Carrizo Plain Ecosystem Project
Combined Report 2014 & 2015
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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 eighth and ninth year of the Carrizo Plain Ecosystem Project (CPEP), a long-term study to quantify these relationships using replicated cattle and GKR exclosures. 2014 was the third consecutive dry year in the Carrizo and while 2015 saw an increase in precipitation and vegetation, cattle were not grazed either year. Precipitation was at a record low in 2014 and though precipitation increased in 2015, levels remained below average. GKR abundance during the spring trapping sessions saw three successive record lows in 2013, 2014 and 2015. 2014 summer abundance was also at a record low but in summer 2015 abundance increased. Overwinter survival of GKR had two successive record lows in 2014 and 2015. Summer apparent survival was also a record low in Center Well pasture in 2014 but in the middle range in Swain. Summer 2015 apparent survival rebounded in Center Well but remained low in Swain pasture. Captures of non-GKR rodent species increased markedly during 2014 and 2015. *Uta* and Blunt-nosed leopard lizards (BNLL) increased in 2014 and reached the third highest level recorded in 2015. 2015 invertebrate data collection has not been completed and invertebrate biomass remained low in 2014. San Joaquin antelope squirrels (SJAS) had the second lowest density recorded in 2015 but survival increased from 2014 and was the highest in three years. Recruitment for SJAS was also higher in 2015 than in 2014. Plant richness reached record lows in 2014 and then record highs in 2015 in Center Well pasture and near record highs in Swain pasture. Overall vegetation percent cover and grass percent cover reached record lows in 2014 with some increase in 2015. Although no cattle were grazed in 2014, overall invertebrate richness and abundance were higher in grazed plots. GKR exclosures also had significant effects on invertebrates in 2014 with overall richness, abundance, and ant and beetle abundance higher where GKR were present. There was no new gopher activity on vegetation plots, and gopher activity was low in 2014 and only present on 5 plots in 2015. Precinct and kit fox den surveys were conducted this year. GKR precinct numbers were similar on all plots, with active and inactive precincts combined, and Swain had the most inactive plots. In 2014 there were 28 active kit fox dens, in 2015 there were none. Precipitation plots were added to the study in 2014 and re-installed in 2015.

Prepared by Rachel Endicott, 2015

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.

In 2014, we started an experiment to predict the consequences of climate change on the Carrizo Plain food-web. Twelve 10 x 10-m rainout shelters are used to catch half of each rainfall event, and water is then pumped to a neighboring area of the same size. By creating extreme drought and wet year conditions within our exclosure experiment, we hope to learn how kangaroo rats modify the response of plants to climate change.

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.

4. To evaluate the effects of future precipitation changes on the Carrizo Plain ecosystem.

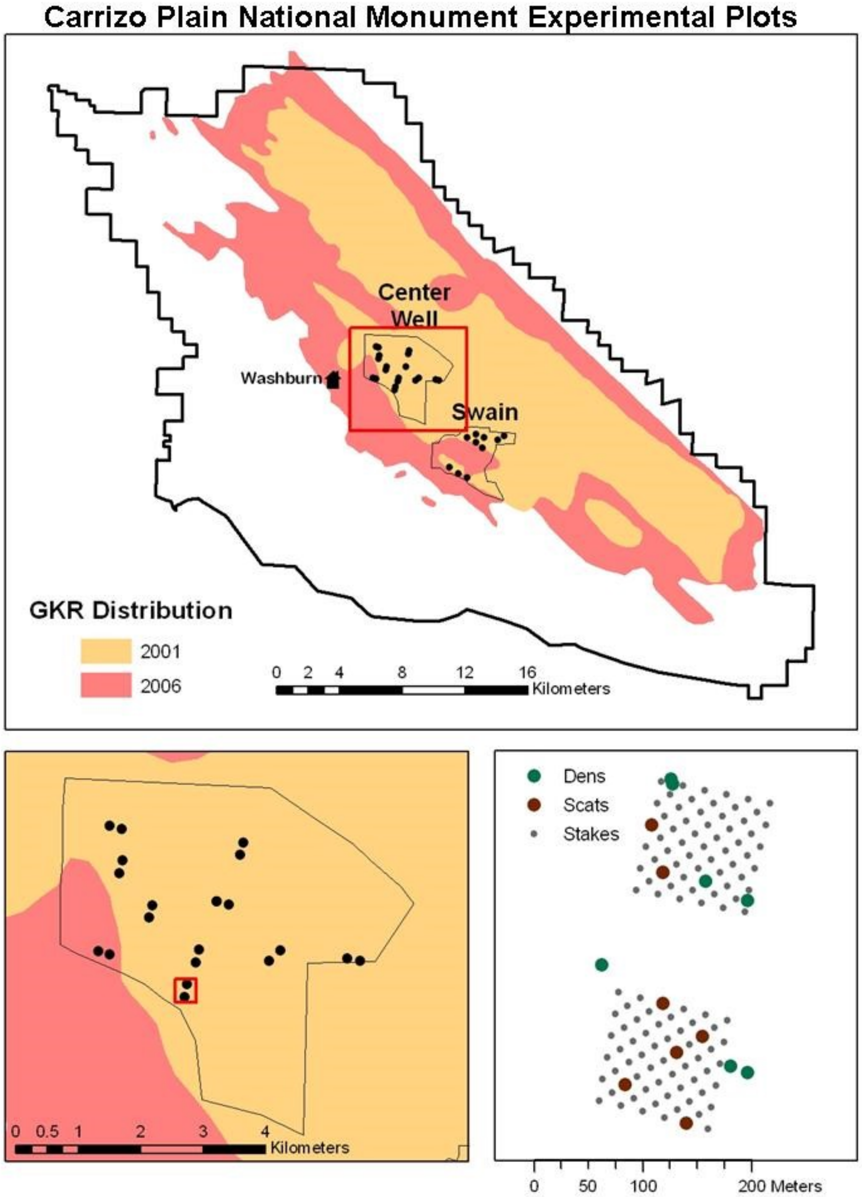

Figure 1. Map of study sites in the Carrizo Plain National Monument. Details are shown for the Center Well pasture and site CW 7. Kit fox dens and scats, as well as trap stakes, are shown for site 7.

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).

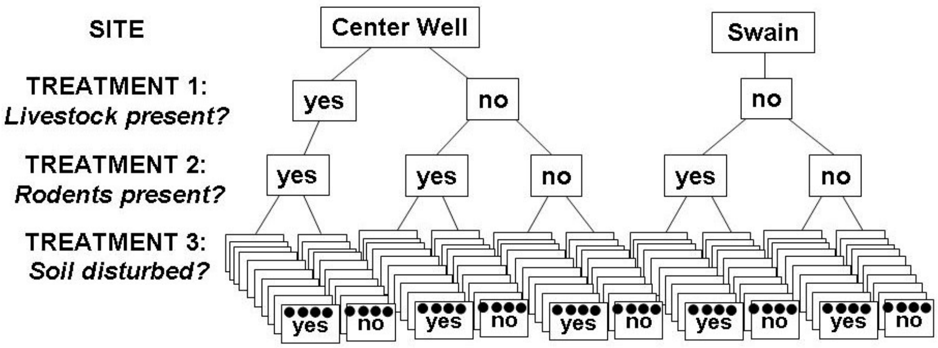

Figure 2. Experimental design of the project. There are ten blocks of each treatment combination and four nested vegetation plots (filled circles) within each block.

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 20100 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).

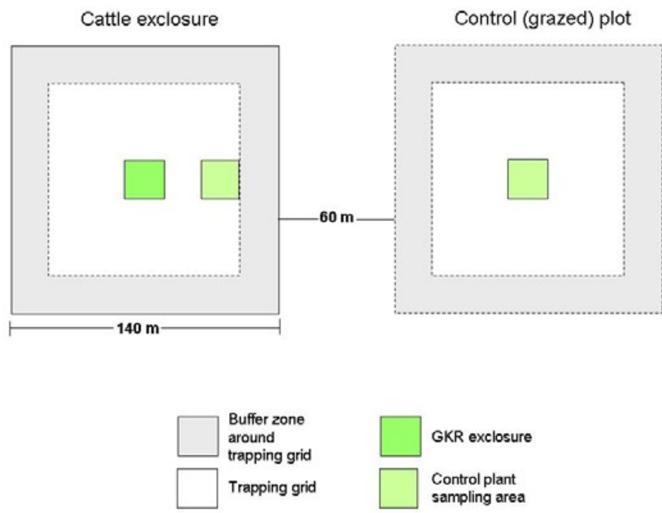

Figure 3. Nested exclosure design to separate livestock and GKR effects on plants, with paired control plot. A buffer zone around each GKR trapping grid ensured that the surveyed population was comprised of individuals living within the plot. This shows the design in Center Well; in Swain each plot is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

Precipitation plot experiment

18 sites were identified for the precipitation plot experiment and precipitation treatments were applied to the paired kangaroo rat exclosures and control plots. Precipitation plots are 10mx10m. Water is transported between paired plots within each site because of the limited road access and dispersion of our sites across a large area. Therefore, sites are grouped into 6 blocks, whereby 3 adjacent sites (each separated by ~ 500 m, each containing paired exclosure and non-exclosure plots) comprise a block. We used our extensive background dataset of plant composition on these sites to verify proper blocking. Within each block, one site was randomly assigned as a precipitation control, and precipitation treatments are not be applied to either plot. On the second site, a rainout shelter was constructed over the kangaroo rat exclosure, and water is transported from the shelter to the kangaroo rat control plot on that site. The third site receives the reverse treatment, with a rainout shelter constructed over the kangaroo rat control plot and water transported to the exclosure.

We used simulations to determine that six replicate blocks should be sufficient to detect significant effects of precipitation, trophic, and engineering effects on plant communities. Mean cover of exotic grasses, native grasses, exotic forbs, and native forbs during years that were drier than average (2007-2009, 2012) and wetter than average (2010-2011) were used to determine minimum effect sizes that may be seen due to precipitation treatments. We simulated data using a Gaussian distribution and the means and variances observed on these plots from 2007-2012, and we analyzed data using generalized linear mixed models with precipitation level, burrow presence, and kangaroo rat presence as fixed effects, block as a random effect, and quadrat as a nested random effect. Four blocks were sufficient to detect significant main effects of these treatments, and six blocks were sufficient to detect interactions between engineering and precipitation with a single year of data. Additional simulations indicated that several years of data would be required to detect interactions with trophic effects and these factors.

