the dry years of 2007-2009 when neither *Schismus* nor *Hordeum* were highest for percent cover, although *Vulpia microstachys* was one of the top plants for percent cover in 2007-2009.

In Swain pasture, the plants dominating percent cover were also the same as in 2012 and these results are similar to the other dry years, with *Bromus* and *Erodium* common in 2007 and *Schismus* and *Erodium* common in 2008 and 2009. *Bromus* and *Erodium* were also common in 2011 in Swain.

Table1. Species richness and relative percent plant cover in the Center Well and Swain pastures, 2007–2013.

Metric	Type	Center Well						
		2007	2008	2009	2010	2011	2012	2013
Species richness	native	18	30	30	31	28	21	15
	exotic	8	7	6	7	9	7	6
	total	26	37	36	38	37	28	21
Plant cover (%)	native	23	28	42	67	35	5	2
	exotic	17	37	28	25	49	16	16
	total	40	65	70	92	84	21	18
		Swain						
		2007	2008	2009	2010	2011	2012	2013
Species richness	native	15	43	40	45	39	34	27
	exotic	7	10	8	6	7	9	6
	total	22	53	48	51	46	43	33
Plant cover (%)	native	17	20	41	57	32	7	7
	exotic	32	33	32	34	44	25	23
	total	50	52	73	90	76	32	30

Table 2. Relative % cover of plant species in the Center Well and Swain pastures in 2013 (*n* = 400 plots), and without GKR ("No GKR", inside GKR exclosures, *n* = 160 plots) and with GKR ("GKR", outside GKR exclosures, *n* = 240 plots).

Species	Type	Center Well	Swain	No GKR	GKR
Erodium cicutarium	Invasive	47.39	36.26	41.46	41.69
Hordeum murinum	Invasive	17.37	6.64	7.70	15.23
Schismus arabicus	Invasive	12.39	7.41	17.06	3.60
Bromus madritensis	Invasive	11.20	25.78	10.89	25.55
Vulpia microstachys	Native	8.37	3.37	8.87	3.11
Lepidium nitidum	Native	1.36	2.93	2.46	1.95
Trifolium gracilentum	Native	0.63	0.77	0.98	0.46
Moss		0.55	1.15	0.68	1.02
Vulpia myuros	Invasive	0.37	-	0.38	< 0.01
Poa secunda	Native	0.21	6.49	4.01	3.04
Astragalus lentiginosus	Native	0.05	-	0.05	-
Tropidocarpum gracile	Native	0.05	0.29	0.16	0.19
Amsinckia tessellata	Native	0.05	0.14	0.22	< 0.01
Dichelostemma capitatum	Native	< 0.01	0.63	0.05	0.56
Lepidium dictyotum	Native	< 0.01	0.58	0.49	0.14
Lotus wrangelianus	Native	< 0.01	0.48	0.38	0.14
Eriogonum gracillimum	Native	< 0.01	0.38	0.33	0.09
Astragalus oxyphysus	Native	< 0.01	0.05	< 0.01	0.05
Allium peninsulare	Native	< 0.01	< 0.01	< 0.01	< 0.01
Lupinus microcarpus	Native	< 0.01	< 0.01	< 0.01	< 0.01
Lactuca serriola	Invasive	< 0.01	-	< 0.01	-
Phlox gracilis	Native	< 0.01	-	-	< 0.01
Lasthenia californica	Native	-	2.38	1.69	0.86
Linanthus liniflorus	Native	-	1.20	0.33	0.88
Pectocarya penicillata	Native	-	1.15	0.76	0.46
Calandrinia ciliata	Native	-	1.11	0.60	0.56
Plantago erecta	Native	-	0.38	0.16	0.23
Hollisteria lanata	Native	-	0.29	0.27	0.05
Chorizanthe uniaristata	Native	-	0.10	< 0.01	0.09
Vulpia bromoides	Invasive	-	0.05	-	0.05
Astragalus didymocarpus	Native	-	< 0.01	-	< 0.01

Table 2 Continued.

Species	Type	Center Well	Swain	No GKR	GKR
Chaenactis glabriuscula	Native	-	< 0.01	< 0.01	< 0.01
Gilia minor	Native	-	< 0.01	< 0.01	-
Gilia sp.	Native	-	< 0.01	< 0.01	-
Guillenia lasiophylla	Native	-	< 0.01	< 0.01	< 0.01
Herniaria hirsuta	Invasive	-	< 0.01	< 0.01	< 0.01
Lasthenia minor	Native	-	< 0.01	< 0.01	-
Microseris elegans	Native	-	< 0.01	-	< 0.01

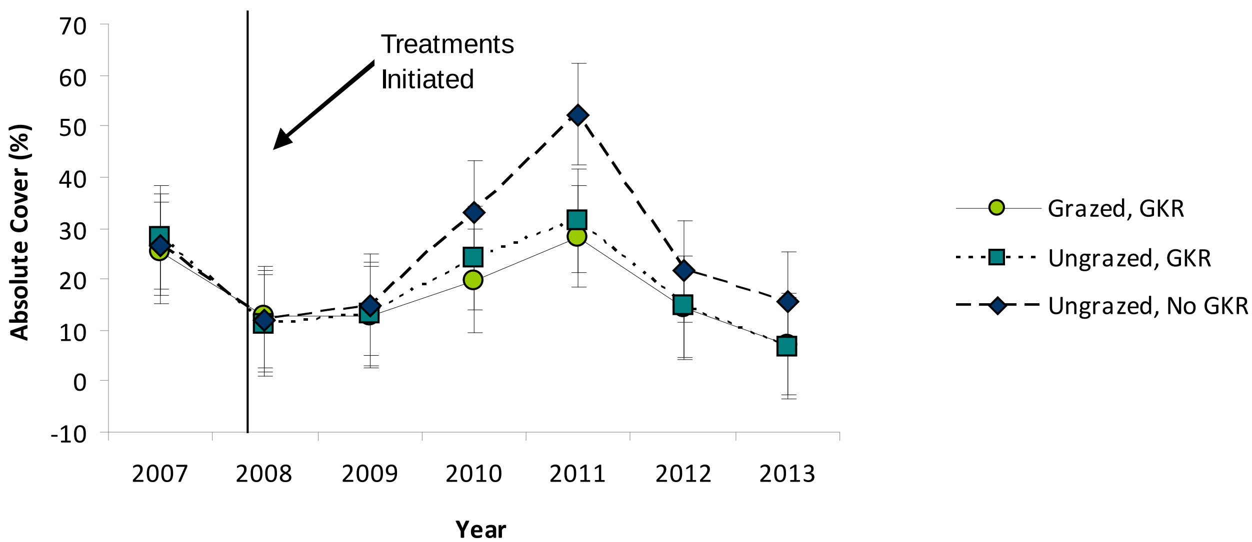


Figure 7. Grass cover in experimental plots within the Center Well pasture. Three treatments were initiated prior to the spring of 2008: kangaroo rat exclosures (ungrazed, no GKR), cattle exclosures (ungrazed, GKR), and control plots (grazed, GKR). Means and standard error bars are shown (*n* = 10 replicates per treatment).

Grazing intensity

For the second year in a row, there was not enough spring forage for grazing this year and so no cattle were turned out in the Center Well pasture.

Biomass removal by cattle and GKR.

Without grazing cattle, only biomass removed by GKR (in both control and cattle exclosure plots) and biomass removed by wind, invertebrates and other factors (in the kangaroo rat exclosures) could be measured this year. We calculated the biomass removed by GKR by subtracting the biomass measured in control plots from the biomass measured within GKR exclosures. In 2013, biomass was measured in April (expected peak) and October (expected minimum).

