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RESPONSES OF SMALL MAMMALS AND VEGETATION TO A REINTRODUCTION OF GUNNISON'S PRAIRIE DOGS

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This study addressed the initial effects of a reintroduction of Gunnison's prairie dogs (*Cynomys gunnisoni*) on resident small mammal and plant communities on the Sevilleta National Wildlife Refuge (SNWR), New Mexico. In spring 1997, 60 prairie dogs (36.8 kg live mass) were introduced onto a former prairie dog colony in a desert grassland site. Small mammals and vegetation were sampled on both a treatment (reintroduction site) and a control site (without prairie dogs) before and after the prairie dogs were reintroduced. We tested for differences in small mammal and plant community change during the 1st year of the colony's existence using repeated measures analysis of variance. Although prairie dog biomass was ca. 32 times greater than that of the resident rodent community (1.2 kg), reintroduction of prairie dogs had no significant effect on the resident small mammal and plant communities. Total biomass and abundance of rodents, and percent cover and species richness of plants did not change during the 1st year following reintroduction of prairie dogs. However, two rodent species showed significant differences in abundance between the prairie dog colony and the control site. The banner-tailed kangaroo rat (*Dipodomys spectabilis*) was significantly more abundant on the treatment site before and after reintroduction of prairie dogs. In contrast, the white-footed mouse (*Peromyscus leucopus*) was significantly more abundant on the control site following reintroduction of prairie dogs. Habitat modifications made by the former prairie dog colony may be responsible for the habitat preferences observed by *D. spectabilis* and *P. leucopus*. Although reintroduction of prairie dogs had no observable influence on the resident small mammal and plant communities in the short-term, their influences may be more evident on a long-term time scale.

Key words: prairie dogs, *Cynomys gunnisoni*, reintroduction, conservation, desert grassland, rodents, vegetation

Prairie dogs (*Cynomys*) are major components of grassland-herbivore communities in the western United States. Prior to the early 1900s, prairie dogs were among the most numerous and widespread herbivores in this ecosystem, with colonies extending across North America from the Rocky Mountain foothills to the central Great Plains and from southern Canada to northern Mexico (Hall, 1981). Seton (1929) estimated that their total numbers exceeded five billion individuals. Since the late 19th century, populations of prairie dogs have declined 98% (United States Department of Interior, 1963), largely as a result of habitat loss, introduction of bubonic plague, unregulated shooting, and targeted mass exter-

mination programs designed to reduce their purported competition with livestock (Wuerthner, 1997). These latter extermination efforts proceeded with little knowledge of the effects of prairie dogs on the grassland ecosystem.

We now know that prairie dogs play significant roles in grassland ecosystems. For example, acting as ecosystem regulators (Agnew et al., 1986; Hansen and Gold, 1977; King, 1955; Whicker and Detling, 1988), black-tailed prairie dogs substantially influence soils, vegetation, and animal species in the grasslands of the western and central Great Plains. Vegetation on colonies receives frequent and intense defoliation by prairie dogs during feeding activities; the

subsequent reduction of taller vegetation may facilitate predator detection (King, 1955). The soil also is regularly disturbed during burrow construction and maintenance. Prairie dog's interactions with vegetation and soil can influence nutrient cycling (Whicker and Detling, 1988), nutritional quality of vegetation (Coppock et al., 1983; Krueger, 1986), and species diversity of plants (Agnew et al., 1986; Bonham and Lerwick, 1976; Gold, 1976; King, 1955; Koford, 1958; Slobodchikoff et al., 1988). These changes often attract large ungulates (e.g., antelope (*Antilocapra americana*), bison (*Bison bison*), and livestock) to the colonies (Coppock et al., 1983; Krueger, 1986). By creating a heterogeneous landscape of patchy vegetation and burrows, prairie dogs create habitat for many animals (King, 1955). As a result, abundance of rodents (Agnew et al., 1986; O'Meilie et al., 1982) and density and diversity of birds (Agnew et al., 1986) are greater on colony sites than on non-colony sites. Prairie dog colonies also are habitats for a number of other prey species, attracting carnivorous mammals and raptors (Agnew et al., 1986; Clark et al., 1982). Reading et al. (1989) estimated that 163 animal species are associated with the prairie dog colony to some degree.

Eradication of prairie dogs has caused significant biological degradation and decline in biological diversity on grasslands in North America (Wuerthner, 1997). Removal of prairie dogs has influenced successional stages, plant species interactions, and vegetation patterns. Weltzin et al. (1997) found that prairie dogs inhibit woody plants from invading grasslands, and suggested that the extirpation of these rodents has played a significant role in woody plant encroachment in grasslands. Removal of this species also causes a ripple effect of secondary extinctions, altering the entire food web associated with prairie dogs (Miller et al., 1994; Sharps and Uresk, 1990). For example, the black-footed ferret (*Mustela nigripes*), swift fox (*Vulpes velox*), bur-

rowing owl (*Athene cunicularia*), mountain plover (*Charadrius montanus*), and ferruginous hawk (*Buteo ragelis*) are among the most rare prairie dog-dependent species (Knowles and Knowles, 1994; Miller et al., 1994). As a result, current research on the prairie dog's interactions in grassland ecosystems (Knowles and Knowles, 1994; Miller et al., 1994) has now identified these rodents as a "keystone species," defined as species that dramatically alter structure and functioning of ecological systems (sensu Paine, 1969).