Rainout shelters were constructed over rainfall reduction plots, using a design whereby shelters intercept a portion of each rainfall event. This design is being used successfully to manipulate rainfall in several grassland sites, including the Seviletta, Konza Prairie, and Shortgrass Steppe LTERs, and it has been shown to produce minimal microclimate artifacts (Yahdjian and Sala 2002).

Based on recent climate projections for California (Cayan et al. 2006), rainfall is reduced by 50% on rainfall reduction plots, and water is collected from shelters and added to rainfall addition plots, thus increasing precipitation by 50%. We manipulate rainfall through both additions and reductions because downscaled climate models deviate on whether future rainfall in the region will increase or decrease over the next century (Brekke et al. 2004, Maurer and Duffy 2005, Thorne et al. 2012). Because we manipulate precipitation based on relative rather than absolute annual rainfall, and expect that our experiment will encompass both dry and wet years under ambient conditions, we will be able to quantify the effects of a large range of precipitation levels on our response variables. Although climate models deviate on predicted trends and the magnitude of changes (Thorne et al. 2012), nearly all models predict increasing variability in precipitation among years (Karl et al. 1995, Timmermann et al. 1999). Our experiment will thus mimic expected changes by producing higher highs and lower lows within a reasonable range of predicted future climate scenarios.

Shelters consist of a steel frame that supports an array of clear acrylic v-shaped shingles that passively reduce each rainfall event by ~50%. Shingles have high light transmission, a low yellowness index, and are UV transparent. The low edge of the shelter is oriented towards the prevailing winds to minimize blow-in, and the shelter will extend 1 m beyond the edge of the plot. The holding tank is large enough to contain runoff from an hour-long downpour (1 cm of water falling on the shelter). This water is subsequently applied to the water addition plots using solar-powered water pumps, hose lines, and a sprinkler in the center of the plot. Because the pump is active during each storm, the tank does not need to hold runoff from an entire storm. The shelter roof and principle irrigation components (battery, pump, solar panel) are removed during the dry season (April-October) to minimize microclimate effects and visual impacts to visitors of the Monument.

To accurately simulate the effects of climate change on plant-animal interactions, we conduct precipitation manipulations at a large enough scale to reduce artifacts that could be created by small scale changes in kangaroo rat movements. For example, if only small plots were sheltered or watered within a kangaroo rat's territory, the kangaroo rat could over-use the watered plot and ignore the sheltered plot, thus giving results that would fundamentally differ from what would occur if precipitation were manipulated across the landscape (as is occurring with climate change). Giant kangaroo rat home ranges are small (~200 m2) and exclusive (Cooper and Randall 2007). Because kangaroo rats are fiercely territorial and our manipulations occur on a scale that will include 1-2 entire territories, it is highly unlikely that our manipulations will result in unnatural aggregations or biased within-territory space use by resident kangaroo rats.

(A)

(B)

Figure 4. Precipitation plot rainout shelter with water storage tank and solar panel (A) and irrigation system (B).

Plant and soil sampling

We established 8 1-m^2 permanent plant sampling quadrats in each of the 50 400m^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 5; 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. In 2015 191 new vegetation plots were added on the precipitation plots and 95 pre-existing vegetation plots were assigned to the precipitation plot study to pinpoint precipitation effects on vegetation. 18 vegetation plots were also removed in 2015 due to conflicts in location with the precipitation plot equipment. There are now 573 plots.

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Figure 5. 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 6; *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 2-24, 2014 (18 trap nights) and August 1-26, 2014 (18 trap nights) and April 9-May 1, 2015 (18 trap nights) and August 4-31, 2015 (21 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.”

GKR precinct surveys

Plots were visited in random order. Seven 140-m long transects spaced 20 m apart were slowly walked by a single observer, and all precincts detected within 10 m on either side of the transect were identified and recorded along with the UTMs for each location and whether precincts were active or inactive.

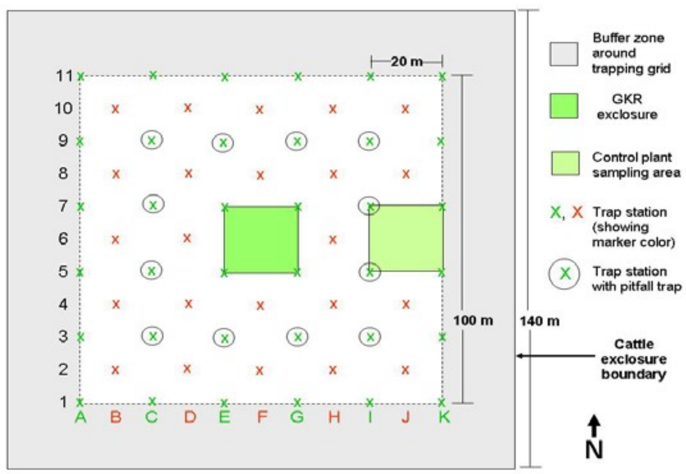


Figure 6. Detailed diagram of a cattle exclosure. Trap stations show trap locations for GKR mark-recapture surveys. Colors correspond to the spray-painted color on the stake marking the location. Letters and numbers identify the grid stakes (A1, B2, etc.).

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 85° F. All captured animals were PIT-tagged, weighed, and sexed. Trapping occurred from May 7-27, 2014 (15 trap days) and May 11- May 2-June 1, 2015 (14 trap days). The RMark package was used to obtain density estimates on each plot each year.

Bird surveys

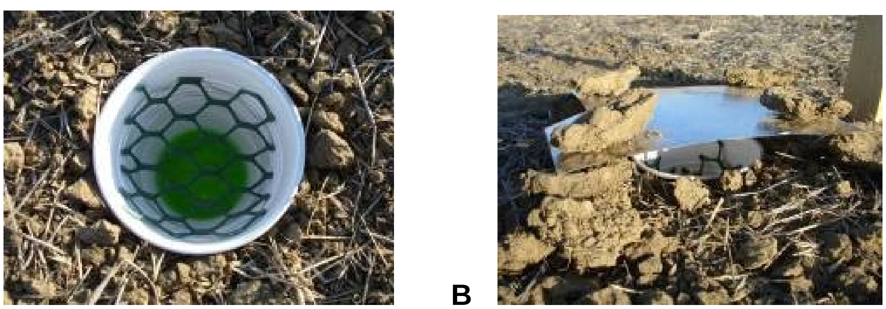
Bird surveys were not conducted this year due to budget limitations. From 2008-2012, point counts were conducted four times on each plot in the spring.

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 15-July 9, 2014 and May 5–July 11, 2015. 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. In 2014 pitfall traps were placed on each plot between June 7-8, 2014 and collected 2 weeks later (n = 8 traps per plot, 240 total). In 2015 traps were placed on each plot between and June 8-9, 2015 (245 total traps, trap number varies per plot). Traps were flooded and many had to be reset on June 18, 2015. 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 7A). Traps were covered with 10x10" pieces of aluminum flashing with an inch of space between the cover and ground (Figure 7B). 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 7A). This probably filtered out larger insects as well. Upon collection, the contents of each trap was rinsed and stored in 50mL 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. In 2015 45 additional invertebrate pitfall traps were added on the precipitation plots and 26 pre-existing invertebrate pitfall traps were assigned to the precipitation plots to pinpoint precipitation effects on invertebrates.



A **B**

Figure 7. Pitfall trap viewed from above (A) and from the side with the aluminum cover (B).

Spotlight survey

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 (May 2-5, 2014 and May

13-16, 2015, *n* = 4 surveys) and summer (July 28-31, 2014 and July 27-30, 2015, *n* = 4 surveys). We used 1-million candlepower spotlights aimed out either side of a slowly moving vehicle and animals were located by seeing eyeshine. Binoculars were used to aid identification. All predators and lagomorphs were identified and recorded, along with their distance from the transect (using a rangefinder), angle from the vehicle, and location along the transect line.

Kit fox activity and diet

In 2014 and 2015, we continued to collect scats deposited on our traps as kit foxes often marked our traps with urine and feces. We collected 103 kit fox scats in 2014 and 55 in 2015. We also recorded all sightings of kit foxes.

Kit fox den surveys

In 2010, kit fox dens found on plots or opportunistically while walking to plots were geo-referenced. Beginning in 2013 kit fox den surveys were conducted on all plots using line transect surveys. Plots were visited in random order. Seven 140-m long transects spaced 20 m apart were slowly walked by a single observer, and all dens detected within 10 m on either side of the transect were identified and recorded, along with the UTMs for each location and whether dens were active or inactive.

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.

Postdoctoral projects

Postdoctoral research associate Nicolas Deguines, University of Washington, Seattle

Nicolas joined the CPEP in November 2014 to investigate how the dynamics of the Carrizo Plain ecosystem are shaped by biological trophic and non-trophic interactions and influenced by multiple environmental changes (climate, species invasions, grazing). He is analyzing the data gathered from the start of the project using structural equation models to understand direct and indirect relationships among the components of the system.

Postdoctoral Research Associate Josh Grinath, University of Colorado Boulder

Josh joined the CPEP in March 2015. He is broadly interested in understanding what determines ecological community structure, and at the Carrizo Plain he is investigating how GKR influence the species composition of plant assemblages. Using data from the GKR exclosure and precipitation experiments, Josh is studying how GKR foraging and soil disturbances affect plant abundances and how these interactions depend on rainfall.

Additionally, Josh is conducting several greenhouse experiments to evaluate GKR effects on the seedbank and soil resource effects on plant growth.

Undergraduate Projects

With funding from NSF, CPEP sponsored two students in the Research Experience for Undergraduates program. Brianna Doran and Janelle Dorcy conducted surveys to determine the potential for burrow counts as a population index by determining whether a relationship exists between the number of active giant kangaroo rat burrow holes in an area and the number of giant kangaroo rats actually living there.