The peak residual dry matter (RDM) on grazed and ungrazed plots with GKR was approximately 1,300 pounds per acre in 2013 (Table 3), roughly half the RDM seen in the record vegetation year of 2011. Removal by GKR was about the same in spring and fall (Figure 9), just over 1,000 pounds per acre removed. Without GKR, RDM levels were reduced from 1,999 to 1,611 pounds per acre (Table 3).

Table 3. Average (± standard error) plant biomass measured in pounds per acre on 10 replicate sites in the Center Well (CW) pasture, 2013. Center Well sites consisted of a control plot which is normally grazed by cattle, ("GKR and cattle" treatment), a cattle exclosure ("GKR only" treatment), and a GKR exclosure ("no GKR or cattle" treatment).

Treatment	April	October
GKR and cattle	513 ± 88	441 ± 435
GKR only	866 ± 179	588 ± 479
No GKR or cattle	1999 ± 332	1611 ± 1453

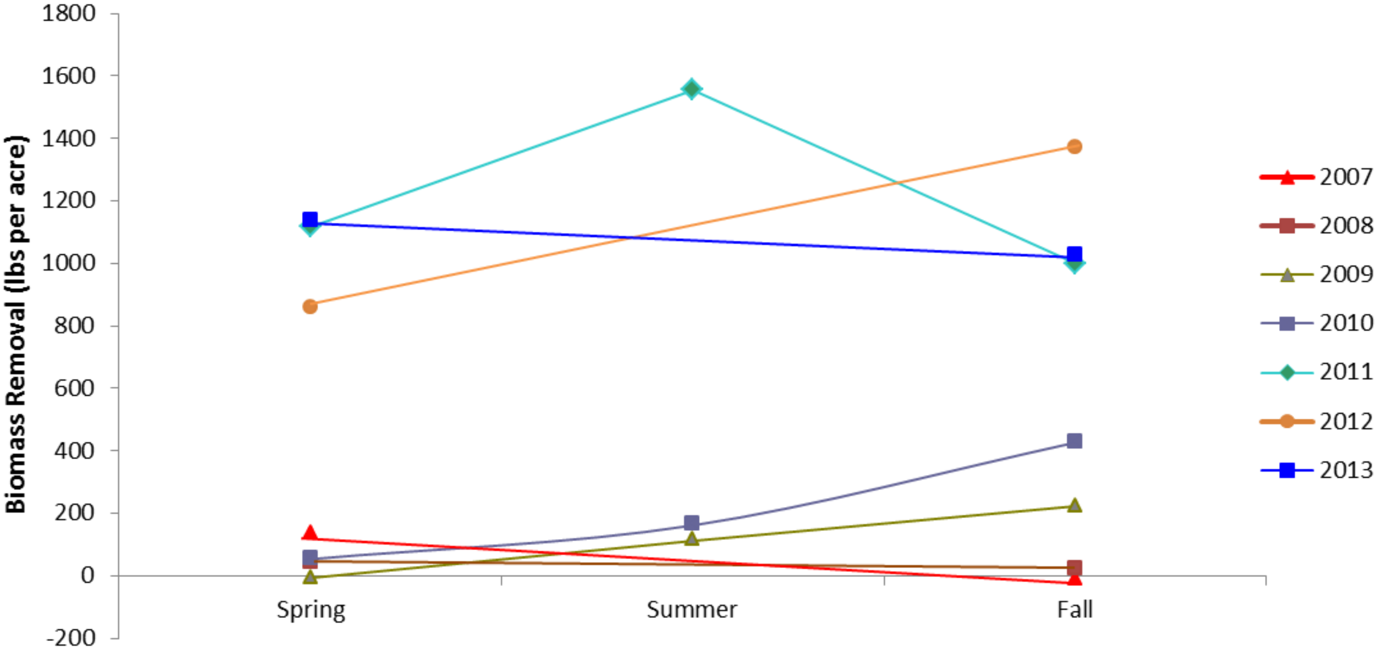


Figure 9. Biomass removal in Center Well pasture by GKR from 2007-2013, measured as the difference in biomass in and out of GKR exclosures.

Native and exotic plant cover

In 2013 native cover was the lowest ever recorded in this study (Table 1, Figure 10). Non-native plant cover was at an all-time low as well, with the exception of inside kangaroo rat exclosures where non-native cover rebounded from a near record low in 2012 to mid-range levels in 2013 (Figure 11).

Native percent cover was 2% in Center Well and 7% in Swain. In both Center Well and Swain pastures, non-native plants were present more often when GKR were absent (t = -10.08, P < 0.005 and t = -4.60, P < 0.005).

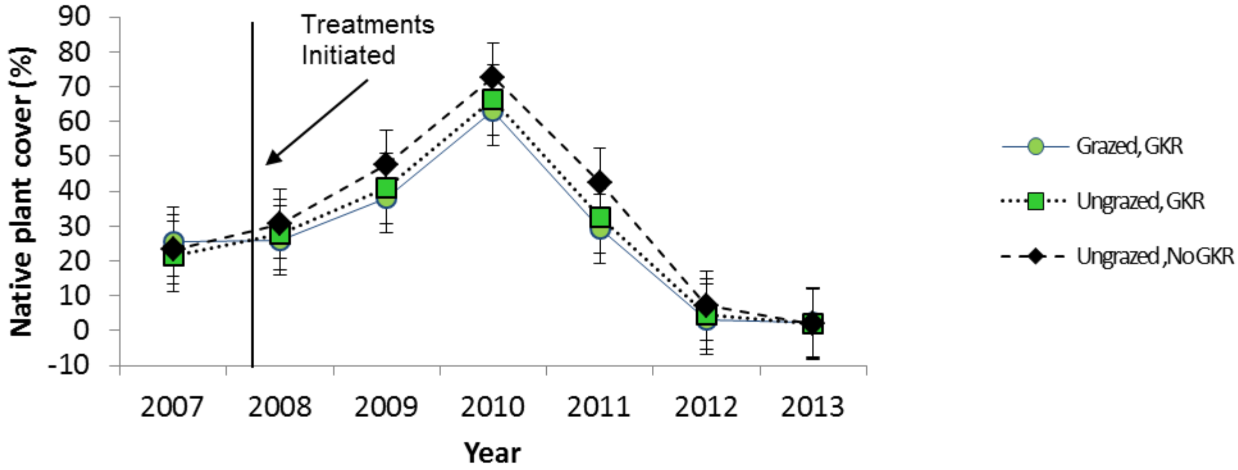
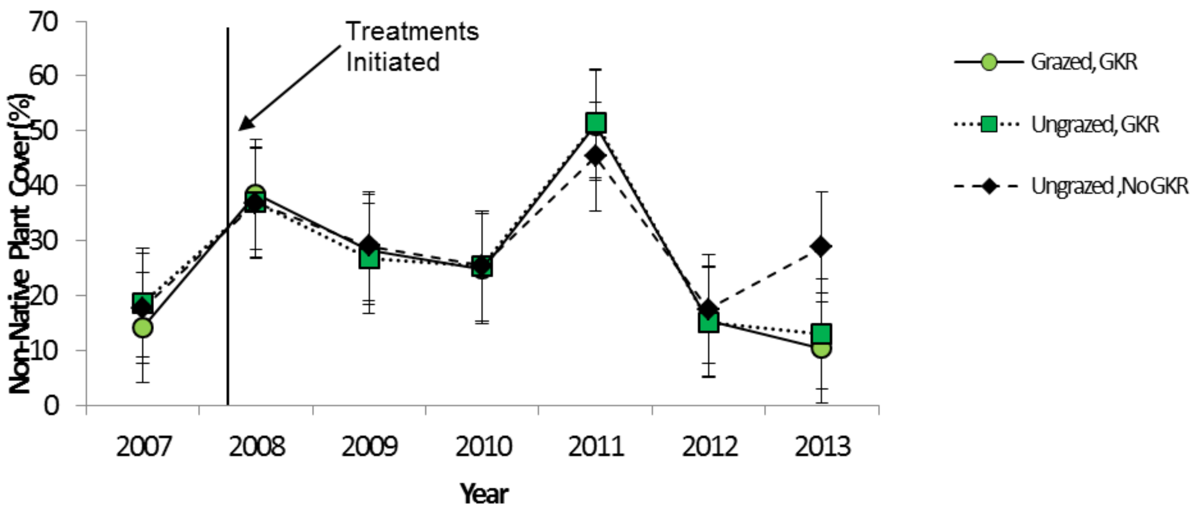


