Baseline surveys for the Carrizo Exclosure Experiment: Final Report

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Objective:

To collect baseline ecological data on sites identified for long-term exclosure experiments in the Carrizo National Monument

Summary

Understanding interrelationships between giant kangaroo rats, plant dynamics, and cattle grazing is necessary to optimize conservation of upland species in the Carrizo National Monument. We completed the first year of a long-term study to tease apart these relationships using replicated cattle and GKR exclosures. Baseline surveys were completed in order to establish pre-existing conditions and determine the amount of heterogeneity on our experimental plots. The following tasks were accomplished: determining plant composition and biomass; taking soil samples; conducting mark-recapture surveys for GKR and San Joaquin antelope squirrels, line transects for reptiles and grasshoppers, point counts for birds, and spotlight surveys for predators and lagomorphs; collecting kit fox scats to assess their diet; determining GKR diet preferences with a seed choice trial; mapping GKR precincts; and assessing the invertebrate community by pitfall trapping. Heterogeneity within and among plots was moderate and levels of replication should be adequate to detect the effects of GKR presence, GKR soil disturbance, and cattle grazing over time. Precipitation will also be added to models as a time-dependent variable. Preliminary data analyses showed that native plant cover was lower on GKR precincts compared with non-precinct areas, and the Center Well pasture was dominated by a native fescue (*Vulpia microstachys*) whereas the Swain pasture, despite having abundant native bunchgrass (*Poa secunda*), was dominated by the invasive red brome (*Bromus madritensis rubens*). GKR, antelope squirrel, and lizard counts were generally higher in Center Well and negatively correlated with plant biomass. The abundance of lizards and squirrels were positively correlated with the number of GKR precincts. We plan to continue monitoring the flora and fauna on our sites and would also like to radio-collar adult and juvenile GKR to assess rates and causes of mortality and juvenile dispersal distances.

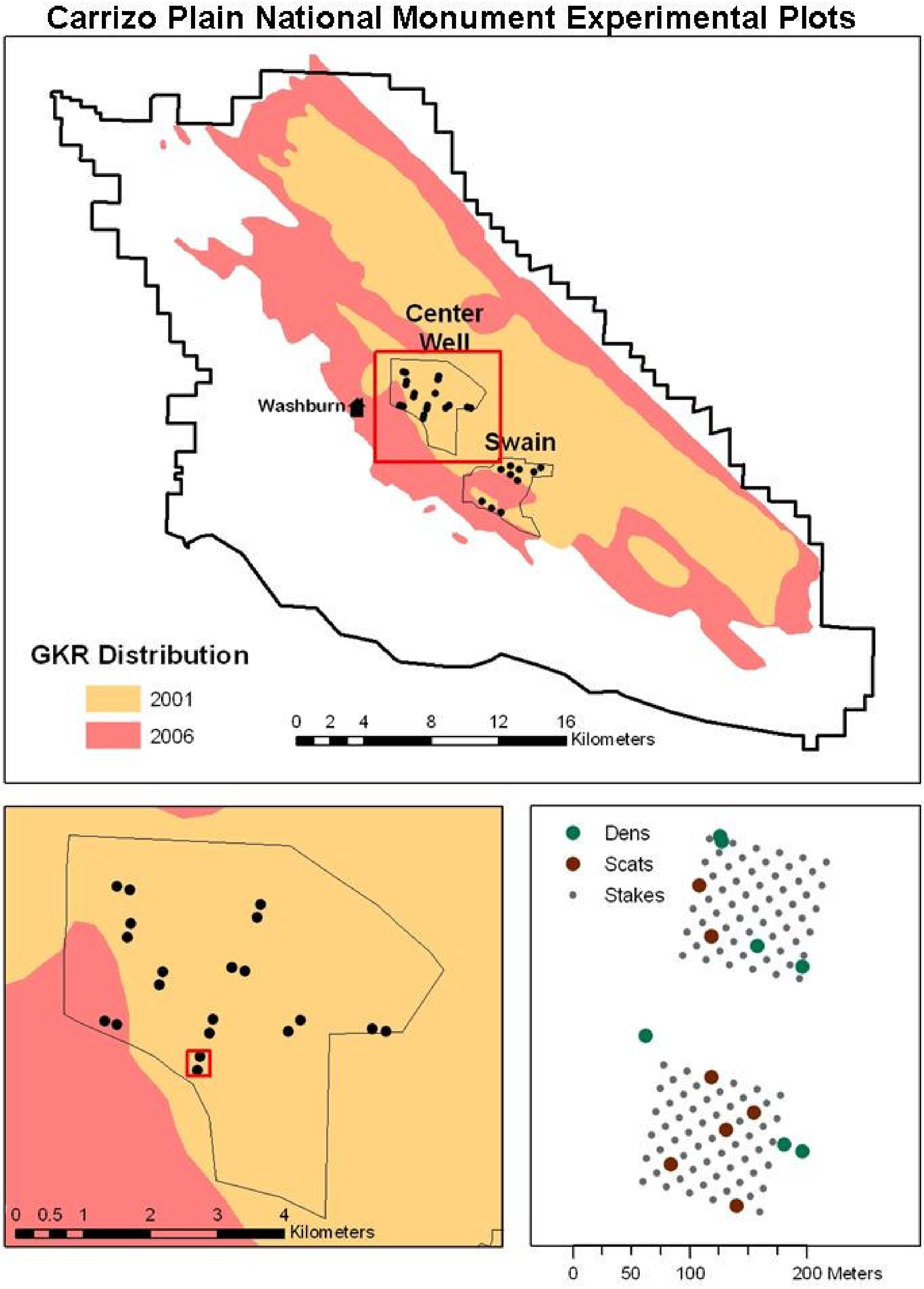


Figure 1. Map of study sites in the Carrizo Plain National Monument. Details are shown for the Center Well pasture and site CW 7. Kit fox dens and scats, as well as trap stakes, are shown for site 7.

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). Many of the imperiled species included in the federal recovery plan for upland species in the San Joaquin Valley occur in the Carrizo (U.S. Fish and Wildlife Service 1998). 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. Thus, management tools such as cattle grazing may benefit one endangered species but inadvertently harm another through direct or indirect trophic interactions.