Results and Discussion

Precipitation

In nine years, the Carrizo Plain Ecosystem Project has seen a wide spectrum of precipitation from record lows of around 7 cm in 2014 to record highs of nearly 40 cm in 2011. 2015 showed an increase from the past two years but was still well below average (Figure 8).

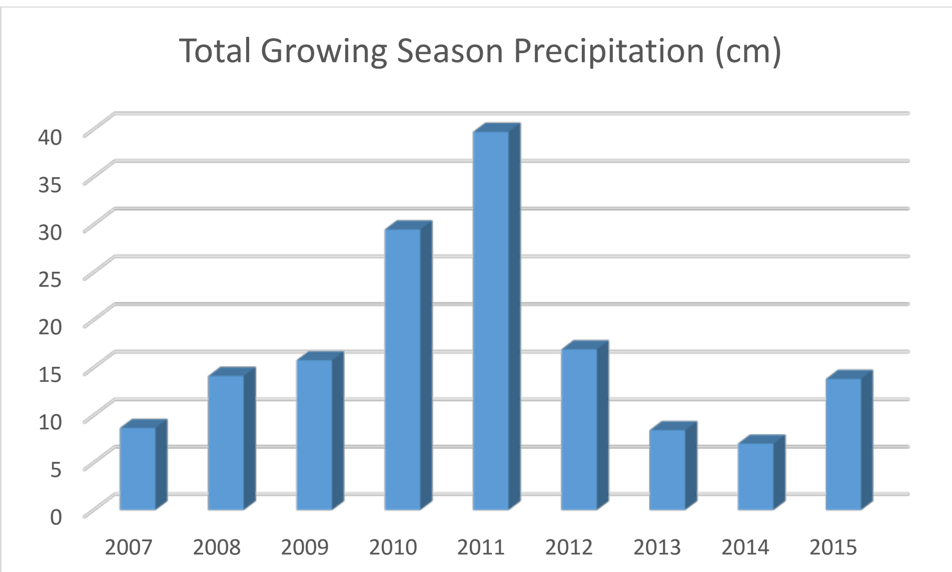


Figure 8. Growing season (October-April) precipitation (cm) levels in the Carrizo Plain National Monument from 2007 to 2015. Growing season for 2007 is defined as October 2006 through April 2007.

Plants

General plant composition

Plant species richness in both Center Well and Swain was low through 2014 with 2013 and 2014 having record lows in Center Well and near record lows in Swain. 2015 saw a dramatic change with record highs in species richness in Center Well and near record highs in

Swain (Table 1). Exotic species richness has remained similar in 2007-2015 (value range: 4-10), with the lowest values occurring in 2014 (Center Well, 4, Swain, 5, Table 1). Native species richness plummeted in 2013 and 2014, with record lows in Center Well and near record lows in Swain, and saw a dramatic rise in both pastures in 2015 (Table 1).

Both pastures saw record lows in percent cover in 2013 (Center Well = 9%, Swain = 13%) with increases in percent cover back to the mid range in 2015 (Table 1). Native percent cover in Center Well was below 5% in 2013 and 2014 and rose to 17% in 2015. Swain saw a similar trend with 6% native cover in 2014 and 25% in 2015. Exotic percent cover in both pastures rose from below 10% in 2015 to the low thirties in 2015 (Table 1).

Grass (*Poaceae)* cover was the lowest ever recorded, less than 2% cover, on all Center Well vegetation plots in 2014. There was a rebound in 2015 but levels were still low (Figure 9).

Schismus arabicus was the dominant grass species in both pastures and in and out of GKR exclosures. *Erodium circutarium* was the most common species overall, in both pastures and in and out of GKR exclosures (Table 2).

In 2014 Center Well's most common plants were *Erodium*, *Calandrinia cliata*, and *Trifolium gracilentum*. In Swain pasture *Erodium* and *Calandrinia ciliate* were also the most prevalent, though *Trifolium* was not. Instead *Lepidium nitidum* was the third most common plant species in Swain. In 2015 the most common species in Center Well were *Erodium*, *Schismus arabicus* and *Lepidium nitidum*. *Hordeum murinum* and *Calandrinia* were also common. In Swain pasture *Erodium* was most common, followed by *Calandrinia ciliate* and then *Schismus* and *Lepidium*. *Pectocarya penicillata* was also common in Swain pasture.

Table1. Species richness and relative percent plant cover in the Center Well and Swain pastures, 2007–2015.

Metric	Type	Center Well								
		2007	2008	2009	2010	2011	2012	2013	2014	2015
Species richness	native	18	30	30	31	28	21	15	16	31
	exotic	8	7	6	7	9	7	6	4	10
	total	26	37	36	38	37	28	21	20	41
Plant cover (%)	native	23	28	42	67	35	5	2	3	17
	exotic	17	37	28	25	49	16	16	6	32
	total	40	65	70	92	84	21	18	9	49
		Swain								
		2007	2008	2009	2010	2011	2012	2013	2014	2015
Species richness	native	15	43	40	45	39	34	27	23	41
	exotic	7	10	8	6	7	9	6	5	6
	total	22	53	48	51	46	43	33	28	47
Plant cover (%)	native	17	20	41	57	32	7	7	6	25
	exotic	32	33	32	34	44	25	23	7	31
	total	50	52	73	90	76	32	30	13	56

Table 2. Relative % cover of plant species in the Center Well and Swain pastures in 2015 (*n* = 554 plots), and without GKR ("No GKR", inside GKR exclosures, *n* = 238 plots) and with GKR ("GKR", outside GKR exclosures, *n* = 316 plots).

Species	Type	Center Well	Swain	No GKR	GKR
Allium sp.	Native	<0.01	<0.01	<0.01	<0.01
Amsinckia menziesii	Native	<0.01	<0.01	-	<0.01
Amsinckia tessellata	Native	0.02	0.04	0.04	0.02
Astragalus didymocarpus	Native	<0.01	<0.01	<0.01	<0.01
Astragalus lentiginosus	Native	<0.01	-	0.00	-
Astragalus oxyphysus	Native	<0.01	<0.01	<0.01	<0.01
Athysanus pusillus	Native	-	<0.01	-	<0.01
Bromus madritensis	Invasive	0.01	0.02	0.01	0.02
Calandrinia ciliata	Native	0.05	0.10	0.09	0.06
Camissonia campestris	Native	-	<0.01	<0.01	<0.01
Camissonia palmeri	Native	-	<0.01	<0.01	<0.01
Capsella bursa-pastoris	Invasive	<0.01	-	<0.01	<0.01
Castilleja exserta	Native	-	<0.01	<0.01	<0.01
Chaenactis glabriuscula	Native	-	<0.01	-	<0.01
Chamaesyce polycarpa	Native	<0.01	-	<0.01	<0.01
Chorizanthe uniaristata	Native	-	0.01	<0.01	<0.01
Crassula connata	Native	-	<0.01	<0.01	<0.01
Descurainia sophia	Invasive	<0.01	-	-	<0.01
Dichelostemma capitatum	Native	<0.01	<0.01	<0.01	<0.01
Eremocarpus setigerus	Native	<0.01	-	<0.01	-
Eriogonum gracillimum	Native	<0.01	0.01	0.01	0.01
Erodium cicutarium	Invasive	0.42	0.39	0.39	0.42
Guillenia lasiophylla	Native	0.02	0.01	0.02	0.01
Herniaria hirsuta	Invasive	<0.01	0.01	<0.01	0.01
Hollisteria lanata	Native	-	0.02	0.01	0.01
Hordeum murinum	Invasive	0.07	0.04	0.04	0.07
Lastarriaea coriacea	Native	-	0.01	<0.01	0.01
Lasthenia californica	Native	<0.01	0.03	0.01	0.02
Lasthenia minor	Native	0.03	<0.01	0.02	0.01
Lembertia congdonii	Native	<0.01	<0.01	<0.01	<0.01

Table 2 Continued

Species	Type	Center Well	Swain	No GKR	GKR
Lepidium dictyotum	Native	0.01	0.01	0.02	<0.01
Lepidium nitidum	Native	0.08	0.06	0.09	0.05
Linanthus liniflorus	Native	-	0.01	<0.01	<0.01
Linanthus parviflorus	Native	-	<0.01	<0.01	-
Lotus wrangelianus	Native	0.04	0.02	0.01	0.05
Lupinus microcarpus	Native	<0.01	<0.01	<0.01	<0.01
Malacothrix coulteri	Native	<0.01	<0.01	<0.01	<0.01
Microseris douglasii	Native	<0.01	<0.01	<0.01	<0.01
Microseris elegans	Native	<0.01	<0.01	<0.01	<0.01
Monolopia lanceolata	Native	<0.01	<0.01	<0.01	<0.01
Pectocarya penicillata	Native	0.01	0.05	0.03	0.02
Phacelia ciliata	Native	<0.01	<0.01	<0.01	<0.01
Phlox gracilis	Native	<0.01	<0.01	<0.01	<0.01
Plagiobothrys canescens	Native	-	<0.01	<0.01	<0.01
Plantago erecta	Native	-	<0.01	<0.01	<0.01
Platystemon californicus	Native	<0.01	<0.01	<0.01	<0.01
Poa secunda	Native	-	0.01	<0.01	0.01
Salsola tragus	Invasive	<0.01	-	-	<0.01
Schismus arabicus	Invasive	0.14	0.09	0.16	0.08
Sisymbrium altissimum	Invasive	-	<0.01	<0.01	<0.01
Stephanomeria exigua	Native	-	<0.01	<0.01	<0.01
Trichostema lanceolatum	Native	<0.01	-	<0.01	<0.01
Trifolium gracilentum	Native	0.05	0.02	0.02	0.05
Tropidocarpum gracile	Native	0.02	0.01	0.02	0.01
Vulpia bromoides	Invasive	<0.01	-	-	<0.01
Vulpia microstachys	Native	0.02	0.02	0.02	0.02
Vulpia myuros	Invasive	<0.01	-	<0.01	<0.01