Figure 10. Native plant cover in experimental plots within the Center Well pasture. Three treatments were initiated prior to the spring of 2008: kangaroo rat exclosures (ungrazed, no GKR), cattle exclosures (ungrazed, GKR), and control plots (grazed, GKR). Means and standard error bars are shown (*n* = 10 replicates per treatment).

Figure 11. Non-Native plant cover in experimental plots within the Center Well pasture.



Three treatments were initiated prior to the spring of 2008: kangaroo rat exclosures (ungrazed, no GKR), cattle exclosures (ungrazed, GKR), and control plots (grazed, GKR). Means and standard error bars are shown (*n* = 10 replicates per treatment).

While overall, GKR presence reduced native plants, results from the Swain pasture continue to show that GKR foraging controls exotic grasses and promotes native bunchgrass, thus counteracting the effects of their soil disturbance, which promotes invasive grasses (Figure 12). For example*,* *Poa secunda* was more abundant in areas where GKR were present despite the fact that it was less abundant on GKR precincts, where soil disturbance was high (Figure 12A). *Bromus m. rubens* showed the opposite pattern, in which it was more abundant in areas without GKR and more than twice as abundant on GKR precincts (Figure 12B). Thus, red brome and other exotic grasses may outcompete *Poa* in the absence of GKR, whereas the presence of GKR likely reduces exotic grass dominance via preferential seed predation.

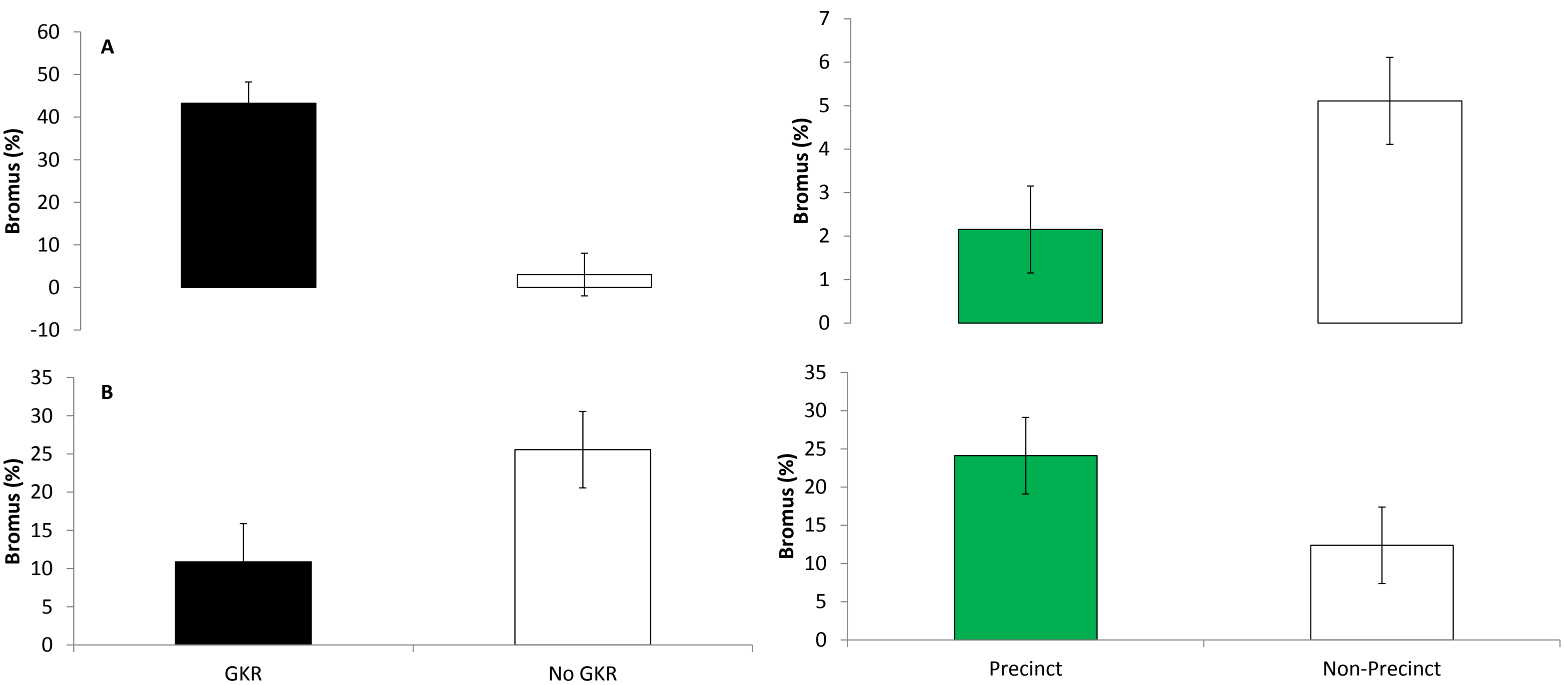


Figure 12. Cover of (A) *Poa secunda* and (B) *Bromus madritensis rubens* in the Swain pasture, 2013. Averages and standard errors are shown for plots in and out of GKR exclosures (No GKR/GKR), and on and off GKR precincts.

Gopher Activity

Gopher (*Thomomys bottae*) activity continued on sites in 2013, however no new gopher activity was documented on vegetation plots. Gopher activity was low in the previous dry years and was first seen in multiple exclosures in 2010 with trapping initiated in 2011.

Overall, sites with gopher activity and percent cover of gopher activity decreased from 2012 but there was an increase in gopher activity on sites with GKR (Table 4, Figure 13). Gopher activity continued to be high in the kangaroo rat exclosures. Gopher activity remained significantly higher in plots without GKR (Figure 13; $t = -4.29$, $P < .005$).

Sites with Gopher Activity

	Center Well			Swain	
	Ungrazed, No GKR	Ungrazed, GKR	Grazed, GKR	Ungrazed, No GKR	Ungrazed, GKR
2011	60%	20%	10%	100%	90%
2012	90%	40%	30%	100%	30%
2013	80%	40%	10%	100%	70%

Table 4. Percent of sites showing gopher activity 2011- 2013.