Like many grasslands in California, the Carrizo is now dominated by annual grasses from Europe. Approximately 556 species of native plants and 110 species of non-native plants occur in the Carrizo, but the vegetative cover is dominated by a few species of European annuals such as red-stemmed fillaree (*Erodium cicutarium*) and red brome (*Bromus madritensis rubens*). The Carrizo is an especially arid grassland and may have been a desert system historically. Thus, these grasses may be particularly detrimental to the native flora and fauna in the Carrizo because they are adapted to open ground cover conditions (Germano et al. 2001). Sound management in the Carrizo thus requires an understanding of factors that control the distribution and abundance of non-native grasses.

While many studies have examined the role of disturbances such as livestock grazing and fire in the spread of invasive plants (e.g., McClaran and Anable 1992, Keeley et al. 2003, e.g., Clarke et al. 2005, Kupfer and Miller 2005, Keeley 2006), few studies have documented interactions between invasive plants and native grazers such as small mammals. Because of their burrowing activities, seed predation, and population irruptions, rodents can dramatically affect plant composition and biomass (Batzli and Pitelka 1970, Borchert and Jain 1978, Howe et al. 2006, Schiffman in press). Often overlooked, these cryptic herbivores can consume over 70% of net primary production (vegetation and seeds) in the absence of livestock grazing (Borchert and Jain 1978, Howe et al. 2006). We hypothesize that this dramatic effect of rodents on flora may partially explain the highly variable and often inconsistent results of livestock grazing studies (McClaran and Anable 1992, Stromberg and Griffin 1996, Denton et al. 1997, Weiss 1999, Bellingham and Coomes 2003, Keeley et al. 2003, Kimball and Schiffman 2003, Tobler et al. 2003). Previous studies assessing the effect of grazing on invasive plants have not controlled for possible differences in native fauna among treatments, and this confounding influence may partially explain the conflicting results obtained by these studies (Fehmi and Bartolome 2002).

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 importance of grazing for upland species. Additionally, they cannot establish causal relationships between invasive plant dynamics and factors such as GKR abundance because they were observational rather than experimental. Although GKR often occur in grazed areas and grazing may benefit native species by removing dense vegetation (Germano et al. 2001), cattle may negatively impact GKR because they consume substantial amounts of vegetation and seed caches from their precincts (Williams et al. 1993). In 2006, surveys recorded high numbers of GKR, which appeared to keep vegetation clipped in the absence of grazing despite abundant rainfall. Based on these results, we hypothesize that the costs and benefits of cattle grazing will depend on factors such as precipitation and GKR abundance, such that grazing will be beneficial in certain circumstances and detrimental in others. For example, grazing may be beneficial in high rainfall years and in areas with low GKR density, whereas it may have a net negative impact on the natural community in low rainfall years and in areas with high GKR numbers. Obtaining a set of scientifically-based decision rules to optimize habitat management is necessary for the recovery and management of giant kangaroo rats and other upland species.

Equally important, a detailed understanding of the interactions between GKR and other species is needed for effective recovery and management. Most importantly, the amount of plant biomass removed by GKR under varying precipitation conditions needs to be quantified in order to accurately determine cattle grazing prescriptions including stocking rates, season of use, and at what point cattle should be removed from a pasture. Additionally, accurate estimates of GKR mortality rates and dispersal distances are needed to predict their response to changing predator densities and food supplies.

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, especially giant kangaroo rats and plants.

TNC funds were used to conduct the baseline surveys critical to the success of this project.

Approach

We are using GKR and cattle exclosures to determine effects of GKR on plants and effects of cattle on plants, GKR, and other species. We conducted a-priori power analyses on simulated data in the program R to determine the number of replicates needed to detect treatment effects. We used plant survey data collected by Dr. Schiffman and others in the Swain pasture of the Carrizo (Schiffman 1994, Kimball and Schiffman 2003) to determine expected levels of variability among plots both on and off of GKR precincts. We found that approximately 10 replicates were needed to detect moderate effect sizes (~30%) on the percent cover of native plants.

Site selection

We used previously-collected data from 25 pastures to choose sites for our study in the Carrizo. We identified areas that were largely within the GKR core area, not recently cultivated, and were not dominated by shrubs. To address our first goal (effect of GKR on plants), we chose two areas with differing plant communities, one with substantial amounts of native bunchgrass (Swain pasture) and one with almost no bunchgrass (Center Well pasture). The Center Well site was also chosen to address our second goal (effect of grazing). We extensively discussed the pros and cons of placing replicates in several pastures versus one pasture with our partners (J. Bartolome, L. Saslaw, K. Sharum, and others). We decided to put all cattle exclosures in Center Well for several reasons. First, our nested exclosures are the units of replication, so unless each replicate could be placed in a separate pasture (which was not feasible), placing replicates in a few pastures would cause problems for analysis because replicates would be grouped and the pastures would become the units of replication. This would be undesirable, not only because it would reduce our sample size and complicate our (already complex) statistical error structure, but also because the pastures are artificial boundaries that are not inherently meaningful to the ecology of the system. Finally, if replicates were split between pastures it would be likely that some pastures would be grazed while others would not in a given year, which would render statistical analyses intractable. Although Center Well may not be grazed every year (2007, for example), our partners at BLM indicated that Center Well is the most likely pasture to receive cattle during years when grazing is allowed on the monument. Thus, we decided that spreading replicates throughout the largest (16,500 ha) pasture within the core GKR area, with the highest likelihood of being grazed each year, was the best approach for the study.

Selection of specific sites for replicates within Center Well and Swain was rigorously randomized. Each pasture was delineated on a USGS topographic map and sectioned into 1-km^2 blocks. Blocks were numbered, and ten were randomly chosen in each pasture. Each block was split into 100 1-ha sub-blocks, and one was randomly chosen. We navigated to the sub-block using a handheld GPS unit to assess the suitability of the site. The site was deemed suitable unless it was dominated by shrubs, within 100 m of a water tank, or there were very few GKR precincts. We also restricted suitable sub-blocks to those between 200-500 m from a road. If a site was unsuitable, another sub-block was randomly chosen and visited. Once a sub-block was chosen, the center was marked with a flag and process was repeated for the next block. We also ensured that sites were separated by at least 500 meters to reduce the chances of spatial autocorrelation. Giant kangaroo rats rarely move more than a few meters from their precincts (see preliminary data), so our replicates should be independent. Sites are shown in Figure 1.