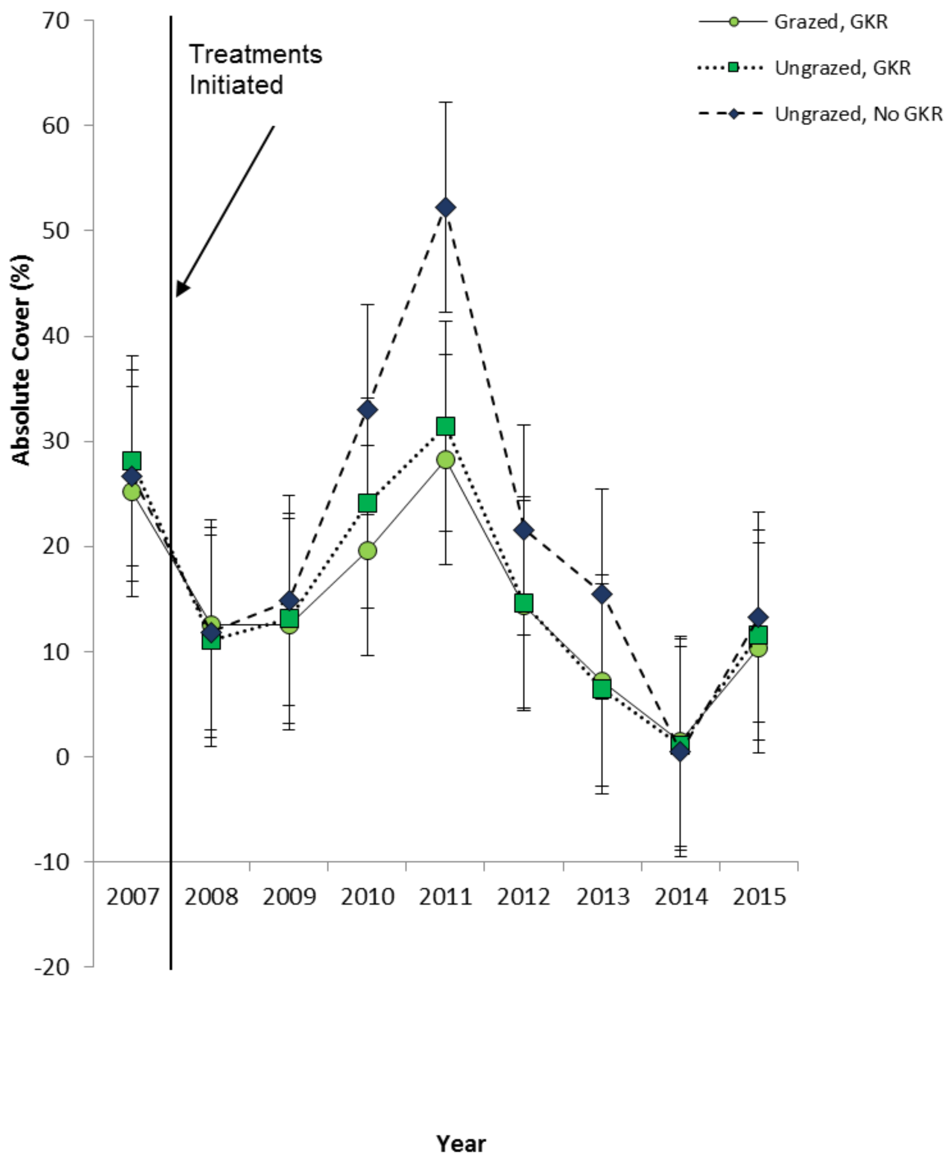


Figure 9. Grass cover in experimental plots within the Center Well pasture. Three treatments were initiated prior to the spring of 2008: kangaroo rat exclosures (ungrazed, no GKR), cattle exclosures (ungrazed, GKR), and control plots (grazed, GKR). Means and standard error bars are shown (*n* = 10 replicates per treatment).

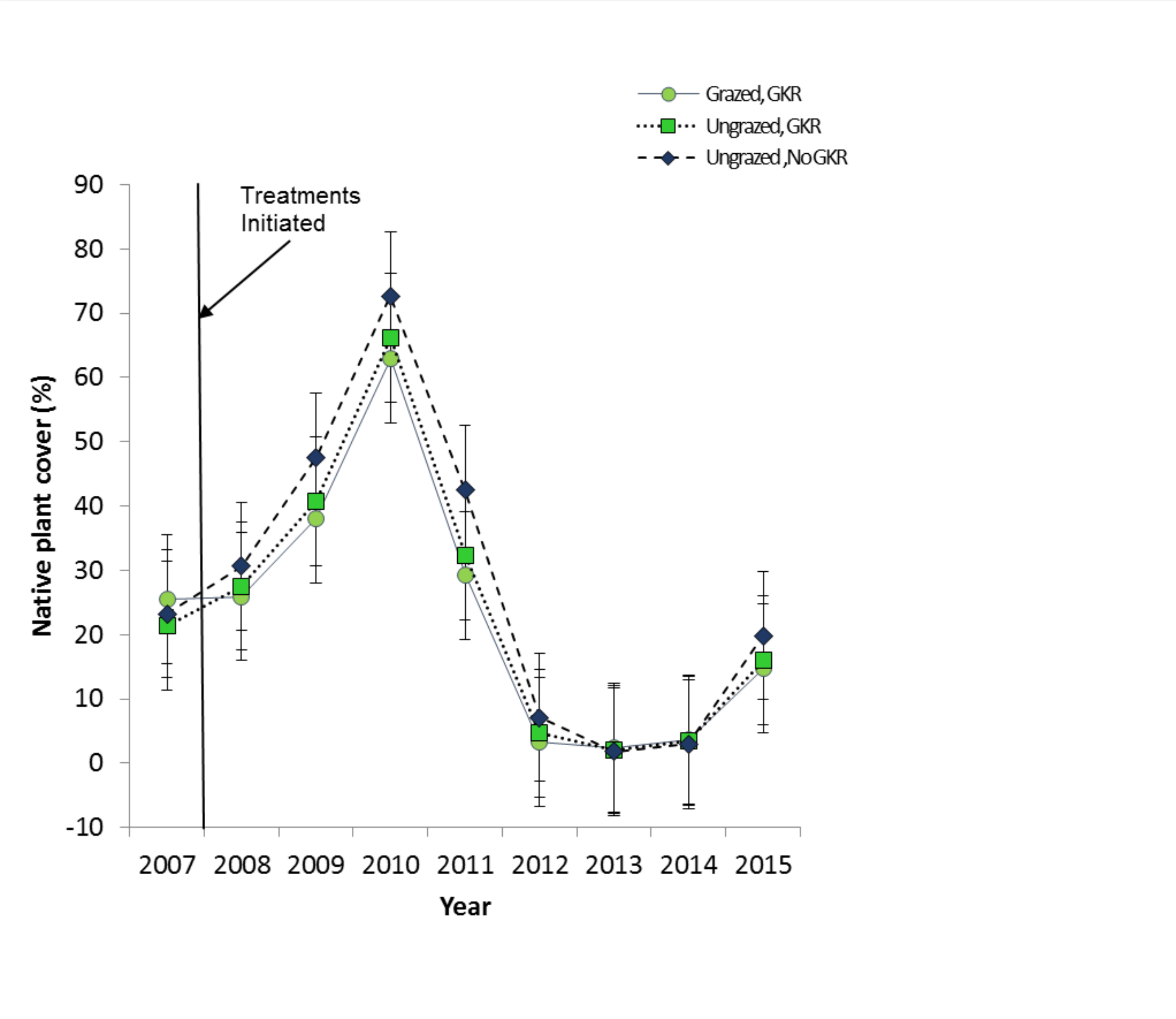


Figure 10. Native plant cover in experimental plots within the Center Well pasture.
Three treatments were initiated prior to the spring of 2008: kangaroo rat exclosures (ungrazed, no GKR), cattle exclosures (ungrazed, GKR), and control plots (grazed, GKR). Means and standard error bars are shown (*n*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

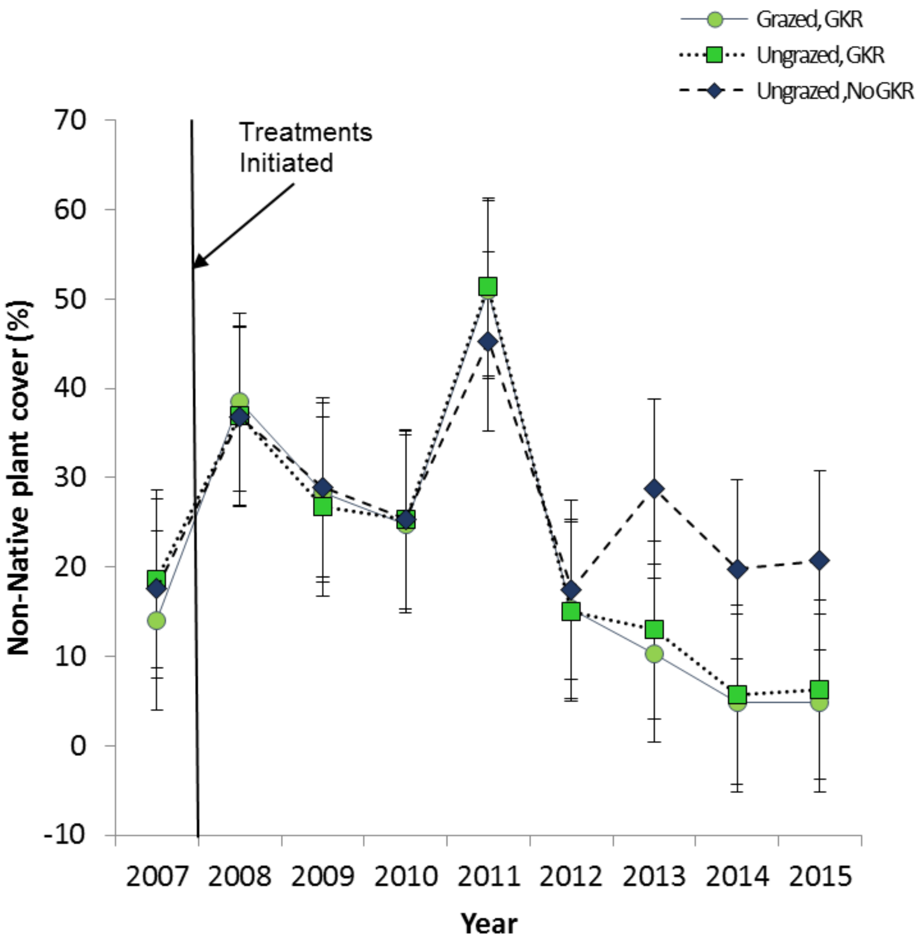


Figure 11. Non-Native plant cover in experimental plots within the Center Well pasture. Three treatments were initiated prior to the spring of 2008: kangaroo rat exclosures (ungrazed, no GKR), cattle exclosures (ungrazed, GKR), and control plots (grazed, GKR). Means and standard error bars are shown (*n* = 10 replicates per treatment).