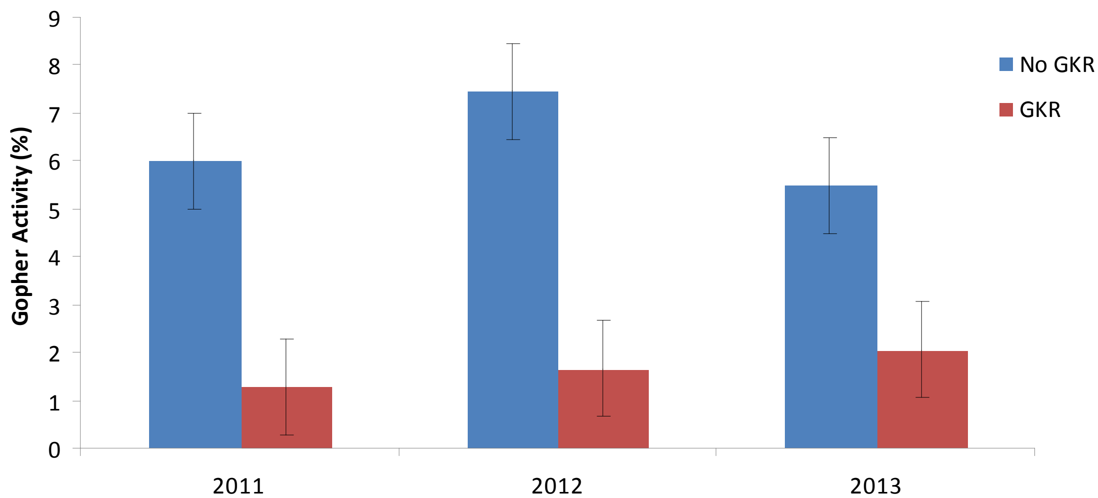


Figure 13. Percent cover of gopher activity in 2011-2013 with and without GKR. Standard error bars are shown.

GKR abundance

A total of 1,720 individual kangaroo rats were captured in 2013; 694 of which had not been previously marked. Two *Dipodomys heermanni* and two *Dipodomys nitratoides* were captured this year. Including recaptures, a total of 3,548 giant kangaroo rat captures occurred. Total trap effort was 12,800 traps*nights.

Mark-recapture estimates of GKR abundance were highly variable among sites this year with 1-71 GKR per plot (Table 5). GKR abundance in the spring was the third lowest recorded in this study. August abundance was the lowest ever recorded for Center Well. Swain abundance in August was the second lowest recorded, with the lowest occurring in August 2007 (9.5 and 10.25 GKR/hectare, respectively). Apparent survival rates varied widely, ranging from zero to 0.65 (Table 5).

There were no significant differences in GKR density between grazed and ungrazed plots in either the Spring or Summer sessions. GKR densities in Swain pasture were significantly lower than those in Center Well in both Spring and Summer sessions (Spring: $t = 3.05$, $P = 0.007$, $n = 10$, Summer: $t = 4.41$, $P = 0.0003$, $n = 10$).

The overwinter survival rate was high but summer apparent survival was the lowest on record (Figure 15). Reproduction matched the recorded low of 2012 at 0.006 juveniles per adult (Table 6; compared with 0.4 in 2008 and 2009 and 0.3 in 2010 and .04 in 2011).

The seasonal genital lesions (likely trombiculid mites) that appear in August trapping sessions remained high in 2013 (74%), only slightly lower than the 2012 record (77%).

GKR estimates on each plot were correlated in Spring and Summer 2012 and 2013 ($r = 0.852$, and $r = 0.797$, $P = 0.05$, $n = 30$).

Table 5. GKR population size and site fidelity (apparent survival) estimates. The number of GKR on each plot were estimated for the April and August 2013 mark-recapture sessions. The proportion of GKR remaining on each site between trapping periods was also estimated (site fidelity). Standard errors (SE) are shown for each estimate.

Pasture	Grazing treatment	Plot	April estimate	April SE	August estimate	August SE	Apparent Survival	Survival SE
Center Well	Grazed	C1	50	0.92	18	0.96	0.55	0.06
Center Well	Grazed	C2	63	1.04	31	2.28	0.51	0.08
Center Well	Grazed	C3	54	0.75	38	0.79	0.62	0.06
Center Well	Grazed	C4*	12		6	0.64	0.00	
Center Well	Grazed	C5	54	0.24	27	0.24	0.42	0.03
Center Well	Grazed	C6*	6		1	0.60	0.00	
Center Well	Grazed	C7	56	1.04	36	1.92	0.65	0.08
Center Well	Grazed	C8	48	0.50	19	0.50	0.43	0.03
Center Well	Grazed	C9	64	0.35	36	0.36	0.46	0.03
Center Well	Grazed	C10	63	0.53	37	0.54	0.45	0.03
Center Well	Ungrazed	E1	35	0.56	13	0.58	0.49	0.06
Center Well	Ungrazed	E2	71	1.71	32	3.59	0.49	0.08
Center Well	Ungrazed	E3	41	0.50	32	0.53	0.55	0.06
Center Well	Ungrazed	E4*	19		22	0.62	0.00	
Center Well	Ungrazed	E5	40	0.23	25	0.23	0.39	0.03
Center Well	Ungrazed	E6*	7		3	0.44	0.00	
Center Well	Ungrazed	E7	60	1.35	40	2.50	0.64	0.08
Center Well	Ungrazed	E8	50	0.61	18	0.61	0.41	0.03
Center Well	Ungrazed	E9	72	0.27	45	0.27	0.42	0.03
Center Well	Ungrazed	E10	63	0.41	29	0.41	0.42	0.03
Swain	Ungrazed	S1	28	0.27	7	0.27	0.38	0.03
Swain	Ungrazed	S2	28	0.19	2	0.18	0.40	0.03
Swain	Ungrazed	S3	54	0.32	21	0.32	0.42	0.03
Swain	Ungrazed	S4	34	0.29	11	0.29	0.39	0.03
Swain	Ungrazed	S5	22	0.24	7	0.24	0.35	0.04
Swain	Ungrazed	S6	32	0.00	19	0.00	0.52	0.08
Swain	Ungrazed	S7	27	0.00	15	0.01	0.54	0.08
Swain	Ungrazed	S8	15	0.09	5	0.08	0.27	0.03
Swain	Ungrazed	S9	10	0.09	2	0.08	0.37	0.04
Swain	Ungrazed	S10	29	0.27	11	0.27	0.49	0.04

*These numbers are estimates as Spring trapping did not take place on C4, C6, E4, E6 in 2013.

Table 6. Age and sex composition of Giant Kangaroo Rats captured in 2013.

		Female	Male	Unknown	Total
GKR	Adult	901	794	2	1697
	Juvenile	7	3	0	10
	Unknown	1	2	10	13
	Total	909	799	12	1720