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 (i.e., dominant plant), 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 will use structural equation modeling to estimate the strength of interactions and indirect effects of cattle (Wootton 1994).

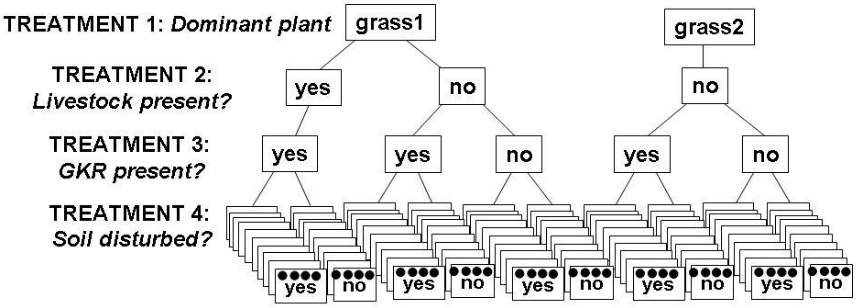


Figure 2. Experimental design of the project. There are ten blocks of each treatment combination and four nested vegetation plots (filled circles) within each block.

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. Trenches were dug along the perimeter of each exclosure using a Ditch Witch, and 4-ft wide hardware cloth (0.25 inch mesh) was placed in each trench and secured with rebar and t-posts. The hardware cloth extends 2 feet above and below ground. Lizards were seen to easily pass through the mesh and antelope squirrels should be able to easily climb the hardware cloth. This design was successfully used to exclude kangaroo rats in a long-term study in the Chihuahuan Desert (Brown and Munger 1985). GKR were trapped out of the exclosures during mark-recapture sessions, marked with ear and PIT tags, and placed in artificial burrows with ~ 2 pounds of bird seed. Artificial burrows were created either in abandoned precincts or unoccupied areas off the plots and geo-referenced. GKR exclosures will be checked periodically to ensure they are vacant.

Cattle exclosures were constructed around each GKR exclosure in Center Well with standard 4-strand barbed wire using established BLM fencing guidelines. 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).

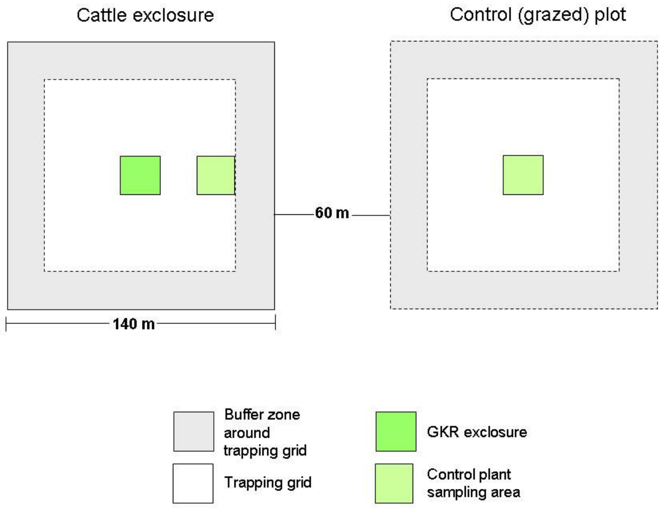


Figure 3. Nested exclosure design to separate livestock and GKR effects on plants, with paired control plot. A buffer zone around each GKR trapping grid ensured that the surveyed population was comprised of individuals living primarily within the plot. This shows the design in Center Well; in Swain each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

Plant and soil sampling

We mapped GKR precincts in each 400-m^2 plant sampling area and numbered each 1-m^2 cell occurring on precincts and off precincts, separately. We did not number any cells that were on the edge of a precinct or the plot. Initially, we randomly chose three precinct cells and three non-precinct cells for permanent plant survey plots (Figure 4). We added a fourth cell on and off precincts because surveys were proceeding more rapidly than expected and preliminary analyses indicated that a fourth replicate would reduce heterogeneity to acceptable levels. Because the 1-m^2 plant plots are nested within our experimental sampling units, they do not add to the statistical power of the study. Rather, they provide an unbiased representation of the vegetation on and off precincts in each plot.

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). We also clipped 1/16-m^2 plots adjacent to each survey plot to estimate biomass (Figure 5). This is a common clip plot size and was recommended by our partner Dr. J. Bartolome. Plant composition and biomass were surveyed in April 2007, and biomass was resurveyed in October 2007. Clip plots cannot be resurveyed in the same spot and are placed adjacent to the previous clip plot.

We randomly chose one precinct and one non-precinct plot per plant sampling area to take soil samples and place i-Buttons to record soil moisture and temperature. Soil samples were collected in October 2007 and sent to the ANR Laboratory at UC Davis for chemical analysis. Total N, C, Bray-P, salinity, texture, and pH will be analyzed. These analyses will allow us to determine how strongly soil chemistry affects plant composition and how chemistry differs on and off of GKR precincts.

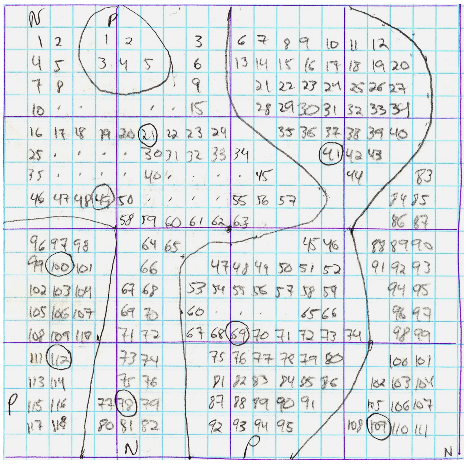
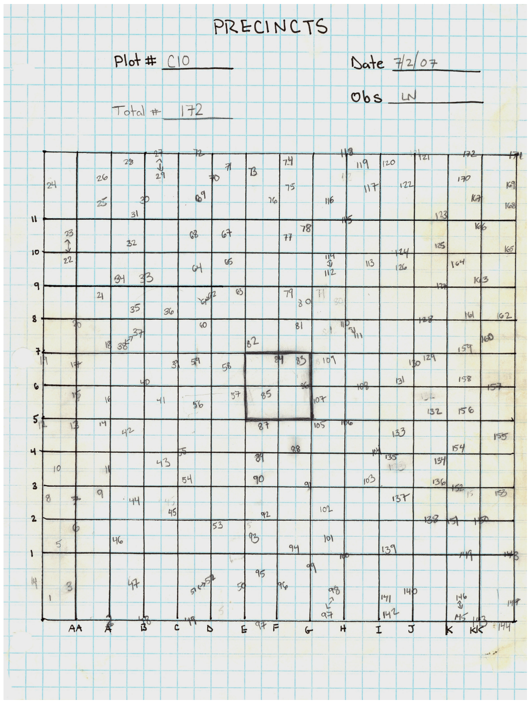


Figure 4. Example map of a 20x20-m plant sampling area. Each numbered square represents 1-m^2. We demarcated 5-m^2 units to facilitate mapping. P = precinct, N = non-precinct. Precinct cells and non-precinct cells were numbered separately. Circled cells show the randomly chosen plots for plant sampling.