Grazing intensity

For the fourth year in a row, in 2015, 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 2014 and 2015, biomass was measured in April (expected peak) and September (expected minimum).

The peak residual dry matter (RDM) on grazed and ungrazed plots with GKR was approximately 496 pounds per acre in 2014 and 1,550 pounds per acre in 2015 (Table 3). Removal by GKR was 1,266 pounds per acre in spring 2014 and 263 pounds per acre in 2015. In Fall 2014 417 pounds per acre were removed by GKR and in Fall 2015 there was actually more vegetation in the ungrazed plots than in the GKR exclosures (Figure 9). Without GKR, RDM levels were reduced from 1,538 to 467 pounds per acre in 2014 and 1,087 to 467 pounds per acre in 2015 (Table 3).

Table 3. Average (± standard error) plant biomass measured in pounds per acre on 10 replicate sites in the Center Well (CW) pasture, 2014 & 2015. 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).

2015

Treatment	April	September
GKR and cattle	726 ± 152	273 ± 66
GKR only	824 ± 128	582 ± 129
No GKR or cattle	1087 ± 193	467 ± 92

2014

Treatment	April	October
Grazed, GKR	224 ± 74	38 ± 10
Ungrazed, GKR	272 ± 70	180 ± 56
No GKR or cattle	1538 ± 483	597 ± 156

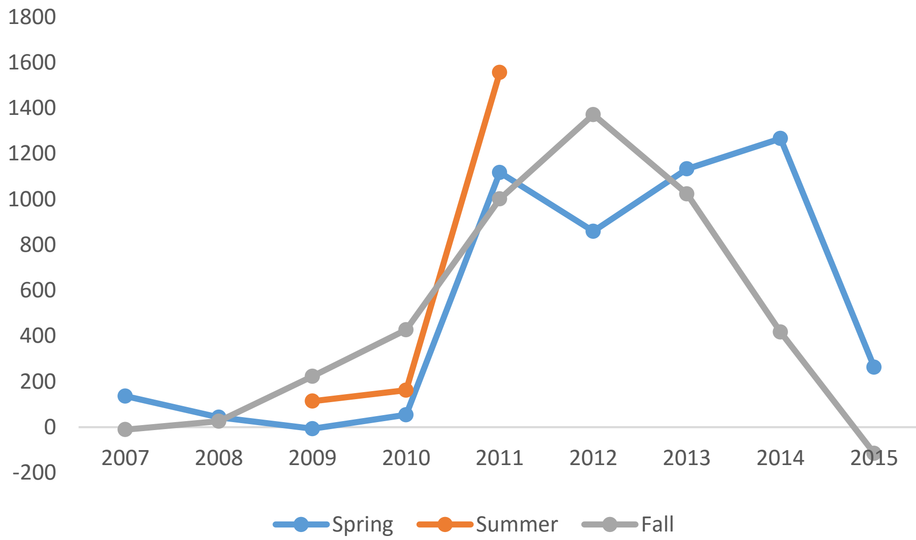


Figure 12. Biomass removal in Center Well pasture by GKR from 2007-2013, measured as the difference in biomass in and out of GKR exclosures.

Gopher Activity

Gopher (*Thomomys bottae*) activity decreased in 2014 and in 2015 only 5 sites had gopher activity (Table 4). Gopher activity was low in the previous dry years and was first seen in multiple exclosures in 2010 with trapping initiated in 2011.

Gopher activity remained higher in plots without GKR in both 2014 and 2015 but was only significant in 2014 (Table 4; 2014: t = -4.71, P < .005, 2015: t = -1.33, P = .19).

Table 4. Gopher activity

	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%
2014	40%	10%	0%	90%	60%
2015	40%	10%	0%	0%	0%

GKR abundance

A total of 201 individual kangaroo rats were captured in 2015; 186 of which had not been previously marked. Including recaptures, a total of 292 giant kangaroo rat captures occurred. Total trap effort was 10,863 traps*nights.

Both 2014 and 2015 saw an increase in non GKR rodent species. In 2015 there were 32 *Peromyscus maniculatus*, 26 *Dipodomys nitratoides brevinasus*, 20 *Perognathus*, 12 *Onychomys*, one *Dipodomys hermenii* and 7 unknown mice captured.

Spring 2015 estimates were the lowest ever recorded, following a record low in 2014. Densities increased during the summer 2015 trapping period . Mark-recapture estimates of GKR abundance in 2015 during both trapping sessions were variable among sites with <0.01 to 33.48 GKR per plot (Table 5). Apparent survival rates varied from <0.01 to 0.67 (Table 5).

There were no significant differences in GKR density between grazed and ungrazed plots in either the spring or summer sessions in both 2014 and 2015.

In 2014 GKR densities in Center Well pasture were significantly higher than those in Swain in spring but not in summer (Spring: t = 4.1036, P <0.005, n = 10, Summer: t = 0.5452, P = 0.592, n = 10). In 2015, the opposite was seen with densities in Center Well pasture significantly higher than those in Swain in summer but not in spring (Summer: t = 2.4595, P <0.005, n = 10, Spring: t = 1.7498, P = 0.1141, n = 10).

Overwinter apparent survival was the lowest ever recorded in 2015 after record lows in 2014. In 2014 summer apparent survival in Center Well pasture was also the lowest ever recorded, though Swain summer apparent survival was in the middle range of results (Figure 14). In 2015, summer apparent survival in Center Well showed a rebound and was the highest seen since Summer 2013, however Swain numbers remained low (Figure 14).

Reproduction remained low in 2014 with 0.03 juveniles per adult and increased in 2015 with 0.11 juveniles per adult.

The seasonal genital lesions (likely trombiculid mites) that appear in August trapping sessions increased to 58% in 2015 after a low of 11% in 2014.

GKR estimates on each plot were correlated in Spring and Summer 2014 and 2015 (r = 0.611, and r = 0.744, 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 2015 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	<0.01	<0.01	4.71	2.05	<0.01	<0.01
Center Well	Grazed	C2	3.00	<0.01	15.36	3.84	0.67	0.59
Center Well	Grazed	C3	<0.01	<0.01	4.35	1.63	<0.01	<0.01
Center Well	Grazed	C4	0.01	<0.01	4.00	<0.01	<0.01	<0.01
Center Well	Grazed	C5	1.00	<0.01	7.54	0.43	0.62	0.30
Center Well	Grazed	C6	0.01	<0.01	<0.01	0.00	<0.01	<0.01
Center Well	Grazed	C7	<0.01	<0.01	33.48	3.44	0.64	0.32
Center Well	Grazed	C8	<0.01	<0.01	3.09	0.83	0.62	0.30
Center Well	Grazed	C9	3.00	<0.01	7.75	0.59	0.66	0.29
Center Well	Grazed	C10	<0.01	<0.01	6.14	0.87	0.64	0.30
Center Well	Ungrazed	E1	<0.01	<0.01	2.01	1.22	<0.01	<0.01
Center Well	Ungrazed	E2	<0.01	<0.01	21.35	6.61	0.65	0.61
Center Well	Ungrazed	E3	4.00	<0.01	10.98	1.22	<0.01	<0.01
Center Well	Ungrazed	E4	0.01	<0.01	6.00	<0.01	<0.01	<0.01
Center Well	Ungrazed	E5	1.00	<0.01	11.52	0.42	0.59	0.31
Center Well	Ungrazed	E6	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Center Well	Ungrazed	E7	9.00	<0.01	25.89	4.03	0.65	0.31
Center Well	Ungrazed	E8	<0.01	<0.01	9.38	1.07	0.62	0.31
Center Well	Ungrazed	E9	<0.01	<0.01	15.58	0.47	0.62	0.30
Center Well	Ungrazed	E10	2.00	<0.01	8.90	0.70	0.62	0.30
Swain	Ungrazed	S1	0.02	<0.01	1.00	<0.01	<0.01	<0.01
Swain	Ungrazed	S2	0.01	<0.01	3.00	<0.01	<0.01	<0.01
Swain	Ungrazed	S3	0.02	<0.01	5.00	<0.01	<0.01	<0.01
Swain	Ungrazed	S4	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Swain	Ungrazed	S5	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Swain	Ungrazed	S6	<0.01	0.04	3.61	1.11	<0.01	0.35
Swain	Ungrazed	S7	<0.01	0.06	8.01	1.88	<0.01	0.37
Swain	Ungrazed	S8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Swain	Ungrazed	S9	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Swain	Ungrazed	S10	0.02	<0.01	3.00	<0.01	<0.01	<0.01

Table 6. Age and sex composition of Giant Kangaroo Rats captured in 2015.