Despite the large number of studies reporting on the ecological role of black-tailed prairie dogs in grasslands, Stapp (1998) suggested that effects of prairie dogs are still poorly understood and caution is required when applying "keystone" status to prairie dogs. In addition, although prairie dogs have been termed a keystone species of grassland ecosystems (Miller, 1994), this status is based on studies of black-tailed prairie dogs. Few quantitative experimental studies have been conducted to test the effects of other prairie dog species in grassland ecosystems (Slobodchikoff et al., 1988). Therefore, it is unknown if these species have the same impacts on grassland ecosystems as black-tailed prairie dogs.

It has been suggested that Gunnison's prairie dogs do not have the same impact on the vegetation and animal communities as do black-tailed prairie dogs. For example, Slobodchikoff et al. (1988) found that, although effects of Gunnison's prairie dogs were similar to black-tailed prairie dogs in that they decreased plant cover, their effects were different in that they decreased rather than increased species diversity. Observations noted by Tileston and Lechleitner (1966) and Hoogland (1981) suggest that colonies of white-tailed prairie dogs (*C. leucurus*) are characterized by taller vegetation, and that white-tailed prairie dogs do not actively remove or shorten vegetation.

Despite uncertainty on the ecological effects of black-tailed prairie dogs on grassland ecosystems or how their effects vary

in different grassland types (Stapp, 1998), and if other species of prairie dogs play keystone roles, there is no debate that prairie dogs play an important ecological role in grassland ecosystems. The emerging recognition of the importance of prairie dogs has resulted in a growing interest in restoring populations of prairie dogs (Robinette et al., 1995). Many published studies have compared existing colonies of black-tailed prairie dogs to non-colony sites. These studies provide predictive value for hypothesizing several possible outcomes of the influence of prairie dog reintroduction on resident small mammal and plant communities. For example, Agnew et al. (1986) and O'Meilia et al. (1982) found greater abundances of small mammals on prairie dog colonies, but fewer species when compared with adjacent grasslands. Many studies also have found significant differences in vegetation characteristics on prairie dog colonies when compared with uncolonized sites. Colony sites demonstrated lower above-ground plant biomass, cover, and height (Agnew et al., 1986; Archer et al., 1987) and greater forb-to-graminoid ratio (Bonham and Lerwick, 1976; Koford, 1958) and plant species diversity (Agnew et al., 1986; Bonham and Lerwick, 1976; Gold, 1976; King, 1955; Koford, 1958). Based on the results of these studies, we would predict that if Gunnison's prairie dogs behave similarly to black-tailed prairie dogs, their reestablishment would have similar influences on a site's resident small mammal and plant communities.

Our purpose was to assess initial impacts of a reintroduction of prairie dogs on the resident small mammal and plant communities in a desert grassland ecosystem in central New Mexico. We tested null hypotheses that prairie dogs would have no effect on abundance and total biomass of small mammals, or plant composition and percent cover during the 1st year following reintroduction of prairie dogs.

MATERIALS AND METHODS

Study site.—Our study was conducted at the Sevilleta National Wildlife Refuge (SNWR) in central New Mexico (34°12'56"N, 106°47'3"W, elevation = 1,536 m). The site was located in a broad swale, ca. 600 m wide with a 1% slope and a westerly aspect, bounded on the north and south by low hills. The soil was classified as Bucklebar Series, which was a fine-loamy, mixed, thermic Typic Haplargid (Soil Conservation Service, 1988). Annual precipitation averaged 270 mm (53% of which occurred during summer monsoons in July, August, and September), with mean monthly temperatures for January and July of 1.5°C and 25.1°C, respectively (climate data from the Sevilleta Long-Term Ecological Research Program's South Gate Meteorological Station, located adjacent to the site, 1989–1997). Vegetation on the site was characteristic of a Chihuahuan Desert grassland; dominant species of grasses included burrograss (*Scleropogon brevifolius*), galleta grass (*Hilaria jamesii*), and alkali sacaton (*Sporobolus airoides*). Dominant species of small mammals included Ord's kangaroo rat (*Dipodomys ordii*), banner-tailed kangaroo rat (*D. spectabilis*), silky pocket mouse (*Perognathus flavus*), southern grasshopper mouse (*Onychomys arenicola*), northern grasshopper mouse (*O. leucogaster*), white-footed mouse (*Peromyscus leucopus*), western harvest mouse (*Reithrodontomys megalotis*), and plains harvest mouse (*R. montanus*).