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

GKR precincts were counted and mapped on each 1.96-ha plot (Figure 6; *n* = 30, 20 plots (paired) in Center Well, 10 in Swain). Inactive precincts and kit fox dens were also noted on maps. 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 7; *n* = 59 traps per plot, minimum trap distance = 14.1 m). L. Saslaw and K. Sharum assisted extensively with mark-recapture sessions prior to obtaining permits. We now have federal and state permits to trap GKR. Traps were baited with parakeet seed (microwaved to prevent germination), oats, and paper towel, and they were set at dusk and checked at or before dawn for five days on each grid. All captured animals were marked with an ear and PIT tag, weighed, sexed, and released. Trapping occurred from August 13 – October 12, 2007.



PRECINCTS

Plot # C10

Date 7/2/07

Obs LN

Total # 172

Figure 6. Example map of precincts on a 1.96-ha control plot in Center Well. The center of each precinct is marked with a number. Arrows were drawn between precincts that appeared to be connected. The plant sampling area is highlighted in the center of the plot. Demarcated grid cells are 10x10-m.

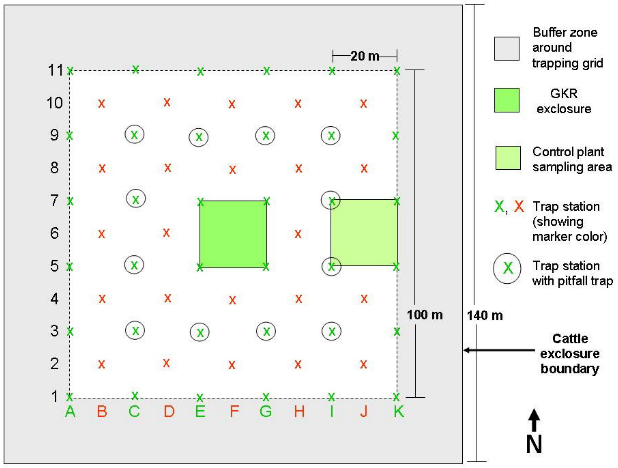


Figure 7. Detailed diagram of a cattle exclosure. Trap stations show trap locations for GKR mark-recapture surveys. Colors correspond to the spray-painted color on the stake marking the location. Letters and numbers identify the grid stakes (A1, B2, etc.).

GKR dietary preferences were determined as part of a UCB student senior thesis project. Seed heads were collected in April, and seed head piles from 10 predominant plant species were placed on 30 precincts (one per plot). Seed piles were placed at dusk and collected before dawn; GKR were the only nocturnal seed predators active at these sites. Piles were of identical weight, and remains were re-weighed to determine the quantity of each type removed. Samples from the 10 plant species were also analyzed by A & L Laboratories for nutritional value. These results are currently being analyzed by the student (B. Olney).

SJAS surveys

San Joaquin antelope squirrel (*Ammospermophilus nelsoni*, hereafter "SJAS") abundance was determined on each plot using mark-recapture surveys. Tomahawk traps were initially placed every 20 m, but this was increased to 40 m checkerboard spacing due to low capture rates and because SJAS have large home ranges (L. Saslaw, pers. comm.). Traps were baited with oats, set at dawn, and checked every two hours until noon or temperatures rose over 90° F. All captured animals were PIT-tagged, weighed, and sexed. Trapping occurred from July 18 – August 3, 2007. L. Saslaw also assisted with SJAS trapping due to permit delays.

Bird surveys

Point counts were conducted four times on each plot from May 9 – 26, 2007. Concentric rings were demarcated with flags from the center of each 1.96-ha plot, marking 10 m, 25 m, 45 m, and 70 m. Point counts lasted 10 minutes and all birds seen and heard during this time were identified and recorded, along with the time heard/seen and which ring the bird(s) occurred in. Birds detected off plot or flying over the plot were recorded separately. We tried to avoid re-counting the same birds during counts on different plots. Plots were conducted from 6-9 am and the order of plots visited was randomized.

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 26 – June 26, 2007. 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). Soil/air temperature, 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. L. Prugh attended the BNLL identification workshop at Cal State Bakersfield in May 2007 to improve identification skills and learn survey protocols.

Invertebrate surveys

Grasshoppers were counted during reptile surveys. Additionally, 12 pitfall traps were placed on each 1.96-ha plot (Figure 7) between June 12-19 and collected 2 weeks later. 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 8A). Traps were covered with 10x10" pieces of aluminum flashing with an inch of space between the cover and ground (Figure 8B). Two cm of safe antifreeze (propylene glycol), diluted with water by 50%, 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 8A). 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.

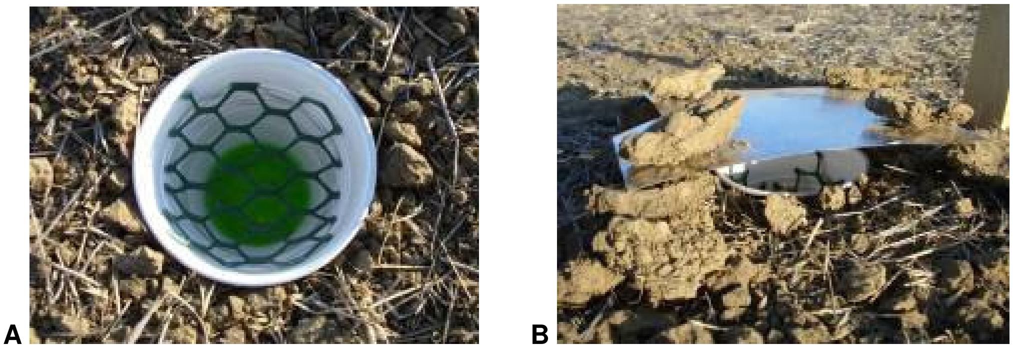


Figure 8. Pitfall trap viewed from above (A) and from the side with the aluminum cover (B).