		Female	Male	Unknown	Total
GKR	Adult	110	66	0	176
	Juvenile	12	7	1	20
	Unknown	1	2	2	5
	Total	123	75	3	201

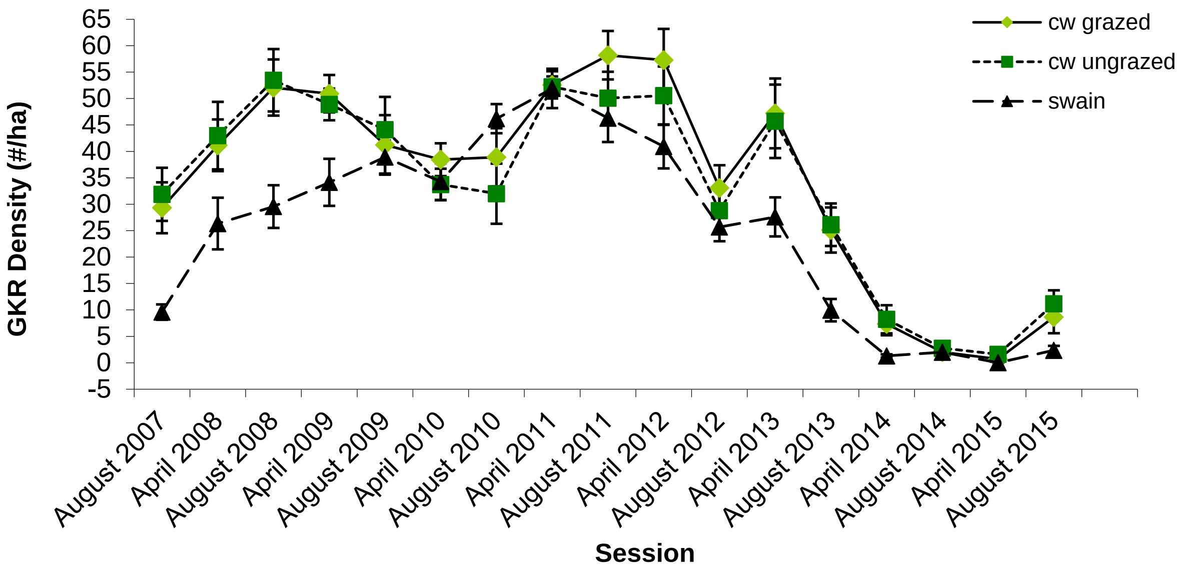


Figure 13. Average GKR population estimates in Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots, from April 2008 to August 2015. Standard error bars are shown (*n* = 10 grids per treatment).

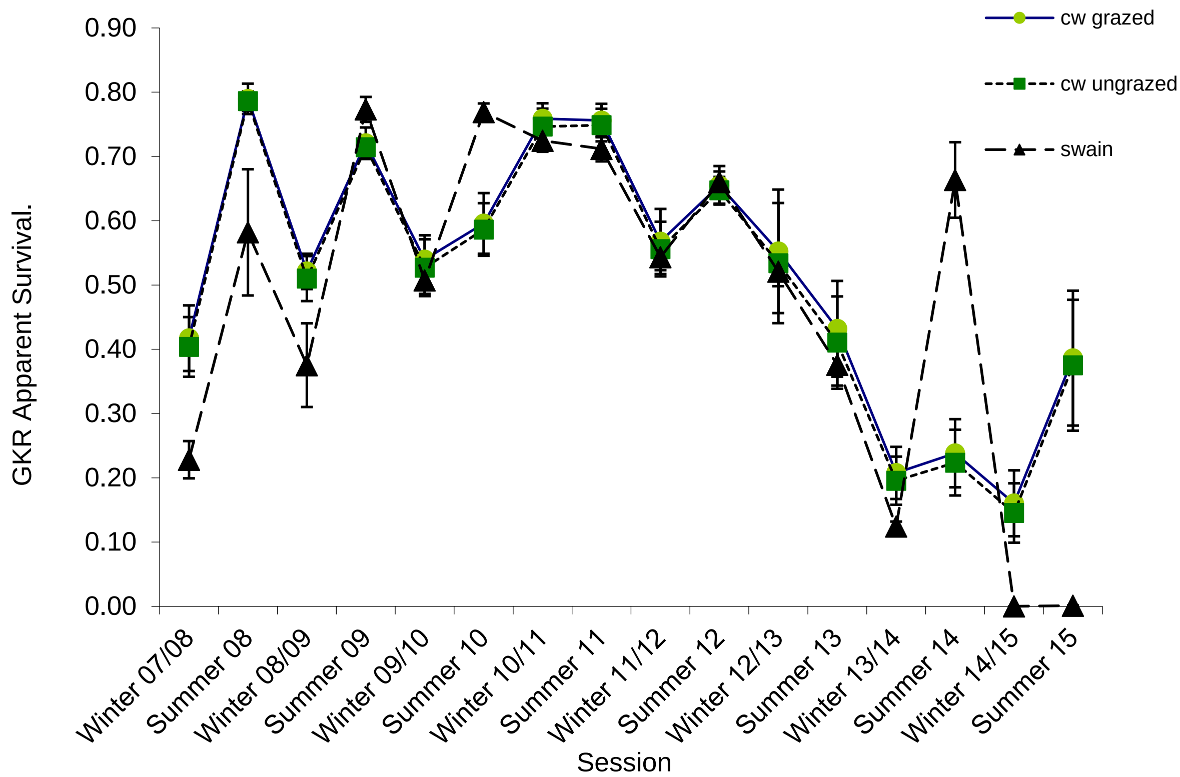


Figure 14. Average GKR apparent survival (site fidelity) estimates in Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots, from winter 2008 to summer 2015. Standard error bars are shown (*n* = 10 grids per treatment).

GKR Supplemental Feeding Plots

Three new plots were installed in Swain Pasture, following the same grid design as this study, though without kangaroo rat exclosures. The plots were installed for a supplemental feeding study led by California Fish and Wildlife under Bob Stafford. The three plots were set up adjacent to plots Swain 1-3. Data on these plots was similar to data on our Swain plots.

A total of 16 individual kangaroo rats were captured on the supplemental feeding plots, none of which had been captured in the CPEP study previously. Including recaptures, a total of 22 giant kangaroo rat captures occurred. Total trap effort was 360 traps*nights.

There were seven male and 8 female GKR captured and 12 adults and 2 juveniles.

There were 14 *Dipodomys nitratoides brevinasus* and 4 *Perognathus* species captured.

The seasonal genital lesions (likely trombiculid mites) were present on all GKR trapped on the supplemental feeding plots.

GKR Precinct Surveys

All plots were surveyed for precincts in 2015. 1,041 active and 2,209 inactive precincts were counted. Grazed plots in Center Well had the most active precincts (577). The ratio of inactive to active plots was most disproportionate in Swain pasture (1044:101). Center Well grazed, Center Well ungrazed and Swain plots all had a similar number of precincts.

SJAS abundance

A total of 65 individual antelope squirrels were captured and a total of 123 captures (including recaptures) occurred. Male and female capture rates were similar (Table 7). In 2015, SJAS overall density levels were 7 SJAS/ha, nearly identical to the density level in 2014 (7.4 SJAS/ha). 2015 had the second lowest density on record for the study (Figure 15). SJAS densities were not significantly different between grazed and ungrazed plots (t = -0.55, df = 9, P = 0.60, n = 10). Densities in Swain pasture (M = 3.50 ± 0.69 individuals per plot) were higher than those in Center Well pasture (both grazed and ungrazed; M = 1.75± 0.56 individuals per plot) but results were not significant (t = -1.89, df = 28, P = 0.07) (Figure 15 & 16).

Apparent survival of SJAS was the highest it has been in 3 years, and significantly increased from 2014 (t = -2.017, df = 58, P = 0.48) (Figure 17). Apparent survival of SJAS was significantly higher in Center Well pasture than in Swain pasture for the first time since the study began (t = 2.33, df = 28, P = 0.03). Recruitment was remarkably higher in 2015 than in 2014, with an average of 2.06 juveniles per adult female versus only 0.02 juveniles per adult female the previous year (Table 7). SJAS estimates on each plot were not correlated between 2014 and 2015 (r = 0.30, P = 0.11; Figure 16).

Table 7. Age and sex composition of San Joaquin antelope squirrels (SJAS) captured in 2015.

		Female	Male	Total
SJAS	Adult	15	19	34
	Juvenile	16	15	31
	Unknown	0	0	0
	Total	31	34	65

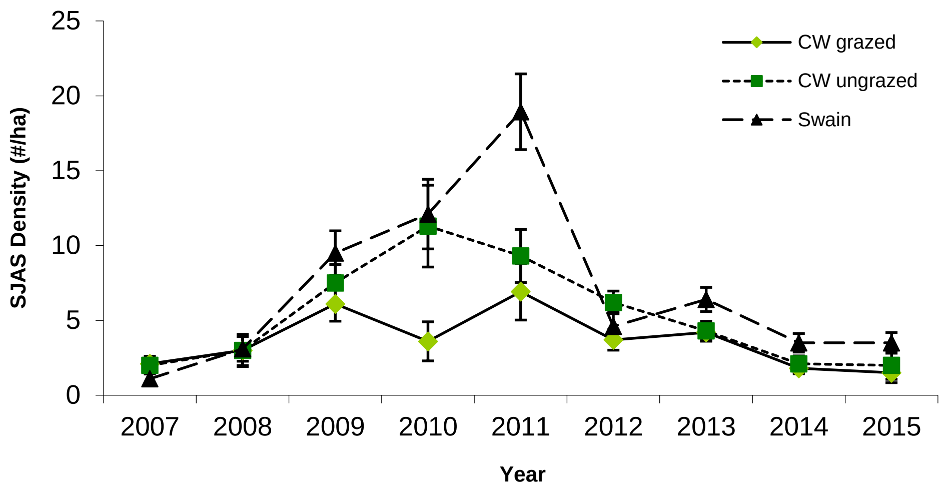


Figure 15. Estimates of San Joaquin antelope squirrel density. Average annual density (± standard error) in Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots.