Experimental design.—The overall experimental design involved relocating a population of Gunnison's prairie dogs (*C. gunnisoni*) onto a former Gunnison's prairie dog colony site on the SNWR. The former colony occupied the site for >25 years and became locally extinct in 1991–1992 for unknown reasons. Small mammals and plants were sampled on a treatment site (prairie dog reintroduction site) and a control site (without prairie dogs; Fig. 1). Repeated measures analysis of variance was used to test null hypotheses that populations of rodents and vegetation variables on the prairie dog site did not differ from the control site following reintroduction of prairie dogs. Because our study dealt with a single population of prairie dogs, statistical inferences of results were limited to our study site.

Colony reestablishment.—Prairie dogs were collected from large vacant lots in Albuquerque, New Mexico, in late March through mid-April

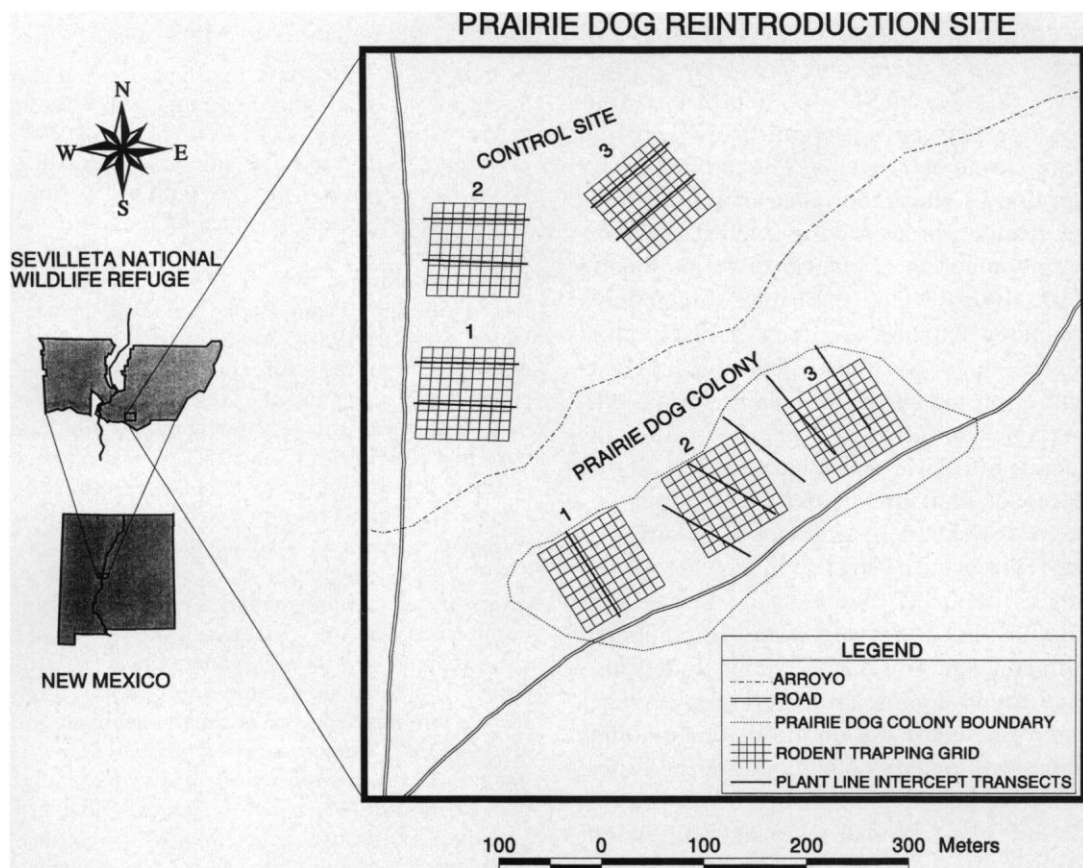


FIG. 1.—Reintroduction site of Gunnison's prairie dog at the Sevilleta National Wildlife Refuge, New Mexico.

1997. Prairie dogs were trapped using Tomahawk[®] live traps (Tomahawk Live Trap Company, Tomahawk, WI) baited with carrots. Traps were set up near active mounds that were flagged and numbered. Mound numbers were mapped to identify spatial relationships among animals that were trapped. Weight, physical characteristics, sex, and reproductive condition were recorded for all captured prairie dogs.

Prairie dogs were transported to the relocation site at SNWR in an enclosed truck and released on the same day of capture into the existing burrows of the former colony. To make the relocation more successful, prairie dogs were released into burrows with family members or near neighbors to help maintain the original social structure from which they were caught.

Following release, mound locations were mapped with Global Positioning System (GPS) units to show the spatial distribution of individ-

uals. Each mound was assigned a mound number and was noted for its level of activity based on presence of fecal pellets and disturbed soil. Monitoring of the prairie dog colony during summer and autumn 1997 allowed us to assess numbers and dispersal of individuals and determine the spatial extent of the prairie dog town (Fig. 1).