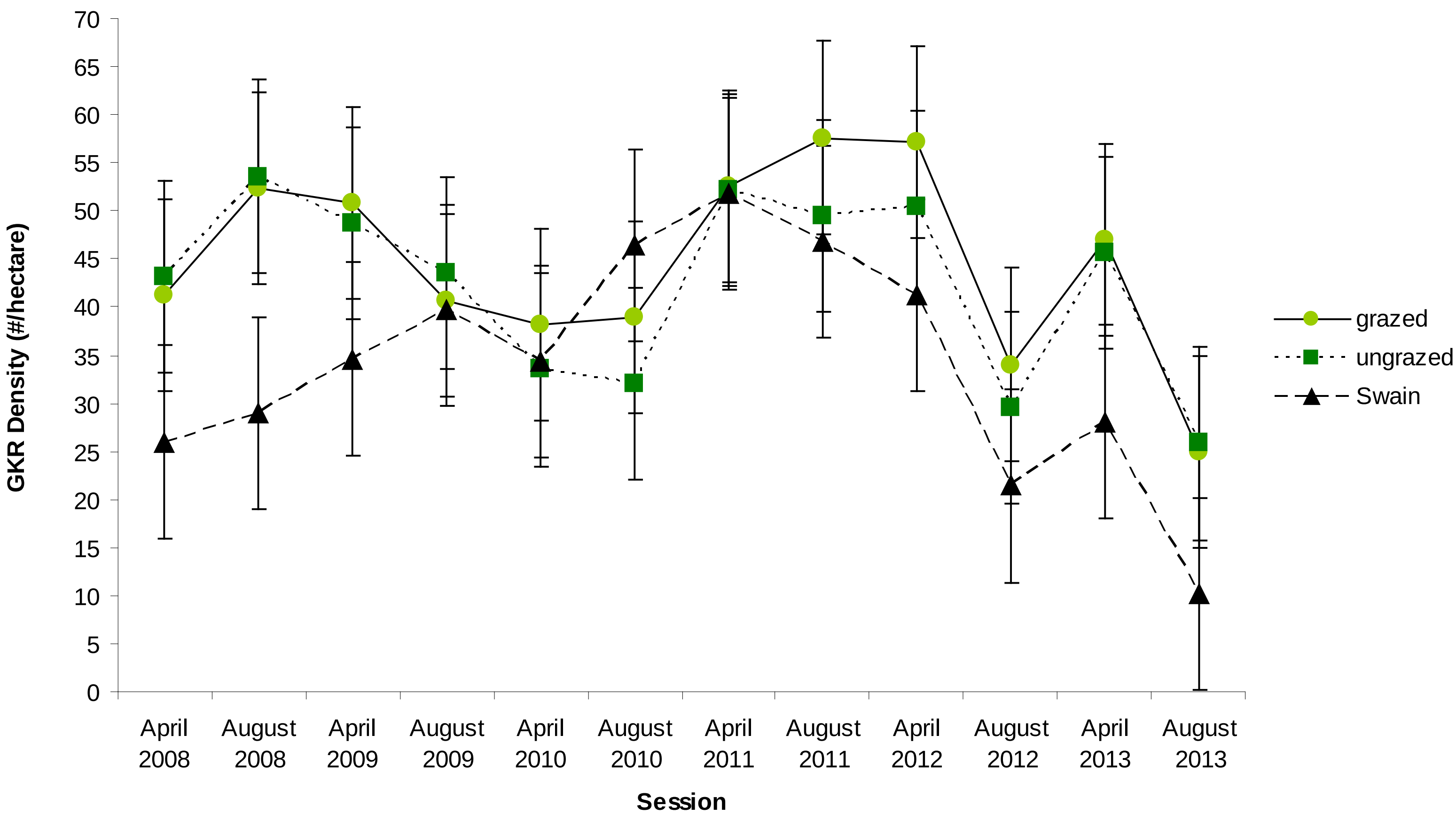


Figure 14. Average GKR population estimates in Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots, from April 2008 to August 2013. Standard error bars are shown (*n* = 10 grids per treatment).

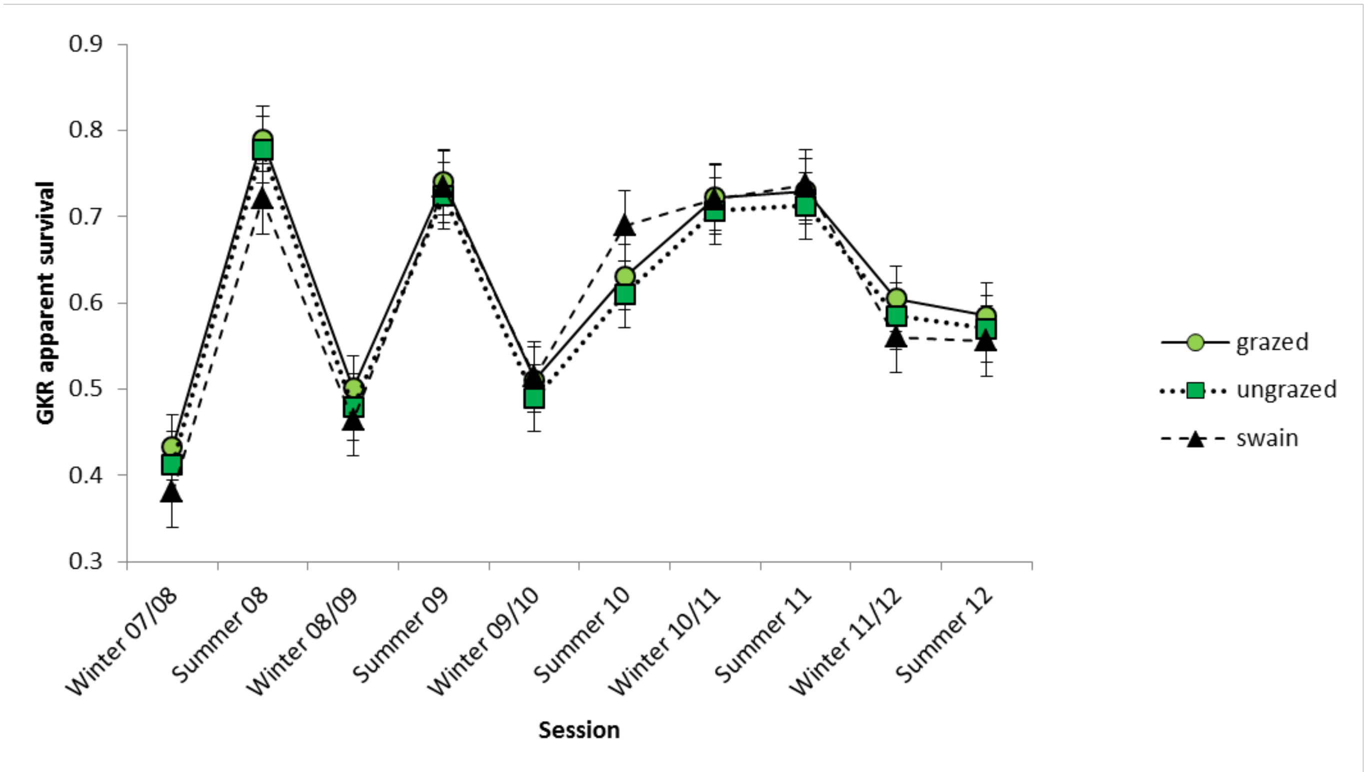


Figure 15. Average GKR apparent survival (site fidelity) estimates in Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots, from winter 2008 to summer 2013. Standard error bars are shown (*n* = 10 grids per treatment).

SJAS abundance

A total of 140 individual antelope squirrels were captured and a total of 526 captures (including recaptures) occurred. Male and female capture rates were similar (Table 7). In 2013, SJAS overall density levels (15.0 SJAS/ha) were similar to density levels in 2012 and were in the middle of the density levels of the previous dry years (Figure 16A). SJAS densities were not significantly different between grazed and ungrazed plots this year (t = -0.15, df = 9, P = 0.88, n = 10). Densities in Swain pasture were higher than those in Center Well pasture (both grazed and ungrazed) but results were not significant (t = -1.99, df = 9, P = 0.08) (Figure 16A&B).

Apparent survival of SJAS was the highest yet recorded, an increase following the trend of previous dry years when increases were seen from 2007-2008 and 2008-2009 whereas apparent survival decreased slightly in the wet years (Figure 16). The juvenile to adult ratio was 0.47, the third highest reproductive rate on record (Table 7). SJAS estimates on each plot were not correlated between 2012 and 2013 (Figure 16).

Table 7. Age and sex composition of San Joaquin antelope squirrels (SJAS) captured in 2013.