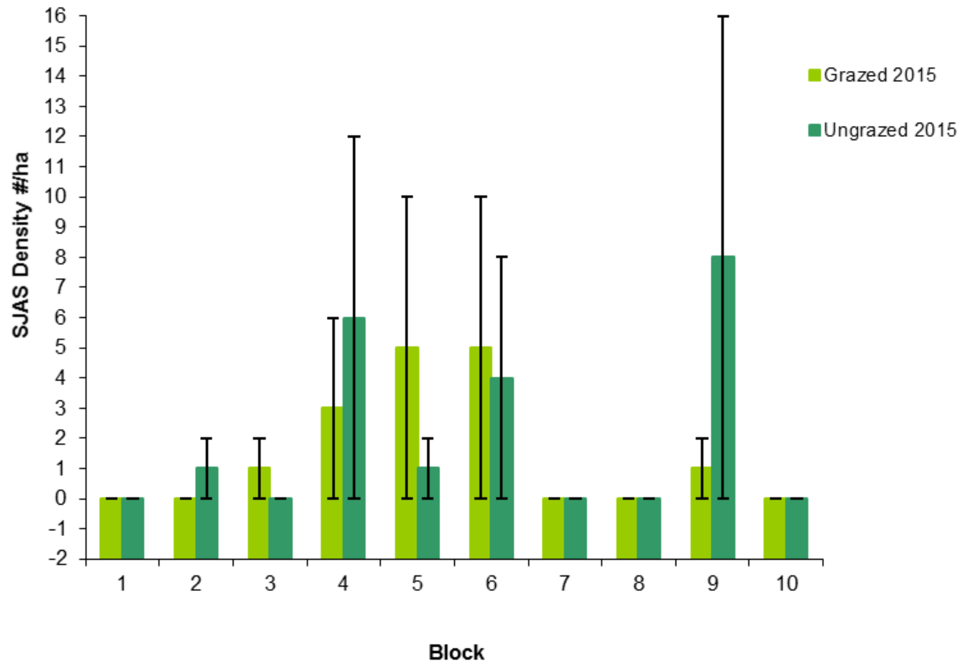


Figure 16. Average annual density (± standard error) in 2015 on each replicate site (block) in Center Well, with 95% confidence intervals.

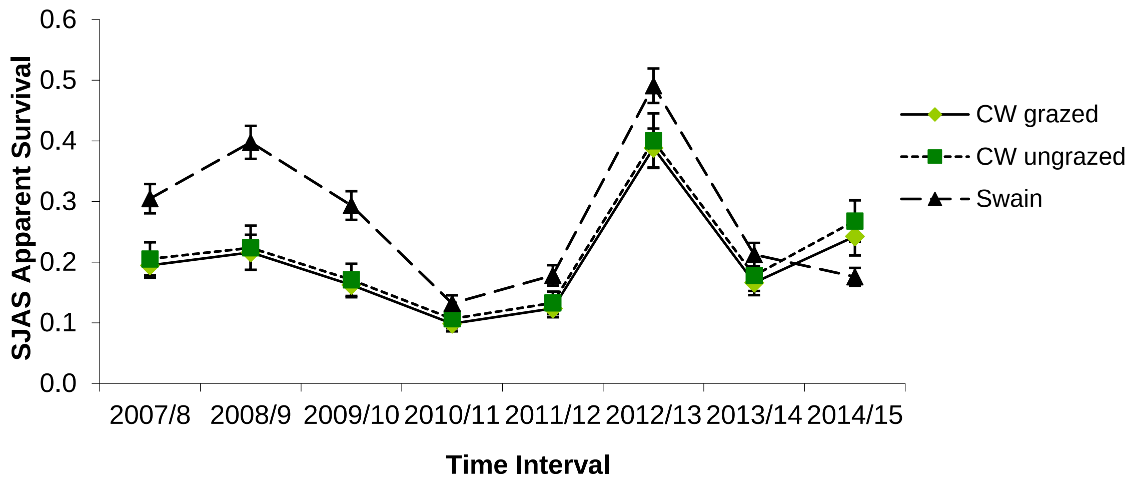


Figure 17. Apparent survival of San Joaquin antelope squirrels on Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots, 2007-2015. Standard error bars are shown.

Reptile abundance

A total of 470 side-blotched lizards (*Uta stansburiana*) and twenty five blunt-nosed leopard lizards (*Gambelia sila*) were seen during reptile surveys (Table 8). All blunt-nosed leopard lizard (BNLL) sightings were geo-referenced. In 2014 four BNLL were sighted in the Center Well (Center Well 5) pasture for the first time in the study. In 2015 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. Two coast horned lizards (*Phrynosoma coronatum*) and and one western rattlesnake (*Crotalus atrox*) were also seen in 2014 during survey in the Swain pasture. BNLL abundance increased in 2014 and was the third highest on record in 2015. UTA sightings continued to rise in 2014 and 2015, the third highest on record in 2015 (Figure 18; Table 8). Grazed pastures had a higher number of lizards than ungrazed pastures in both 2014 and 2015 but results were only significant in 2015 (2014: t = -0.8776, P = 0.403, 2015: t = 2.2648, P = 0.04979).

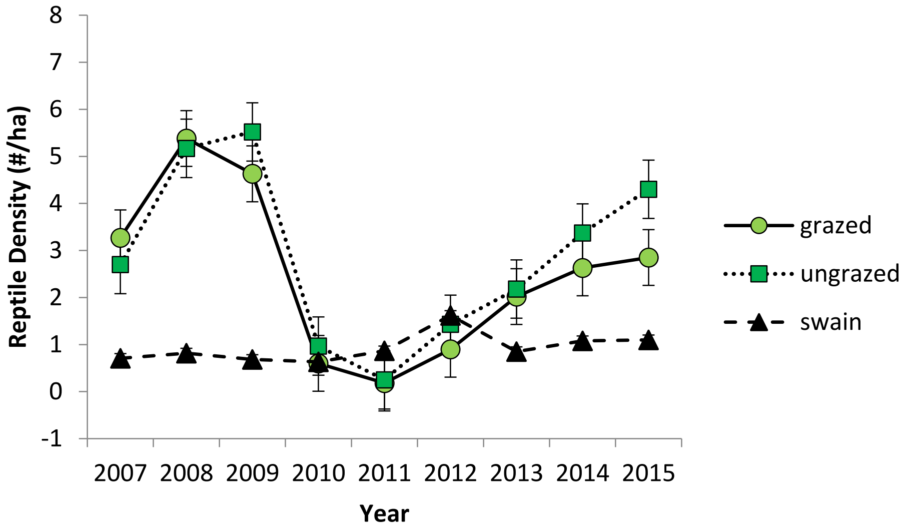


Figure 18. Estimates of reptile density each year from 3 replicate surveys on Center Well grazed plots, Center Well ungrazed plots, and Swain ungrazed plots. Standard error bars are shown.

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	2014	2015
BNLL	4	7	19	18	36	37	2	11	25
UTA	419	675	631	114	42	200	301	413	470

Invertebrates

Species identification and counting has not been completed for the 2015 invertebrate samples. Once this data is collected (likely mid to late 2016) data regarding 2015 invertebrates will be distributed. From casual observation, invertebrate numbers and diversity appear to have increased in 2015.
2014 data is discussed below.

GKR exclosures continued to have effects on the invertebrate community in 2014. Where GKR were present, there was higher overall abundance and richness and also higher numbers of beetles and ants (Figure 19 & 20; t = -4.5246, P < 0.005, t = -3.8413, P > 0.005, t = -3.7738, P < 0.005, t = -2.3996, P = 0.019). Though there were no cattle this year, grazed areas had a higher biomass and overall abundance than ungrazed areas (Figure 19 & 20, t = -2.8635, P = 0.005, t = -1.9715, P = 0.05). In 2012 there was a record high 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 in 2014 biomass levels remained low (Figure 19 & 20).

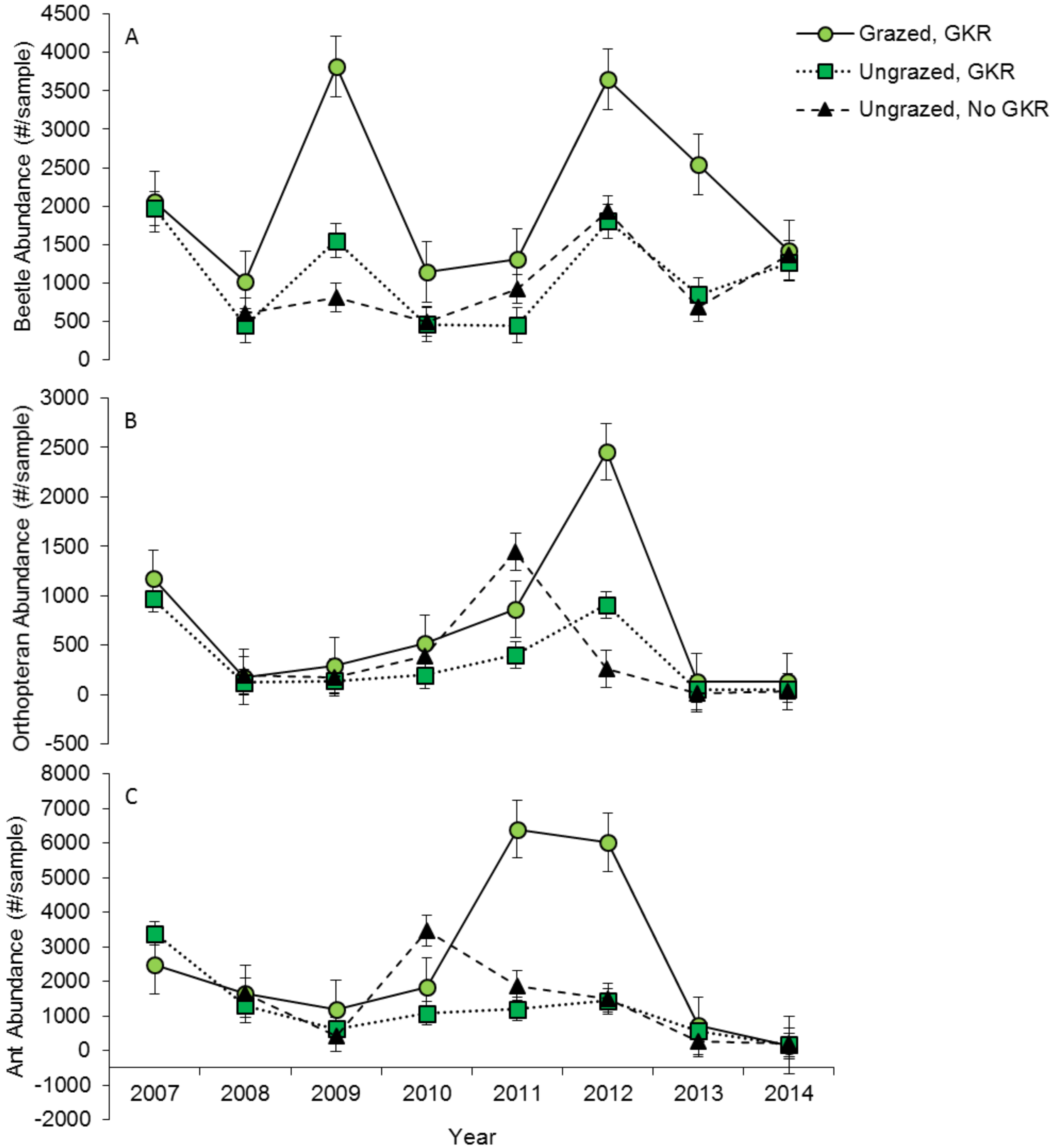


Figure 19. Response of (A) beetle, (B) orthopteran and (C) Ant abundance to GKR and cattle exclosures in the Center Well pasture, 2007-2014. Standard error bars are shown.