Small-mammal sampling.—To test the null hypothesis that reintroduction of prairie dogs had no direct effect on abundance and biomass of other rodent species, rodent trapping grids were established, three on the control and three on the treatment (Fig. 1). Each grid was 90 m by 90 m and separated from one another by 50 m. Each grid was sampled with 100 Sherman live traps placed in a 10 m by 10 m matrix with a 10-m trap interval. Trap locations were marked permanently with labeled stakes. Small mammals were trapped in March 1997 (before prairie

dogs were reintroduced) and in May, July, and September 1997 (after reintroduction).

Rodents were sampled using mark-and-recapture methods. Each trapping session lasted for 3 consecutive nights and consisted of baiting traps in the early evening and checking them early the next morning. Animals caught in traps were identified to species and examined for previous capture and individual identification marks, sex, age, mass, and reproductive status. *Perognathus flavus* were marked by toe clipping; other species were marked with numbered ear tags. All animals caught were processed quickly and immediately released at the trap location of their capture. Safety precautions for prevention of transmission of zoonotic disease followed procedures of Mills et al. (1995).

Vegetation sampling.—To test the null hypothesis that prairie dogs had no effect on the vegetation in the 1st year after being established, 12 100-m permanent line-intercept transects were established: six on the control and six on the treatment (Fig. 1). Coverage of plant species, litter, and bare ground was sampled along the line-intercept transects by identifying species or substrate intercepting the line at 1-cm resolution. As a part of another study, transects located on the treatment were sampled in late June 1996 before summer monsoons and in late July 1996 after summer monsoons initiated growth of plants. For this study, control and treatment transects were sampled in mid-June 1997, shortly after prairie dogs were reintroduced and in mid-October 1997.

Statistical analysis.—Based on mark-recapture data of rodents, species-specific population sizes were estimated for each grid. Population sizes of rodent species caught at low abundances were based on the actual number of individuals caught on each grid during a given trapping period. For *P. flavus*, which occurred in greater numbers than other species, we used program CAPTURE to estimate population sizes (White et al., 1982). Program CAPTURE used a variety of estimators, each of which was based on different assumptions of capture probabilities (White et al., 1982). Program CAPTURE used a model selection routine to pick the most appropriate model for each dataset and computed the estimate of population size. Models used in that analysis included: M_0 (null model), M_h (heterogeneity model), M_t (time model), M_b (behavior model), M_{bh} (behavior-heterogeneity), M_{tb}

(time-behavior), and M_{th} (time-heterogeneity). After each rodent population estimate was computed, repeated measures ANOVA was used to test for changes in abundances through time between treatment and control grids for each species of rodents. As a cautionary check for a potentially non-normal distribution of data, rodent abundance data were transformed using a square-root transformation and were then analyzed with a repeated measures ANOVA. However, both analyses produced similar results; hence, the results of the untransformed data were reported. Repeated measures ANOVA also was used to test for changes in total biomass of rodents through time between treatment and control grids.

For vegetation data, repeated measures ANOVA was used to compare species richness of plants, and mean percent cover of vegetation, litter, and bare soil through time between treatment and control transects. We used data from June 1997 to represent the initial vegetation community because prairie dogs would have had little influence on the vegetation by that date. Using repeated measures ANOVA, data from June 1997 were compared with data from October 1997 which represented the vegetation community following the 1st year of occupation by prairie dogs. Data from 1996 provided baseline information on the structure and composition of the vegetation community on the treatment before reintroduction, but was not used in the repeated measures ANOVA.

RESULTS

Prairie-dog reestablishment.—Sixty prairie dogs were reintroduced onto the SNWR, resulting in an input of 37.8 kg of live rodent mass onto the site. Sixty individuals was the recommended minimum number of black-tailed prairie dogs that should be released onto a site to establish a successful prairie dog colony (Robinette et al., 1995). The area occupied by the reintroduced prairie dogs was ca. 3.5 ha, yielding a density of prairie dogs of 17 individuals/ha. "Natural" densities of Gunnison's prairie dog have been documented to range from 8–12 individuals/ha (Fitzgerald and Lechleitner, 1974; Longhurst, 1944). All reintroduced prairie dogs were adults, with a sex ratio of 1:1.

TABLE 1.—Rodent species captured and summary of numbers of total captures and individuals caught during the prairie dog reintroduction study on the Sevilleta National Wildlife Refuge, New Mexico.

Species	Total no. captures		Total no. individuals	
	Control	Treatment	Control	Treatment
Heteromyidae				
<i>Dipodomys ordii</i>	10	28	9	14
<i>Dipodomys spectabilis</i>	2	30	2	12
<i>Perognathus flavus</i>	249	236	190	135
Muridae				
<i>Onychomys arenicola</i>	4	8	3	7
<i>Onychomys leucogaster</i>	1	6	1	3
<i>Neotoma albigula</i>		2		1
<i>Neotoma micropus</i>	1		1	
<i>Peromyscus leucopus</i>	23	8	15	4
<i>Peromyscus truei</i>	3		2	
<i>Reithrodontomys megalotis</i>	10	8	8	6
<i>Reithrodontomys montanus</i>	4	4	2	2
Total	307	330	233	184