		Female	Male	Unknown	Total
SJAS	Adult	49	46	0	95
	Juvenile	19	25	1	45
	Unknown	0	0	0	0
	Total	68	71	1	140

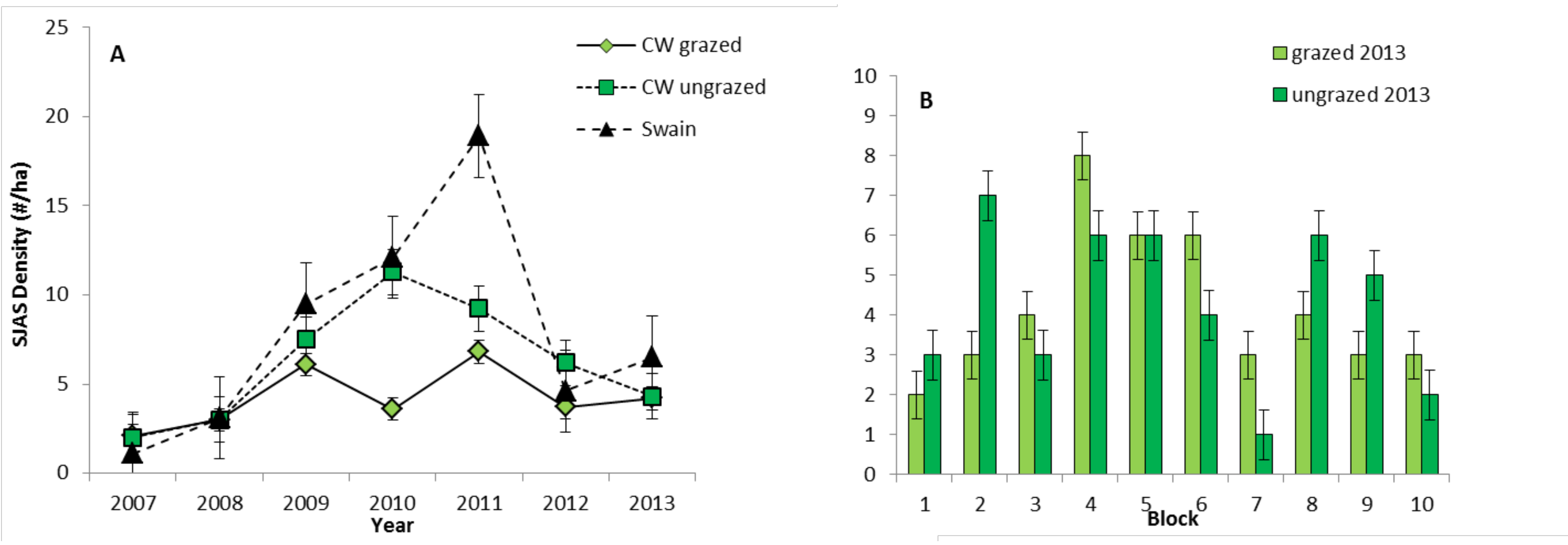


Figure 16. Estimates of San Joaquin antelope squirrel density. (A) Average annual density (± standard error) in Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots. (B) Density in 2013 on each replicate site (block) in Center Well, with 95% confidence intervals.

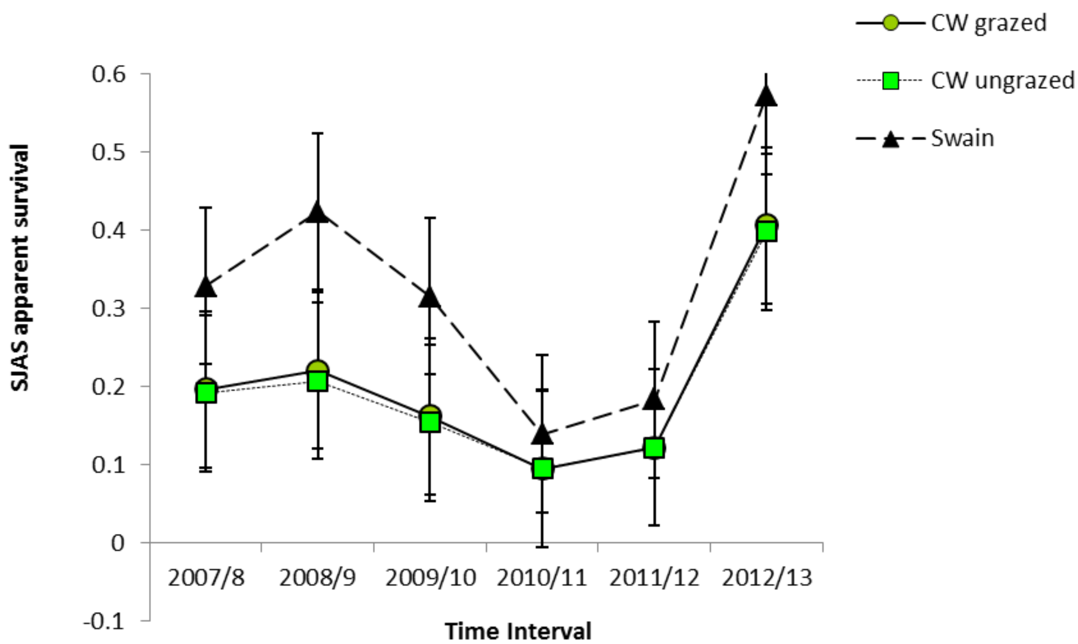


Figure 17. Apparent survival of San Joaquin antelope squirrels on Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots, 2007-2013. Standard error bars are shown.

Reptile abundance

A total of 301 side-blotched lizards (*Uta stansburiana*) and two blunt-nosed leopard lizards (*Gambelia sila*) were seen during reptile surveys, three unidentified lizards were also seen (Table 8). All blunt-nosed leopard lizard (BNLL) sightings were geo-referenced. As in previous years, all BNLL sightings during surveys were in the Swain pasture; however sightings of BNLL were recorded again on or near Center Well 5 during other activities. BNLL abundance dropped to a record low in 2013 after record highs in 2011 and 2012 (36, 37). UTA sightings were the lowest ever recorded in 2011 (42) but climbed to 200 in 2012 and continued to rise this year (Figure 18; Table 8). There were no significant differences in lizard density between grazed and ungrazed plots in 2013.

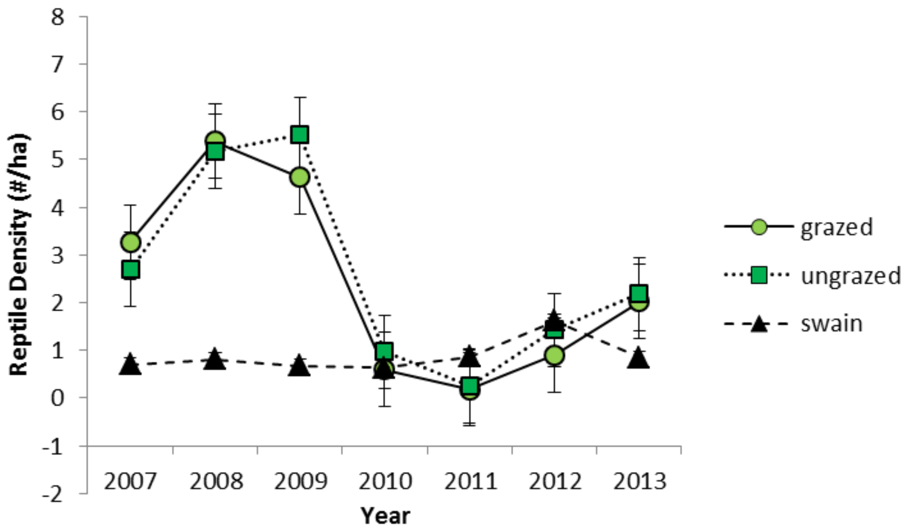


Figure 18. Estimates of reptile density each year from 3 replicate surveys on Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots. Standard error bars are shown.

