SAN JOAQUIN ANTELOPE SQUIRREL
(*AMMOSPERMOPHILUS NELSONI*) STUDY - 1988

Final Report

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by

Daniel F. Williams and Walter Tordoff III
Department of Biological Sciences
California State University, Stanislaus
Turlock, California 95380

and

John H. Harris
Biology Department
Mills College
5000 Mac Arthur Blvd.
Oakland, California 94613

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nitratoides, and G. silus and their associated vertebrate species on the Elkhorn Plain Ecological Reserve, San Luis Obispo County, California, and their response to grazing; and 2) establish efficacious methods for inventory of A. nelsoni and determine populations densities at different sites with a range of plant communities reflecting differences in habitat quality.

Organization of Research Program

The studies were organized into two parts and responsibilities for each part were assigned to different researchers: 1) grazing and demographic studies focused on and near the Elkhorn Plain Ecological Reserve headed by D. Williams and W. Tordoff; and 2) population and distribution studies of A. nelsoni headed by J. Harris.

In the following sections, Part 1 will detail methods and results of the grazing and demographic studies on the Elkhorn Plain Ecological Reserve and Part 2 will report on the population and distribution studies of A. nelsoni.

PART 1

EFFECTS OF LIVESTOCK GRAZING ON AN ENDANGERED COMMUNITY: ELKHORN PLAIN, SAN LUIS OBISPO COUNTY, CALIFORNIA

by

Daniel F. Williams and Walter Tordoff III

METHODS

Small Mammals

Small mammals censuses were conducted by simultaneous livetrapping on 1-ha experimental (no grazing) and control (grazing) plots established in 1987. Additional information on habitat, movements, and reproduction were obtained from livetrapping on line transects, the experimental plot, and 0.25- and 1-ha plots established on the Reserve in 1988. A total of 5650 trap nights (1 trap set for 1 night) have been accumulated during 1988. During all but the July and August sessions, traps were left open during the day to capture antelope squirrels. Table 1 lists the sampling periods and sampling efforts between February and October 1988. Two-day livetrapping sessions are planned for November and December 1988 to continue monitoring reproduction.

Table 1. Locations, dates, and total livetrapping efforts on and near the Elkhorn Plain Ecological Reserve during 1988. P1 = experimental plot; P2 = control plot; P3 = 1-ha plot within Reserve; P4 = 0.25-ha plot within Reserve; T1 = transect in arroyo on reserve; T2 = transects at increasing distances around plot 1.

Dates	Location	Purpose	No. Traps	Trap Effort
12-14 Feb	P1	Monitor Reproduction	100	200
12-13 Mar	T1	Monitor Reproduction	50	50
24 Mar-5 Apr	P1 P2	Population Census	200	2200
30 Apr-2 May	P1 P2	Monitor Reproduction	200	400
31 May-2 Jun	P1 P2	Monitor Reproduction	200	600
25 Jun-2 Jul	P3 T2	Monitor Movements	80	560
8-15 Aug	P1 P2	Population Census	200	1200
7-9 Oct	P1 P2 P4	Monitor Reproduction	240	440

Traps were baited with a mixture of seeds, mainly millet with small amounts of sunflower, wheat, sorghum and others. During February, March, and April, traps were checked two or three (February) times between sunset and sunrise. During subsequent sessions, traps were checked once between 2 and 4 h after dark and again around sunrise.

Captives were placed in cloth bags, weighed with Pesola scales, and identified or tagged and released at the capture site. Initially, size 1, numbered, monel fingerling tags were attached to the outer edge of cheek pouches of kangaroo rats and the ear pinnae of antelope squirrels. During the March-April census period we ceased attaching tags to cheek pouches of kangaroo rats and started attaching them on ear pinnae, but tags were placed on the cheek pouches of Perognathus inornatus, whose ears were too small to hold a tag.

Each time an animal was captured, it was weighed and its probable age (young, adult), reproductive condition, and capture site were recorded. Conditions recorded for females were estrus, pregnant, lactating, not reproducing; for males, testes swollen but less than maximum size, testes scrotal and of maximum size, testes not evident were the states noted.

During February, March, and April the location of the burrow an animal retreated to upon release was also recorded, as had been done in 1987. We stopped recording this information when it was clear that many animals were not retreating to their home burrows and to monitor each animal until it settled into its home burrow would require so much time that other animals still in traps would suffer excessively.

Data from 6- to 10-day population censuses on experimental and control plots were used to estimate population sizes and densities. Methods for estimating population size were capture-recapture, closed-population models (Otis et al., 1978). Capture data for each session by species and plot were analyzed to determine the nature of capture heterogeneity, capture probabilities, and the appropriate population estimation model, using the computer program Capture (White et al., 1982). Models to choose from based on sources of variation in capture probabilities were: 1) null (no variation); Darroch (time); Zippin (behavior), jacknife (heterogeneity not due to time or behavior), and generalized removal (behavior and heterogeneity). Capture data exhibiting variation by time and behavior or heterogeneity or a combination of the three have no known population estimator (White et al., 1982), so simpler models must be substituted. Once the appropriate model was determined, population estimates were computed and densities were estimated using the nested subgrid method (White et al., 1982). For nested subgrid calculations, each plot with a 10 x 10 array of traps was partitioned into four subgrids, with x-y coordinates of 4 - 7, 3 - 8, 2 - 9, and 1 - 10, respectively. Differences in estimates on experimental and control plots were compared using the two-tailed z-test.

Animals known to die during census periods were excluded from the data set unless their death occurred on the last day of the session, which does not effect population estimates for that session.