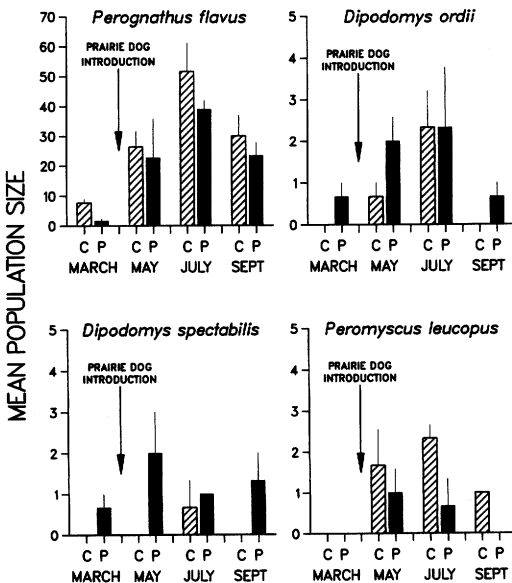


FIG. 2.—Mean (\pm SE) population size of *Perognathus flavus*, *Dipodomys ordii*, *Dipodomys spectabilis*, *Peromyscus leucopus* on control plot C—without prairie dogs) and treatment plot (P—with prairie dogs) before and after reintroduction of prairie dogs on the Sevilleta National Wildlife Refuge, New Mexico.

Following reintroduction, observations and subsequent trapping indicated that no young were born during the 1st year (1997) and there were ≥ 36 (60%) known survivors at the end of the 1st summer (density ca. 10 individuals/ha). Relocations occurred during the time when prairie dogs would have been copulating; disturbance from trapping was probably the main reason for no reproduction in 1997.

Rodent response.—Eleven species of rodents were captured in 7,200 trap nights (Table 1). The murid rodents were the most species rich, while the heteromyid rodents were numerically dominant. Murids were nocturnal and predominantly insectivorous or omnivorous, and heteromyids were nocturnal and predominantly granivorous. No herbivorous, diurnal rodents (other than prairie dogs) were observed or captured on the site.

No significant differences occurred between the treatment and control sites for most of the species of small mammals. Results indicated that abundances of *D. ordii*, *P. flavus*, *O. arenicola*, *P. leucopus*, *R. megalotis*, and *R. montanus* peaked in mid-summer and declined in autumn (Fig. 2, Ta-

TABLE 2.—Summary of repeated measures analysis of variance for rodent populations during the prairie dog reintroduction study on the Sevilleta National Wildlife Refuge, New Mexico.

Species	Source	d.f.	F	P > F
Heteromyidae				
<i>Dipodomys ordii</i>	Treatment	1	2.290	0.2051
	Error	4		
	Time	3	3.960	0.0356
	Time × Treatment	3	0.320	0.8108
	Error	12		
<i>Dipodomys spectabilis</i>	Treatment	1	10.56	0.0314
	Error	4		
	Time	3	0.620	0.6124
	Time × Treatment	3	1.050	0.4047
	Error	12		
<i>Perognathus flavus</i>	Treatment	1	1.580	0.2273
	Error	4		
	Time	3	13.87	0.0003
	Time × Treatment	3	0.180	0.9050
	Error	12		
Muridae				
<i>Onychomys arenicola</i>	Treatment	1	4.000	0.1161
	Error	4		
	Time	3	8.600	0.0026
	Time × Treatment	3	2.400	0.1187
	Error	12		
<i>Onychomys leucogaster</i>	Treatment	1	1.120	0.3486
	Error	4		
	Time	3	0.690	0.5768
	Time × Treatment	3	1.690	0.2224
	Error	12		
<i>Peromyscus leucopus</i>	Treatment	1	10.00	0.0341
	Error	4		
	Time	3	4.320	0.0277
	Time × Treatment	3	1.040	0.4100
	Error	12		
<i>Reithrodontomys megalotis</i>	Treatment	1	0.060	0.8149
	Error	4		
	Time	3	5.230	0.0154
	Time × Treatment	3	0.400	0.7584
	Error	12		
<i>Reithrodontomys montanus</i>	Treatment	1	0.250	0.6433
	Error	4		
	Time	3	6.250	0.0084
	Time × Treatment	3	0.250	0.8598
	Error	12		

ble 2). Two of the rodent species (*D. spectabilis* and *P. leucopus*) showed a significant treatment effect, but no significant time by treatment interaction occurred (Table 2).