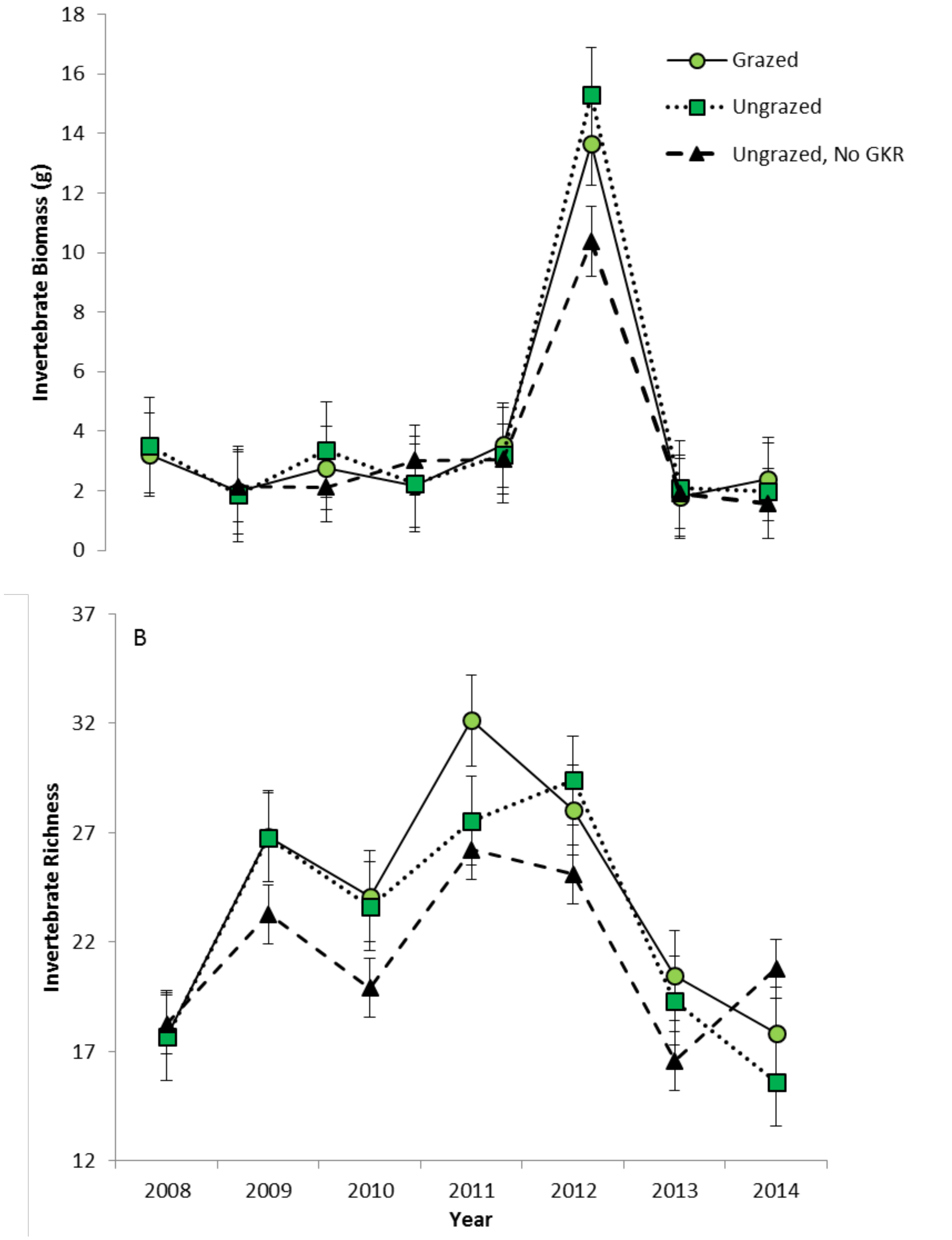


Figure 20. Response of invertebrate biomass (grams) (A) and richness (B) to GKR and cattle exclosures in the Center Well pasture, 2008-2014. Standard error bars are shown.

Kit Fox Dens

All plots were surveyed for kit fox dens in 2014 and 2015. In 2014 there were 28 active and 144 inactive dens, in 2015 there were no active dens and 89 inactive dens. All types of plots (i.e., Swain, Center Well control and cattle exclosure plots) had kit fox dens. In 2013 active dens were more common in cattle exclosures but in 2014 active dens were common on both control and exclosure plots. Cattle exclosures also had the greatest number of inactive and active dens combined in all years.

Species associations

Table 9 shows the associations among the flora and fauna on our plots. In 2014 and 2015, 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. In 2014, invertebrate richness was correlated with all plant categories and in 2015 it was correlated with plant diversity and richness.

Table 9. 2014 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.

	N squirrels	*N* GKR	GKR survival	*N* lizards	Plant Biomass	Plant Height	Plant Diversity	Plant Richness	Invertebrate Biomass
N GKR	**-0.43**								
GKR survival	**-0.43**	**0.85**							
N Lizards	-0.16	**0.67**	**0.65**						
Plant Biomass	**0.51**	-0.33	-0.27	-0.26					
Plant Height	**0.44**	-0.28	-0.23	-0.15	**0.82**				
Plant Diversity	0.02	0.00	0.14	0.03	0.00	0.12			
Plant Richness	0.05	0.00	0.16	0.03	0.14	0.21	**0.96**		
Invertebrate Biomass	-0.09	**0.41**	**0.49**	**0.40**	0.21	-0.05	0.01	0.05	
Invertebrate Richness	**0.48**	-0.26	-0.21	-0.26	**0.57**	**0.53**	**0.35**	**0.39**	0.26

Table 9. 2015 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.

	N squirrels	*N* GKR	GKR survival	*N* lizards	Plant Biomass	Plant Height	Plant Diversity	Plant Richness	Invertebrate Biomass
N GKR	-0.26								
GKR survival	**-0.34**	**0.37**							
N Lizards	-0.27	**0.56**	**0.59**						
Plant Biomass	0.34	-0.01	**-0.43**	0.08					
Plant Height	0.25	-0.03	-0.17	0.22	0.80				
Plant Diversity	0.18	-0.14	-0.14	-0.06	-0.01	0.03			
Plant Richness	0.26	-0.15	**-0.36**	-0.07	0.25	0.24	**0.91**		
Invertebrate Biomass	-0.08	-0.13	**-0.38**	-0.18	0.29	-0.01	0.30	**0.41**	
Invertebrate Richness	0.15	-0.18	**-0.46**	**-0.36**	0.18	-0.01	**0.61**	**0.71**	**0.65**

Conclusions and Future Directions

2014 was another year of record lows in the Carrizo but 2015 brought some increases. 2014 had record low plant richness, percent cover and grass cover in the third year of a drought that left much of the study area barren of vegetation and subsequently population numbers were low in 2014 for most species. GKR were hit particularly hard with record lows in all areas through the spring of 2015. The increase in vegetation in early 2015 didn't help the overwintering GKR population but summer trapping numbers showed a definite increase in the GKR population.

With the low numbers of GKR in the last two years, other species have moved into the study area. Whereas during peak GKR density years there are few if any other species, numbers of non GKR species were common during all trapping sessions in 2014 and 2015.

SJAS population and survival were low in 2014, though not as low as GKR, and they also increased in 2015. In particular, SJAS recruitment saw a turnaround in 2015 from an average of 0.02 juveniles per adult female in 2014 to 2.06 in 2015.

Uta densities continued to rise in 2014 and 2015 and after dropping to a record low in 2014, BNLL also increased in 2015.

Precinct and kit fox den surveys were conducted this year. GKR precinct numbers were similar on all plots, with active and inactive precincts combined, and Swain had the most inactive plots. In 2014 there were 28 active kit fox dens, in 2015 there were none. Kit fox numbers have dropped along with the GKR population and it is likely that if GKR continue to rebound that Kit fox populations will follow.

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. Residual dry matter (RDM) was low in 2014 but tripled in 2015. The low removal rates seen in spring 2015 were likely due to the record low of GKR.

While no cattle were grazed this year, cattle exclosures did appear to have a continued impact on invertebrates in 2014 with higher biomass and abundance on grazed plots.

GKR exclosures showed a strong effect on invertebrates in 2014 with overall richness, abundance and beetle and ant abundance higher where GKR were present. 2015 will likely show an increase in invertebrates as vegetation numbers were higher in 2015.

Gopher activity dropped in 2015 showing that this species has also been impacted by the drought.

Precipitation plots were installed in fall of 2014 and preliminary data is being reviewed. The plots were re-installed in 2015 in what promises to be a year of high precipitation. Two new post-doctoral candidates joined the Carrizo project.

Products of the Carrizo Plain Ecosystem Project

44) Deguiines, N. 2015. Precipitation effects on a semi-arid food web – Preliminary findings from the Carrizo Plain ecosystem. Talk presented at the annual Ecological Society of America. Baltimore, Maryland.
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