Table 8. Totals of Blunt Nosed Leopard Lizards (*Gambelia sila)* and Side Blotch Lizards (*Uta stansburiana)* over time.

Species	2007	2008	2009	2010	2011	2012	2013
BNLL	4	7	19	18	36	37	2
UTA	419	675	631	114	42	200	301

Invertebrates

GKR exclosures continued to have strong effects on the invertebrate community in 2013. Invertebrate richness and abundance as well as arachnid abundance were higher where GKR were present in both pastures, while beetle abundance was higher where GKR were absent (Figure 19 & 20; t = 2.81, P = 0.006, t = 2.98, P = 0.004, t = 3.31, P = 0.001, t = -4.35, P = 4.107e-05). Invertebrate richness, abundance and beetle abundance were all higher within Center Well pasture in grazed verses ungrazed plots (Figure 19 & 20, t = 3.55, P = 0.0007, t = 3.64, P = 0.0005, t = 2.18, P = 0.032). In 2012 there was a record for invertebrate biomass due to the large number of orthopterans. In 2013, biomass levels dropped to record lows in all but the cattle exclosures and ant and orthopteran presence was very low (Figure 19 & 20).

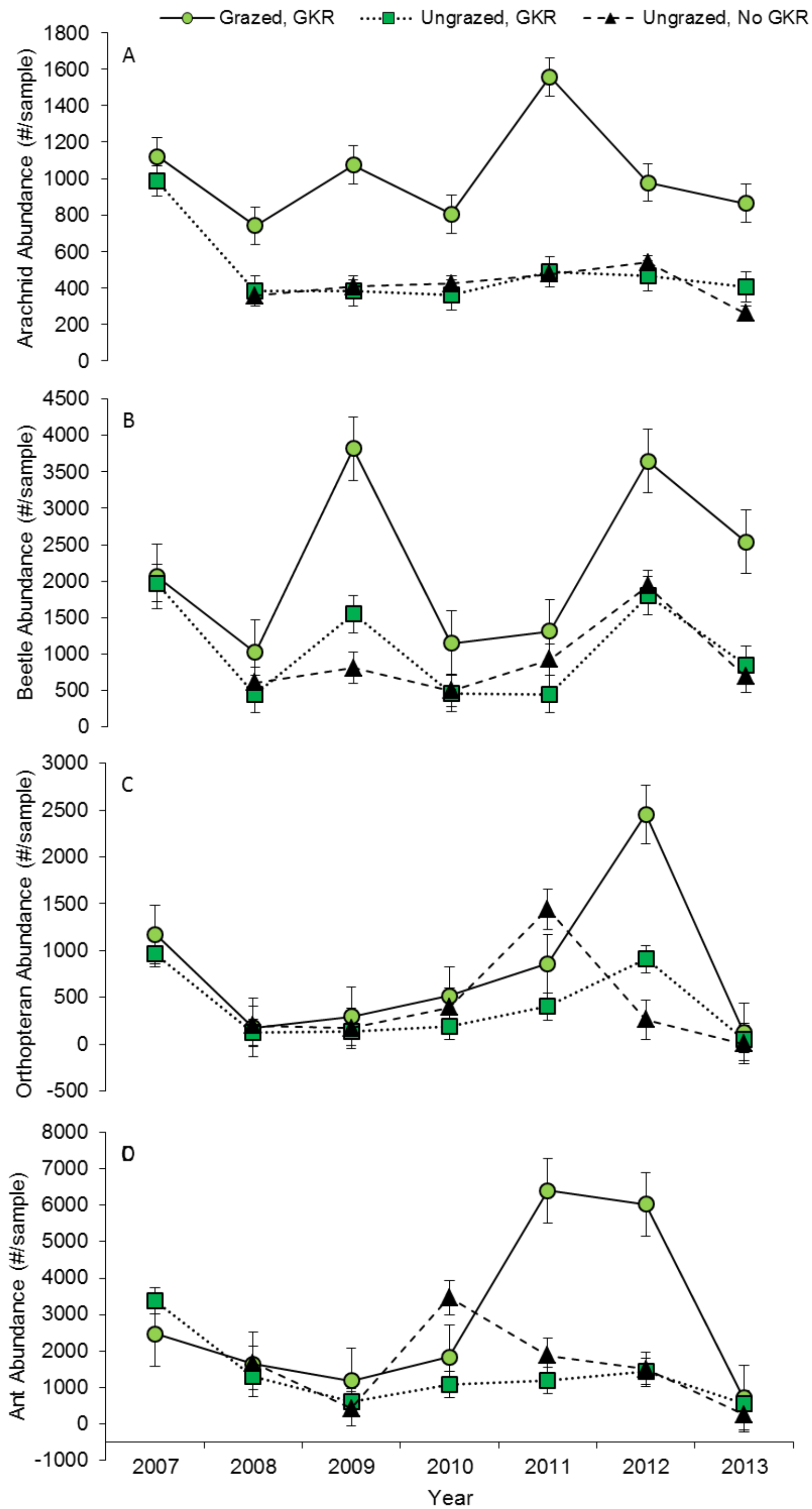


Figure 19. Response of (A) arachnid (B) beetle, (C) orthopteran and (D) Ant abundance to GKR and cattle exclosures in the Center Well pasture, 2008-2013. Standard error bars are shown.