Spotlight surveys

Ten spotlight routes ranging in length from 1.9-5.5 km (total distance = 35.4 km for all 10 routes) were surveyed 5-7 times from July 17-September 20, 2007. Routes were along dirt roads occurring in our study areas. Surveys were conducted using 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.

Kit fox activity and diet

Kit fox dens found on plots or opportunistically while walking to plots were geo-referenced. Kit foxes often marked our rodent traps with urine and feces, and we collected scats deposited on our traps. We found 47 kit fox dens, one burrowing owl den, and one badger den in our study areas, and we collected 92 kit fox scats. Scats are currently being analyzed as part of a UCB student senior thesis. The student (J. Castillo) is also collecting other predator scats (coyote, owl) for a comparative diet study in the Carrizo.

Antelope abundance

We recorded the number and approximate location of all antelope (*Antilocapra americana*) seen each day. We also recorded any birds of prey or mammalian predators seen. We noted whether the animal was seen from a vehicle or on foot, and we recorded the observer(s), number of hours on foot and in vehicle, and distance traveled on foot and in vehicle.

Preliminary Results

Plants

As expected from previous research (Schiffman 1994), the relative cover of native plants was higher in non-precinct plots than precinct plots, both in Center Well and Swain (Figure 9A). There was no significant interaction between pasture and precinct presence, indicating that GKR activity had similar effects on native cover in both pastures (linear mixed effects model; pasture $F_{1,23} = 50.2$, $p < 0.001$, precinct $F_{1,9} = 41.6$, $p < 0.001$, pasture*precinct $F_{1,23} = 3.2$, $p = 0.09$). However, we were surprised to find that relative native cover was lower in Swain than Center Well (Figure 9A) despite the higher prevalence of native bunchgrass in Swain (Table 1). Swain was dominated by exotic red brome whereas Center Well was dominated by native fescue (Table 1). Additionally, native species richness was lower in Swain and showed the same patterns as native cover (Figure 9B; linear mixed effects model; pasture $F_{1,23} = 22.3$, $p < 0.001$, precinct $F_{1,9} = 20.2$, $p = 0.002$, pasture*precinct $F_{1,23} = 3.1$, $p = 0.09$). This was true when calculating richness at the 1-m^2, 400-m^2, and 1.96-ha plot scales.

In contrast to native cover, the distribution of total biomass differed among pastures, as evidenced by a strong interaction between pasture and precinct (Figure 9C, linear mixed effects model; pasture $F_{1,23} = 29.7$, $p < 0.001$, precinct $F_{1,9} = 10.3$, $p = 0.01$, pasture*precinct $F_{1,23} = 25.8$, $p < 0.001$). Biomass did not differ between precinct and non-precinct plots in Center Well, whereas biomass was much higher on precincts in Swain. Indeed, visually it was obvious that precincts in Swain had a thick cover of red brome, whereas the vegetation was clipped very low on Center Well precincts.

Heterogeneity in relative native cover was fairly low among the four nested replicates on and off precincts in each plot, but it was higher on precincts (mean CV off precincts = 30.9%, mean CV on precincts = 64.9%, $t_{98} = -4.4$, $p < 0.001$). Figure 10 illustrates the variability among nested replicates. Variation in biomass among nested replicates showed similar patterns and was higher in general (mean CV off precincts = 58.4%, mean CV on precincts = 83.2%, $t_{98} = -4.1$, $p < 0.001$).

Plant seeds varied in their nutritional value and size (Table 2). Peppergrass (*L. nitidum*), which was commonly seen in GKR pit caches, had the highest amount of protein, while bunchgrass (*P. secunda*) had the highest moisture content, barley (*H. murinum*) had the highest fat content, and fewflowered fescue (*V. microstachys*) had the highest amount of carbohydrates. Red brome had moderate levels of all nutrients and the largest seeds.

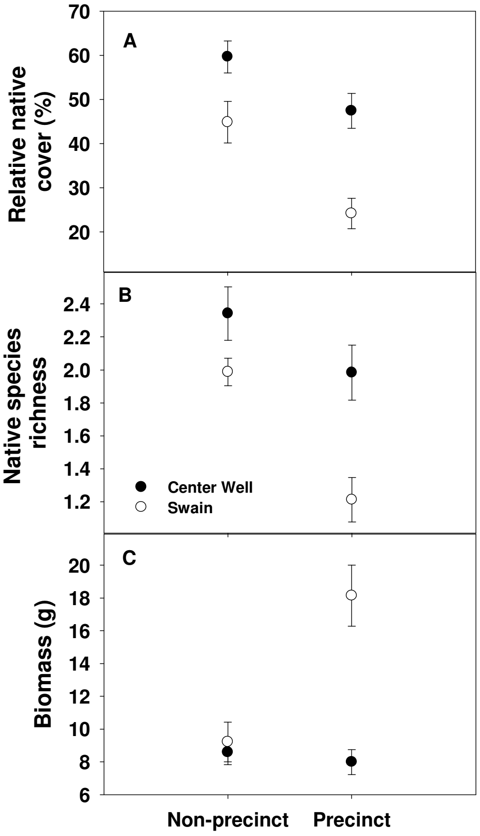


Figure 9. Relative cover of native plants (A) and total biomass from clip plots (B) in relation to the presence of GKR precincts, shown separately for each pasture. Standard error bars are shown.