D. spectabilis was found in greater abundance on the prairie dog colony than on the control site before and after reintroduction (Fig. 2). In contrast, *P. leucopus* was found

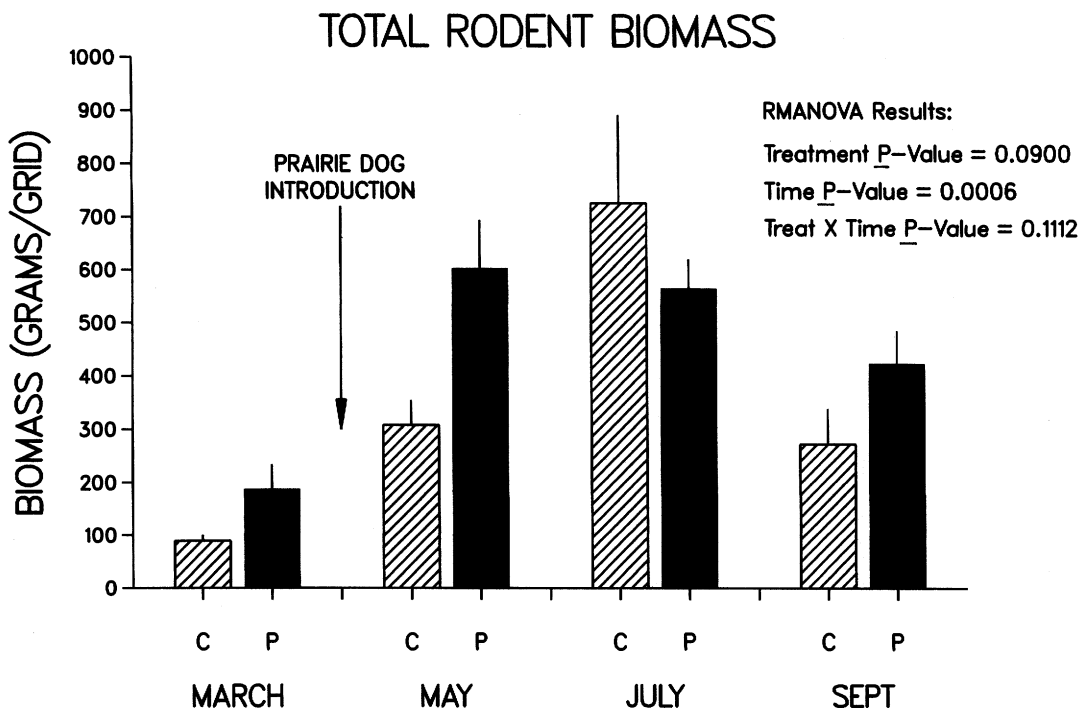


FIG. 3.—Mean (\pm SE) total rodent biomass on control plot (C—without prairie dogs) and treatment plot (P—with prairie dogs) before and after prairie dog reintroduction on the Sevilleta National Wildlife Refuge, New Mexico. Repeated measures ANOVA indicated no significant treatment effect but a significant change through time.

in greater abundance on the control site compared with the treatment site (Fig. 2), although no *P. leucopus* were captured on either the control site or treatment site before reintroduction. As a result, for both of those species, we could not attribute the observed differences to the reintroduction; rather, it appeared that the former prairie dog colony may have modified the local habitat, making it more favorable for *D. spectabilis* and less so for *P. leucopus*. In addition, a more conservative statistical analysis could use a protected P -value of 0.00625 ($P = 0.05$ divided by eight repeated measures ANOVA for all species combined). If we adopted that perspective, the significance of the treatment analysis reported in Table 2 disappeared. In summary, we could not demonstrate that species composition and abundances of rodents were affected by reintroduction of prairie dogs.

There was no significant change in total

biomass of rodents as a result of reintroduction of prairie dogs (Fig. 3). Mean biomasses of rodents on control plots ranged from 89 g/grid in March to a maximum of 726 g/grid in July. Biomasses on treatment plots ranged from 188 g/grid in March to a maximum of 603 g/grid in May. *Dipodomys spectabilis* and *P. flavus* comprised the majority of the biomass on each plot. Total biomass of rodent species on the treatment site before reintroduction of prairie dogs was 1,160 g and increased to 3,488 g by July following reintroduction of prairie dogs. However, no significant treatment effects on biomass of rodents occurred between the control and treatment sites. Although biomass did change significantly through time ($d.f. = 3$, $F = 12.25$, $P < 0.0006$), the time by treatment interaction was not significant. Therefore, reintroduction of prairie dogs had no effect on total biomass of rodents.

TABLE 3.—Species richness and mean percentage cover (\pm SE) of vegetation, litter, and bare ground on control plot (without prairie dogs) and treatment plot (with prairie dogs) following reintroduction of prairie dogs on the Sevilleta National Wildlife Refuge, New Mexico.