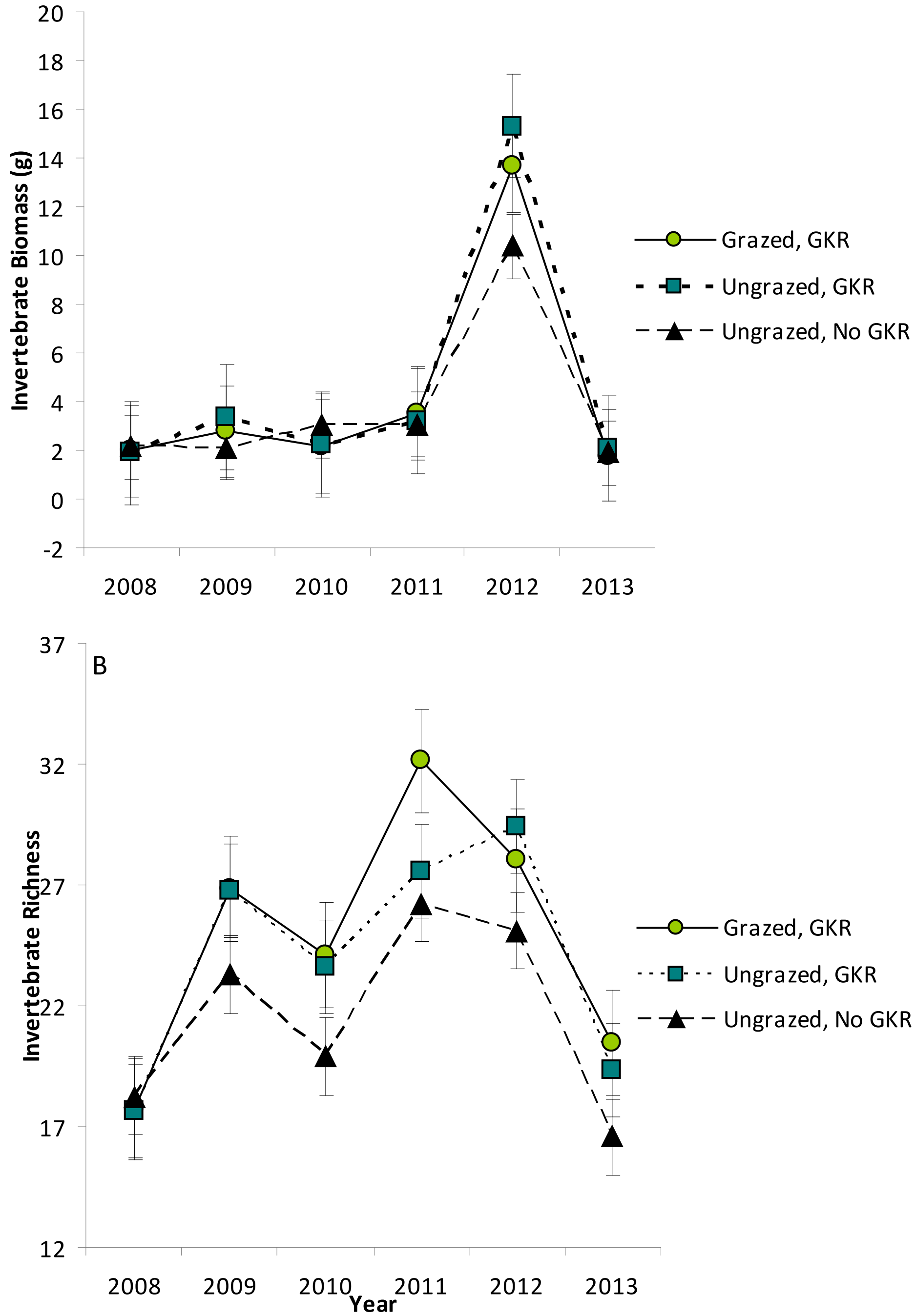


Figure 20. Response of invertebrate biomass (grams) (A) and richness (B) to GKR and cattle exclosures in the Center Well pasture, 2008-2013. Standard error bars are shown.

Kit Fox Dens

All plots were surveyed for kit fox dens in 2013. Twelve active and 48 inactive dens were found on plots. All types of plots (i.e., Swain, Center Well control and cattle exclosure plots) had kit fox dens, with most active dens (8) occurring in cattle exclosures. Cattle exclosures also had the greatest number of inactive and active dens combined, with thirty total.

Species associations

Table 9 shows the associations among the flora and fauna on our plots. GKR density and survival were negatively correlated with squirrel densities and positively correlated with lizard densities. Squirrels may compete directly with kangaroo rats for burrows and plant seeds and squirrels compete with lizards for invertebrate prey, so lizards may do better in areas with high GKR densities. Lizard densities were negatively correlated with plant height. Lizards may benefit from lower plant height and an increased ability to see predators.

Table 9. Matrix of correlation coefficients (*r*) among species counts on each of the 30 plots. Significant correlations ($P < 0.05$) are highlighted in bold. Richness is the number of species.

2013	*N squirrels*	*N GKR*	*GKR Survival*	*N Lizards*	*Native Cover*	*Plant Biomass*	*Plant Height*	*Plant Diversity*	*Invert Biomass*
N GKR	**-0.52**								
GKR Survival	**-0.35**	0.24							
N lizards	-0.20	**0.70**	0.06						
Native Cover	**0.39**	**-0.37**	-0.08	-0.21					
Plant Biomass	0.32	-0.32	**-0.39**	-0.31	0.16				
Plant Height	**0.64**	**-0.53**	**-0.53**	**-0.45**	**0.40**	**0.51**			
Plant Diversity	**0.42**	**-0.42**	-0.20	-0.16	**0.80**	**0.35**	0.34		
Invert Biomass	0.30	**-0.38**	**-0.46**	-0.29	**0.54**	0.21	**0.35**	**0.54**	
Invert Diversity	-0.20	0.18	**0.54**	0.11	**-0.44**	-0.24	**-0.38**	**-0.53**	**-0.74**

Conclusions and Future Directions

2013 was another year of record lows in the Carrizo. Some of the striking numbers include 5 cm of annual precipitation, 2 BNLL counted, and 2% native cover in Center Well and 7% native cover in Swain.

2012 was a record low for native cover, but levels dropped even further in 2013. Grass cover was the lowest ever recorded on grazed and ungrazed plots with GKR and the third lowest where GKR were excluded. The record lows seen for invertebrate biomass and other species counts are likely tied to these low vegetation numbers.

GKR abundance, summer apparent survival and reproduction were all low in 2013, reflecting the continuing vegetation lows. In contrast, SJAS did well with average abundance and record apparent survival. This contrast may be due to the decrease in GKR which may be competitively dominant over SJAS.

Uta densities are continuing to rise after the record lows in 2011 but they are still not as high as seen in 2007-2009. It is likely that if 2014 proves to be another record low year for invertebrates, *Uta* populations will begin to fall again.

Sites were surveyed for kit fox dens this year and dens were found on all plots. Cattle exclosures had the highest number of kit fox dens although most dens (48) were inactive.

Our exclosures allow us to determine what proportion of vegetation loss was due to cattle, GKR, or other forces (wind, insects, etc.). Without cattle grazing, we were only able to calculate biomass removed by GKR and other factors. Removal by GKR was about the same in spring and fall, just over 1,000 pounds per acre removed. Without GKR, RDM levels were reduced from 1,999 to 1,611 pounds per acre by factors such as insect herbivory, wind, and foraging by squirrels. Vegetation biomass remained about the same all year, likely due to the low percent cover and little vegetation available for removal by GKR and other species. In addition removal rates were likely impacted by the decreases in GKR and invertebrates.

While no cattle were grazed this year, cattle exclosures did appear to have a continued impact on invertebrates with greater overall richness, abundance and beetle abundance on grazed plots.

GKR exclosures showed a strong effect on invertebrates with overall richness, abundance and arachnid abundance more prevalent on plots with GKR and beetle abundance greater where GKR were absent. In 2012 invertebrate biomass reached the highest levels seen in the study due primarily to a large increase in grasshopper biomass. Biomass numbers were the lowest recorded in 2013 and orthopteran numbers were a large part of the cause. Ants were also scarce this year. The orthopteran boom seen in 2012 was likely tied to the high levels of vegetation available in 2011 and probable high reproduction rates. However, orthopterans had little to eat in 2012 and likely did not reproduce as successfully for 2013.

While the highest levels of gopher activity were still in GKR exclosures, there was a slight increase in gopher activity in other areas, suggesting that gophers prefer the GKR exclosures for the increased vegetation, verses an avoidance of GKR.

A continuing trend was the positive effect of soil disturbance on exotic grass cover and the contrasting reduction of these grasses by GKR foraging, thus restricting exotic grass distribution primarily to their disturbed mounds. Although GKR precincts may function as foci of invasion, once exotic grasses are present in an area, GKR may actually benefit native bunchgrasses by removing exotic grass seeds and preventing their spread. However, native species that GKR prefer to eat, such as *Lotus*, are more abundant in the absence of GKR, and native cover overall was higher where GKR were excluded.

In the 2014 field season, we propose to add precipitation manipulations to this study through the construction of rain shelters, to investigate the possible outcomes of climate change. We will continue to monitor flora and fauna on our experimental plots. One graduate project is currently underway in the Carrizo and will continue in 2014.

Products of the Carrizo Plain Ecosystem Project

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17) Bean, W.T., R. Stafford, and J.S. Brashares. In press. The effects of small sample size and sample bias on threshold selection and accuracy assessment of species distribution models. Ecography.
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