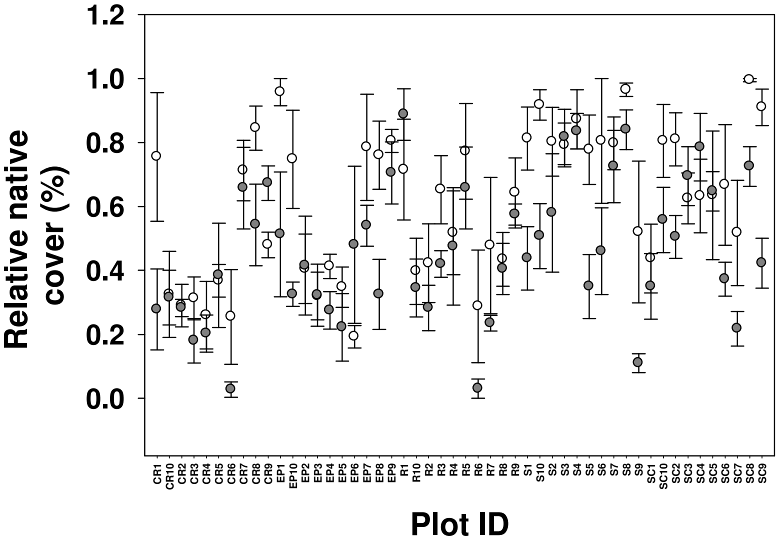


Figure 10. Means and standard errors of native cover estimates for the four 1-m^2 sample plots on precincts (grey circles) and off precincts (open circles) on each 400-m^2 plot (*n* = 50 plots).

Table 1. Relative cover of plant species in each pasture, *n* = 240 plots in Center Well and 160 plots in Swain (half on precincts, half off precincts).

Center Well		
Species	**Type**	**Relative % cover**
Vulpia microstachys	native	35.39
Lepidium nitidum	native	14.01
Vulpia myuros	exotic	12.26
Erodium cicutarium	exotic	10.89
Schismus arabicus	exotic	8.94
Hordeum murinum	exotic	7.00
Microseris elegans	native	3.80
Bromus madritensis rubens	exotic	2.55
Tropidocarpum gracile	native	1.01
Lepidium dictyotum	native	0.79
Pectocarya penicillata	native	0.69
Lasthenia californica	native	0.68
Guillenia lasiophylla	native	0.63
Microseris douglasii	native	0.35
Calandrinia ciliata	native	0.33
Dichelostemma capitatum	native	0.13
Lasthenia minor	native	0.10
Lotus wrangelianus	native	0.09
Bromus hordeaceus	exotic	0.06
Amsinckia tessellata	native	0.06
Amsinckia menziesii	native	0.06
Capsella bursa-pastoris	exotic	0.05
Marrubium vulgare	exotic	0.05
Malacothrix coulteri	native	0.03
Trifolium gracilentum	native	0.03
Poa secunda	native	0.01

Swain		
Species	**Type**	**Relative % cover**
Bromus madritensis rubens	exotic	37.24
Vulpia microstachys	native	22.23
Erodium cicutarium	exotic	17.53
Poa secunda	native	9.11
Schismus arabicus	exotic	6.39
Hordeum murinum	exotic	2.50
Vulpia myuros	exotic	1.32
Lepidium nitidum	native	1.27
Lasthenia californica	native	0.70
Pectocarya penicillata	native	0.57
Amsinckia tessellata	native	0.39
Linanthus liniflorus	native	0.23
Eriogonum gracillimum	native	0.11
Sisymbrium altissimum	exotic	0.09
Chaenactis glabriuscula	native	0.09
Lastarriaea coriacea	native	0.06
Herniaria hirsuta	exotic	0.05
Chorizanthe watsonii	native	0.05
Astragalus oxyphysus	native	0.03
Hollisteria lanata	native	0.02
Trifolium gracilentum	native	0.02
Tropidocarpum gracile	native	0.02

Table 2. Nutritional values of seed heads from 10 plant species in the Carrizo. Values are percentages. Seed sizes are from Schiffman (1994).

Species	Moisture	Crude Protein	Crude Fat	Total Carb	Seed length (mm)
Amsinckia tessellata	7.9	15.8	3.0	64.1	3.3
Astragalus lentiginosus	7.6	14.2	1.3	68.3	3.0
Bromus madritensis rubens	10.0	11.0	1.7	70.1	8.5
Erodium cicutarium	10.2	16.1	2.2	62.5	5.5
Hordeum murinum	9.0	16.6	4.7	61.0	6.0
Lasthenia californica	9.8	10.3	3.8	67.9	2.3
Lepidium nitidum	10.0	21.9	2.2	61.2	3.3
Poa secunda	15.8	12.9	2.9	66.8	2.0
Vulpia microstachys	8.2	7.8	1.2	75.4	4.0
Vulpia myuros	7.7	10.8	1.1	75.1	4.0

GKR abundance

A total of 651 GKR were captured and marked, and a total of 1328 captures occurred. The GKR was the only species captured during surveys. Mark-recapture estimates of GKR abundance varied widely among sites, from 3-78 GKR per plot (Figure 11). GKR estimates often differed substantially between paired cattle exclosure and control plots in Center Well (CW), thus highlighting the importance of establishing baseline conditions on the sites. Paired t-tests indicated that GKR abundance was not consistently higher in controls or exclosures ($t_9 = -1.1$, $p = 0.87$). Indeed, mean abundance estimates in CW controls and exclosures were quite similar, and higher than mean abundance in Swain (CW exclosure $\bar{x} = 38.9$ GKR/plot, CW control $\bar{x} = 40.0$, Swain $\bar{x} = 12.9$; ANOVA $F_{2,27} = 6.93$, $p = 0.004$, Tukey tests show Center Well sites differ significantly from Swain). These estimates do not include the 20 GKR that were removed from GKR exclosures. Maximum movement distances between captures was low; 52% of the 322 individuals with >1 capture were only captured at one trap location, and the average maximum movement distance between captures was 10.1 m. GKR moved approximately twice as far in Swain as in Center Well (Figure 12).

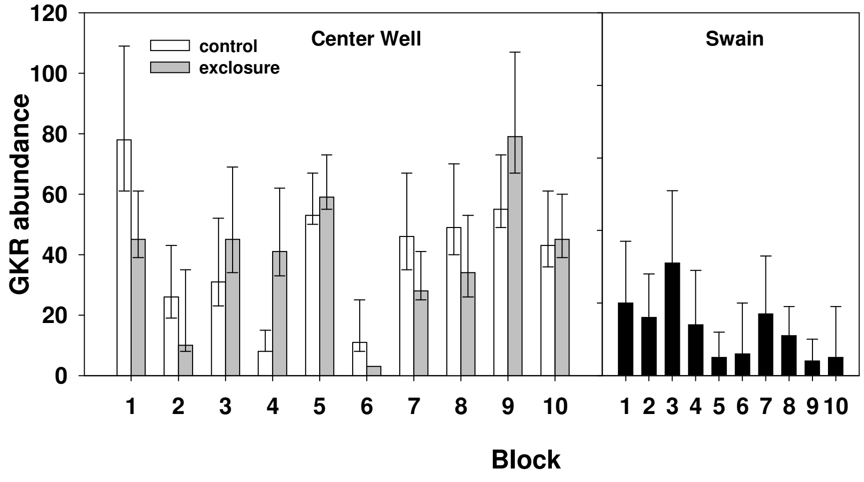


Figure 11. Mark-recapture estimates of giant kangaroo rat abundance on each 1.96-ha plot. Analyses were conducted using program CAPTURE. Standard error bars are shown.