Variable	Spring 1996 treatment	Summer 1996 treatment	Spring 1997 control	Spring 1997 treatment	Summer 1997 control	Summer 1997 treatment
Species richness						
Total no. species			22	22	33	34
Mean no. species per transect			11 \pm 1	9 \pm 1	19 \pm 1	16 \pm 1
Percent cover of grasses						
<i>Bouteloua gracilis</i>				T ^a		1 \pm 1
<i>Hilaria jamesii</i>	12 \pm 2	12 \pm 2	20 \pm 3	14 \pm 1	30 \pm 4	29 \pm 2
<i>Muhlenbergia arenacea</i>	2 \pm 1	T			T	2 \pm 1
<i>Scleropogon brevifolius</i>	7 \pm 1	9 \pm 9	2 \pm 1	9 \pm 0.7	2 \pm 1	12 \pm 2
<i>Sporobolus airoides</i>	T	2 \pm 2	T	T	T	T
Other species		1 \pm 0.2	T	T	3 \pm 2	2 \pm 1
Total grasses	21 \pm 4	23 \pm 13	22 \pm 4	25 \pm 3	36 \pm 7	47 \pm 8
Percent cover of forbs						
<i>Caesalpinia drepanocarpa</i>		6 \pm 2	1 \pm 1	2 \pm 1	2 \pm 1	6 \pm 1
<i>Chamaesyce micromera</i>					3 \pm 3	T
Euphorbiaceae species		5 \pm 2	2 \pm 1		T	
<i>Kallstroemia parviflora</i>					6 \pm 5	T
<i>Portulaca oleracea</i>		T			1 \pm 1	T
<i>Salsola kali</i>		T	1 \pm 1	T	9 \pm 2	1 \pm 1
Other species	5 \pm 2	2 \pm 1	2 \pm 1	T	3 \pm 2	2 \pm 1
Total forbs	5 \pm 2	13 \pm 6	7 \pm 3	2 \pm 1	24 \pm 13	10 \pm 3
Total plant percent cover ^b	26 \pm 5	36 \pm 19	29 \pm 7	27 \pm 3	60 \pm 18	58 \pm 12
Total litter percent cover	19 \pm 2	12 \pm 2	18 \pm 3	20 \pm 2	13 \pm 1	15 \pm 2
Bare soil, gravel, rock	55 \pm 3	51 \pm 3	63 \pm 12	54 \pm 5	41 \pm 5	38 \pm 2

^a T = trace, <1% cover.

^b Total plant cover includes shrubs.

Vegetation response.—Species composition of plants was similar on the control and treatment sites (Table 3). Grasses dominated both sites, and forbs comprised a relatively small percentage of the plant cover. A general trend of greater grass cover on the prairie dog colony than on the control site was observed, and forbs had a greater percent cover on the control site than on the colony (Table 3). The overall grass and forb cover increased through the growing season (following summer monsoons), but relative proportions of grass and forb cover between the control and treatment sites remained constant through time (Table 3).

There were significant differences in percent cover between the control and treatment for two plant species. A protected *P*-

value of 0.0045 ($P < 0.05$ divided by 11 plant species tested) was used to determine significant results (Table 4). Burro grass (*S. brevifolius*) had a greater percent cover on the prairie dog colony, and Russian thistle (*Salsola kali*) had a greater percent cover on the control site. A significant difference through time occurred for three plant species: galleta grass (*H. jamesii*), hog potato (*Caesalpinia drepanocarpa*), and Russian thistle. However, there was no significant time by treatment interaction for any of the plant species sampled. Our analysis indicated that vegetative differences between the control and treatment sites were present before reintroduction, and thus, the reintroduction of prairie dogs had no observable influence on the vegetation.

TABLE 4.—Summary results of repeated measures analysis of variance for plant species, litter, and bare soil during 1997 for the prairie dog reintroduction study on the Sevilleta National Wildlife Refuge, New Mexico.

Variable	Source	d.f.	F	P > F
Grasses				
<i>Bouteloua gracilis</i>	Treatment	1	1.000	0.3409
	Error	10		
	Time	1	1.000	0.3409
	Time × Treatment	1	1.000	0.3409
	Error	10		
<i>Hilaria jamesii</i>	Treatment	1	1.180	0.3035
	Error	10		
	Time	1	23.48	0.0007
	Time × Treatment	1	0.910	0.3624
	Error	10		
<i>Muhlenbergia arenacea</i>	Treatment	1	1.730	0.2182
	Error	10		
	Time	1	3.310	0.0991
	Time × Treatment	1	1.730	0.2182
	Error	10		
<i>Scleropogon brevifolius</i>	Treatment	1	53.51	0.0001
	Error	10		
	Time	1	5.120	0.0471
	Time × Treatment	1	3.590	0.0874
	Error	10		
<i>Sporobolus airoides</i>	Treatment	1	0.480	0.5054
	Error	10		
	Time	1	2.460	0.1476
	Time × Treatment	1	0.510	0.4931
	Error	10		
Forbs				
<i>Caesalpinia drepanocarpa</i>	Treatment	1	3.550	0.0889
	Error	10		
	Time	1	23.98	0.0006
	Time × Treatment	1	9.080	0.0130
	Error	10		
<i>Chamaesyce micromera</i>	Treatment	1	0.810	0.3902
	Error	10		
	Time	1	1.120	0.2970
	Time × Treatment	1	0.810	0.3902
	Error	10		
Euphorbiaceae species	Treatment	1	5.210	0.0457
	Error	10		
	Time	1	1.800	0.2090
	Time × Treatment	1	1.800	0.2090
	Error	10		
<i>Kallstroemia parviflora</i>	Treatment	1	1.050	0.3294
	Error	10		
	Time	1	1.340	0.2741
	Time × Treatment	1	1.050	0.3294
	Error	10		

TABLE 4.—Continued.

Variable	Source	d.f.	F	P > F
<i>Portulaca oleracea</i>	Treatment	1	3.170	0.1052
	Error	10		
	Time	1	4.400	0.0623
	Time × Treatment	1	3.170	0.1052
	Error	10		
<i>Salsola kali</i>	Treatment	1	18.84	0.0015
	Error	10		
	Time	1	24.64	0.0006
	Time × Treatment	1	11.65	0.0066
	Error	10		
Bare soil	Treatment	1	0.700	0.4223
	Error	10		
	Time	1	11.33	0.0072
	Time × Treatment	1	0.340	0.5707
	Error	10		
Litter	Treatment	1	0.460	0.5144
	Error	10		
	Time	1	16.03	0.0025
	Time × Treatment	1	0.010	0.9219
	Error	10		

DISCUSSION

Our results indicated that reintroduction of Gunnison's prairie dogs had no observable, initial impact on the resident small mammal and plant communities. These results were surprising for several reasons. First, prairie dogs are large rodents, known to significantly alter structure and function of grassland ecosystems through their grazing and burrowing activities. Second, this rodent species was introduced into a grassland site where the assemblage of small mammals had been functioning without prairie dogs for 6 years. Third, biomass of prairie dogs (36.8 kg) introduced into the community was disproportionately large relative to the biomass of the resident rodents (1.2 kg). Fourth, introduction of these large rodents occurred abruptly, over a period of several days. Despite these circumstances, there was no evidence of competition for food between prairie dogs and the other rodent species, nor was there evidence of rodent species being displaced via interference competition, or as a result of habitat

modification through changes in vegetative structure.

Many conditions could account for these results. For example, the site received above normal precipitation during winter 1996–1997 and summer 1997. Above average precipitation may have counteracted any effect that the prairie dogs may have had on the vegetation, minimizing competition for food between prairie dogs and other small mammals. Interference competition between prairie dogs and the other small mammals also may not have occurred because prairie dogs were diurnal and the other rodents were nocturnal, and therefore direct contact was probably minimal, perhaps occurring only in burrow systems.

Dipodomys spectabilis appeared to favor prairie dog activity. *D. spectabilis* was the largest rodent (averaging 127 g) on the site prior to reintroduction of prairie dogs. It inhabits desert grasslands and occupies large honeycombed mounds (Findley, 1987). *D. spectabilis* was significantly more abundant on the prairie dog colony than on the con-

control site both before and after reintroduction. At the time of reintroduction, the site had already been altered by the former prairie dog colony. *D. spectabilis* may have favored the colony because of the previous prairie dog burrowing activity that created numerous burrows potentially available for them to modify and inhabit.

Unlike *D. spectabilis*, *P. leucopus* was more abundant on the control site than on the prairie dog colony. *P. leucopus*, weighing an average of 20 g, is a grassland species that is widespread throughout North America (Findley, 1987). *P. leucopus* may have preferred the control site because of the more continuous vegetation cover (i.e., no patches of large prairie dog mounds lacking vegetation). Our results for *P. leucopus* differ from those of Agnew et al. (1986), which involved the deer mouse (*P. maniculatus*) and O'Meilie et al. (1982), which involved both *P. leucopus* and *P. maniculatus*, who found *Peromyscus* more abundant on well-established prairie dog colonies than on adjacent grassland sites. However, those studies were based primarily on populations of *P. maniculatus* (*P. leucopus* was in low abundance in O'Meilie et al., 1982), which has a different life history than *P. leucopus*. The studies by Agnew et al. (1986) and O'Meilie et al. (1982) also were conducted on colonies of black-tailed prairie dogs in mixed-grass and short-grass prairies, respectively. Our study was conducted on a Gunnison's prairie dog colony in a desert grassland in the Southwest; the more arid climate may have caused *P. leucopus* to prefer the more continuous grass cover on the control sites.

Comparison of our results with other studies is not possible because there have been no studies evaluating the initial ecological effects of reintroduction of prairie dogs, despite the large number of studies assessing ecological effects of black-tailed prairie dogs in established colonies. There also is little information on the influences of Gunnison's prairie dogs on grassland ecosystems. Hence, the question still re-

mains as to whether Gunnison's or other prairie dog species have the same keystone-level effects on grassland ecosystems as do black-tailed prairie dogs.

Our results may be used to provide information on restoration ecology in grassland ecosystems. Restoration efforts in grasslands have involved attempts to return vacated agricultural lands back to native grassland sites, limit or remove livestock grazing, reintegrate fire into the ecosystem to help restore original soil properties and vegetation communities, and restore biodiversity by protecting or reintroducing rare species (Hunter, 1996). Recent efforts to restore grassland biodiversity and ecosystem functioning have included reintroductions of black-footed ferrets (Clark et al., 1987) and prairie dogs (Robinette et al., 1995). Based on the ecological significance and amount of time, energy, and economical resources involved in reintroductions, it is useful to know if and how long it takes for influences of reintroduced species to have an impact on an ecosystem. Our results suggest that influences of reintroduced prairie dogs into a desert grassland ecosystem will not be immediate but may develop over time.

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