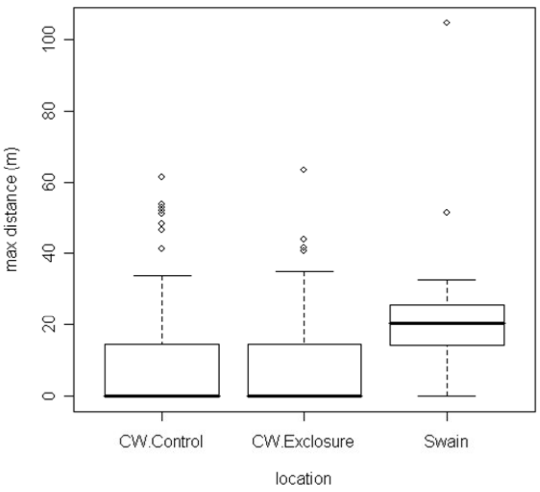


Figure 12. Boxplot of maximum movement distances for GKR individuals captured more than once (n = 322).

SJAS abundance

A total of 54 SJAS were captured and marked, and a total of 268 captures occurred. Capture rates were too low to conduct separate mark-recapture analyses on each plot; only 1.6 squirrels were captured per plot on average (Figure 13). Marginally more squirrels were caught per plot in Center Well than in Swain (t_{28} = 1.9, p = 0.06). Maximum movement distances for individual SJAS caught more than once (n = 40) averaged 71.1 m (range = 21-160 m).

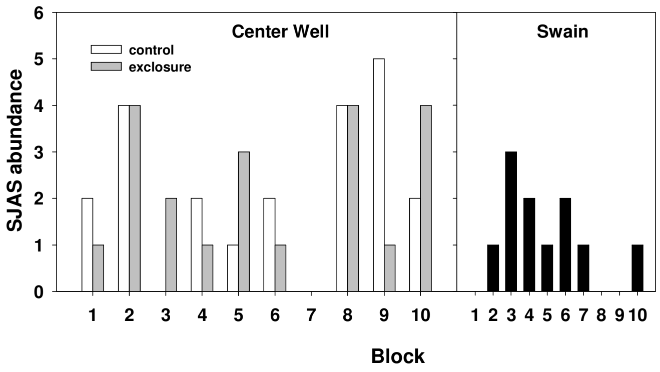


Figure 13. Number of San Joaquin antelope squirrels captured on 1.96-ha plots in each pasture.

Bird abundance

A total of 2450 individuals from 17 bird species were detected during point counts. Horned larks (*Eremophila alpestris*) were the dominant species, accounting for 78% of all observations. These totals include birds detected off our plots; only three bird species were observed on or flying over our plots, 95% of which were horned larks (western meadowlarks (*Sturnella neglecta*) and Brewer's blackbirds (*Euphagus cyanocephalus*) accounted for the other 5%). Detections were too sparse to allow for density estimates using the concentric rings. Thus, it appears unnecessary to delineate rings for point counts in future years, and the utility of point counts may be limited to providing an annual index of horned lark abundance. However, within-site variability was high (Figure 14) because horned larks were in large flocks and did not appear to form breeding pairs this year. We saw no evidence of breeding behavior.

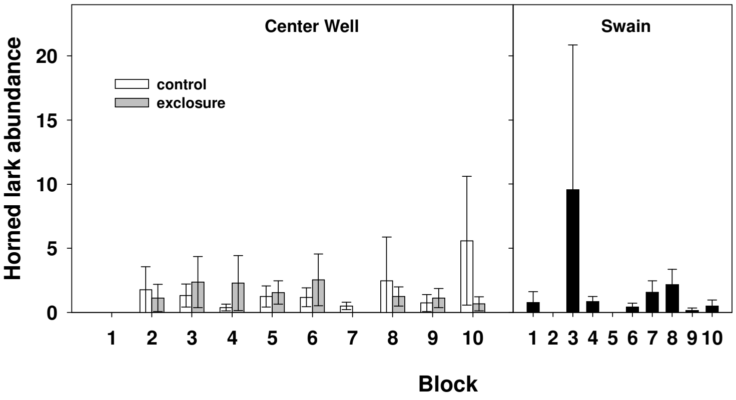


Figure 14. Mean number of horned larks seen during 10 minute point counts at each site ($n = 4$ counts per site). Standard error bars are shown.

Reptile abundance

A total of 419 side-blotched lizards (*Uta stansburiana*), 4 BNLL (*Gambelia sila*), 1 coast-horned lizard (*Phrynosoma coronatum*), and 1 gopher snake (*Pituophis catenifer*) were seen during reptile surveys. All BNLL and horned lizard sightings (including several seen off plots) were geo-referenced. Side-blotched lizards were the only reptiles seen during surveys in the Center Well pasture. *Uta* hatchlings first appeared in surveys on June 18th. All BNLL seen were adults. Density estimates will be calculated using distance estimators. A preliminary look at the data indicates that three replicates per site were sufficient to obtain reasonably precise estimates (Figure 15). As with GKR, lizard abundance was generally higher in Center Well than in Swain ($t_{28} = 3.1$, $p = 0.005$).

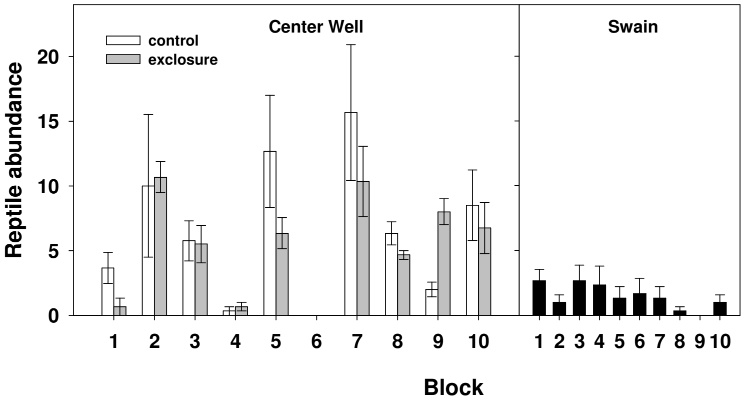


Figure 15. Mean counts of reptiles seen during transect surveys in each plot. Three surveys were conducted per plot. Standard error bars are shown.

Invertebrate abundance

Grasshopper abundance was high and generally less variable among plots than vertebrate abundance, and there was no difference in average grasshopper counts among plots in Center Well versus Swain (Figure 16, $t_{28} = -1.1$, $p = 0.30$). Invertebrate data from pitfall traps has been recorded and is currently being entered and analyzed. The invertebrate community appeared to be abundant and diverse; it was not uncommon to find more than 20 species of invertebrates in a single sample. Samples were processed such that diversity, abundance, richness, and biomass can be calculated for each sample ($n = 360$). Additionally, these metrics can be calculated at larger scales (plot, pasture, etc.) for beetles, ants, and orthopterans.

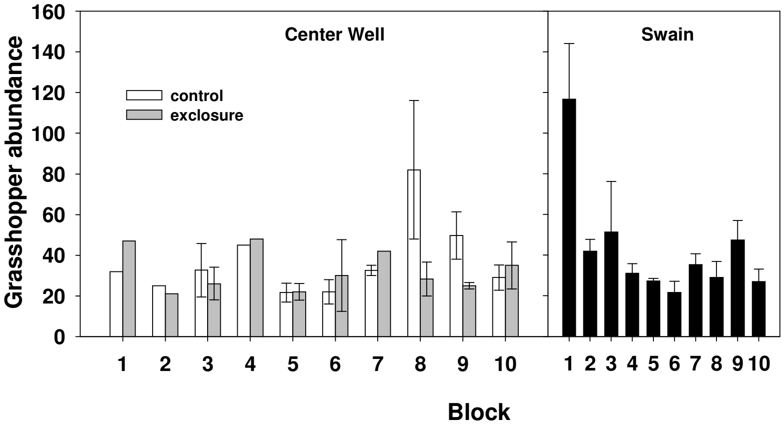


Figure 16. Mean counts of grasshoppers seen during reptile surveys on each plot. Grasshoppers counts were added to the survey protocol so some plots had fewer than three replicates. Standard error bars are shown; CW sites 1, 2, and 4 only had one count per plot.

Species associations

We predicted that reptile abundance would be positively correlated with grasshopper abundance and that GKR abundance would be positively correlated with precinct counts. However, reptiles were positively correlated with precinct counts (and with GKR counts), while GKR showed only a weak correlation with precinct counts (Table 3). SJAS were also positively correlated with precinct counts. Our counts may better reflect burrow density than individual precincts because identifying precinct boundaries was difficult due to drought conditions. Next year we plan to conduct the counts earlier in the season when they are easiest to identify and to repeat counts on each plot to assess their reliability.

All species except grasshoppers had negative correlations with plant biomass (Table 3). This data supports the hypothesis that native species in this system prefer open habitat conditions. However, it is also possible that the species themselves cause the open habitat conditions via foraging activities. They may be less abundant in certain areas for reasons other than vegetative cover (e.g., higher predator densities or different soil conditions), and their absence allows vegetation to accumulate. Monitoring sites over time should help to distinguish among these hypotheses. If thick vegetative conditions cause low numbers of native species, we expect that declines should be observed following years of high plant cover (after heavy rainfall years, for example). Conversely, if low animal numbers cause high vegetation, then we expect vegetative growth to increase following years with low animal counts. Spotlight surveys conducted by CDF&G for the past 35 years show that GKR numbers are not correlated with rainfall (L. Prugh unpublished analyses), so we should be able to untangle the interrelationship between rainfall, plant biomass, and native species abundance by monitoring plots over time.

Table 3. Matrix of correlation coefficients (*r*) among species counts on each of the 30 plots. Significant correlations ($p < 0.05$) are highlighted in bold, and correlations with a *p*-value of 0.06 are italicized.

	SJAS	GKR	Precincts	Reptiles	Grass-hoppers	Horned larks	Native plant cover (%)
GKR	0.25						
Precincts	**0.43**	*0.35*					
Reptiles	0.13	**0.46**	**0.56**				
Grasshoppers	0.02	0.01	0.15	-0.19			
Horned larks	0.22	0.08	0.31	0.03	0.06		
Native plant cover (%)	0.15	-0.10	-0.24	0.11	-0.18	-0.01	
Plant biomass	-0.28	*-0.34*	-0.15	**-0.43**	0.15	-0.19	**-0.42**

Role of baseline surveys and future directions

The baseline surveys funded by TNC provided data critical to the success of the long term study because we needed to know the pre-existing conditions on each plot in order to accurately detect treatment effects. Additionally, the surveys have allowed us to determine the level of variability within and among our replicates, optimize protocols, prioritize surveys, and better estimate the amount of funding and personnel needed to monitor sites in future years. For example, we had planned to have two sessions of pitfall trapping because the insect community changes dramatically from spring to summer, but we found that processing just one session took our large crew a good portion of the summer. We learned that continuing the surveys will require more personnel than we originally thought because of the time it takes to repeatedly survey all 30 1.96-ha plots. The baseline vegetation surveys provided particularly useful information, notably that the Swain pasture is not a pristine “native-dominated” area as we originally thought. However, the plant communities in Swain and Center Well are divergent enough that it will be useful to compare the effects of excluding GKR in these pastures.

Rainfall will certainly play an important role in the dynamics of this system. Unfortunately it is not feasible to add precipitation as an experimental treatment, but over time we can include rainfall as a time-dependent variable in our models. We hope to identify threshold levels of precipitation and GKR densities that alter system dynamics (e.g., grazing may benefit native species when the ratio of precipitation-to-GKR falls below a certain level).

Next year we plan to continue basic monitoring of plant and animal communities on our plots. Additionally, we would like to add a spring trapping session for GKR to allow calculation of demographic rates such as reproductive rates and overwinter survival. We would also like to radio-collar adult and juvenile GKR this spring to determine rates and causes of mortality as well as juvenile dispersal distances.

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