Comparisons of numbers of individuals captured by species, year, and grid and overall captures by grid were compared using log-ratio goodness-of-fit tests. The goodness-of-fit values closely approximate the Chi-square distribution ($\underline{x}^2$); the latter is used to determine significance (Sokal and Rohlf, 1969).

Seed Caches of Giant Kangaroo Rats

Between 1 and 5 May seed caches made by giant kangaroo rats were measured on experimental and control plots and on 10-m wide strips along the western boundary of the Reserve, both inside and outside the reserve (transects were 60-m apart, 30-m each side of the fence). Seed caches consist of a honeycomb-like arrangement of small pits dug in the surface of the soil, filled with seedheads, and covered with loose soil (pit caches). Most pit caches also had additional seedheads spread on the surface, varying from a thin layer a few mm deep to a definite pile several centimeters high (stacks or haystacks). We did not disturb surface material to determine if stacks were always placed over clusters of pit caches, but it seemed to be the case for most of the stacks we watched grow between late March and May.

The area of each cache was measured in two dimensions at right angles. Length and width were subjectively measured at an "average" position and recorded to the nearest cm. Height of surface caches were recorded to the nearest cm, being averaged from measurements of heights at different levels of the stacks. All separate seed caches were measured and recorded. For most precincts there was a single seed cache, but a few consisted of two to four smaller, separate piles of seeds in close association (i.e., within a meter of each other). For statistical comparisons, the area and volume of surface material for these separate, but related caches were combined and treated as a single cache.

Tests for Trap Bias

Standard large, folding Sherman aluminum livetraps (LFA; 7.62 x 7.62 x 22.86 cm) traps often catch and injure the tail of kangaroo rats in the door when it springs closed. A newer, extra-large trap (ELFA; 7.62 x 9.53 x 30.48 cm) prevents most injuries to tails of kangaroo rats. The budget in 1987 was sufficient to purchase 100 ELFA traps, but they were unavailable at the start of the studies in July 1987. LFA traps were used on both grids during the first 12-day trapping session in 1987. For subsequent trapping sessions in 1987 and 1988, a combination of LFA and ELFA traps were used. Alternate columns of traps received the shorter and longer traps on each plot. Long and short traps were switched to the opposite columns after every 7 days of trapping during 1987 and 1988. To test if traps of different sizes were equally effective, data on captures in traps by size and plot by day were analyzed by using ANOVA and paired $\underline{t}$-tests using the computer program Systat. Each column of each grid was trapped with long and short traps for equal numbers of days overall.

Studies of Blunt-Nosed Leopard Lizards

During April, 1988, two 20-acre (8.1 ha) plots were established to census leopard lizards. One was located within the reserve and the other was located on BLM land approximately 1.5 mi northwest of the reserve. The dimensions of the plots were 907.5 ft by 960 ft after the method of Tollestrup (1976). In both plots the 907.5-ft axis was oriented approximately north-south. Sampling lines were established at 60-ft intervals in the N-S direction. Every effort was made to ensure that the two plots contained the same amounts of similar habitat. Accepted procedures for sampling for leopard lizards involves walking these grids along the 907.5-ft axis at 60-ft intervals 10 times during May and June (prime adult activity period). To acquire data on territoriality and movement of lizards, two 10-day periods were planned, one at the beginning of May and the other at the beginning of June. Two field workers would each do one plot per day, alternating plots from day to day. Unfortunately, the first half of May 1988 was unusually cool and the researchers were only able to sample on 1 day within the accepted temperature and time conditions (24-35°C air temperature; 30-41°C soil temperature; 0800-1300 h). The majority of the data thus were collected during the 10-day sampling period in June. Additionally each plot was sampled on alternate days during a 6-day sampling period in August. The plot on the reserve was sampled once in October.

On every visit (April, May, June, August, October) the fence around the reserve was inspected and all animals impaled on barbed wire by loggerhead shrikes were recorded. These include the remains of leopard lizards. These data will provide indexes on predation by shrikes on juvenile leopard lizards and may prove useful in other ways. These samples have not been thoroughly analyzed yet and no results are included in this report.

Primary Productivity of Herbaceous Plants

From 2 to 4 April when the seed heads were ripening and annual grasses were beginning to dry, and before antelope squirrels and kangaroo rats had began to cut significant amounts of seedheads, the herbaceous biomass was sampled. All green herbaceous material on 200 0.25 m^2 plots, stratified as follows, was clipped at ground level: 50 on precincts and 50 from the ground between precincts of giant kangaroo rats, both from the ungrazed reserve and the grazed pasture. Positions of the samples on and off of each precinct were determined randomly, but each off-precinct sample came from an area in the space around its matched precinct. Twenty-five samples of each treatment came from the ephedra and annual grassland associations. Samples were placed in paper bags, labeled, and dried for storage. Before recording weights, samples were sorted to remove any pebbles, dung, and woody material, then were dried to uniform weight. Samples on and off of the reserve were tested for significant differences and homogeneity of variances before pooling samples from the ephedra and grassland associations. Differences were tested by ANOVA and paired t-tests for on- and off-precinct comparisons within reserve and pasture, and independent t-tests for comparisons between reserve and pasture.

Measurements of Growth of Shrubs and Subshrubs

Between 12 and 15 August individually tagged shrubs and subshrubs (8 species, 20 individuals each with 10 reserve and 10 pasture) and height and length of all shrubs and subshrubs on 30-m transects (8 reserve, 8 pasture), established in 1987, were measured. For *Haplopappus acradenius* and *Gutierrezia bracteata* fewer than 10 were originally located on the reserve in 1987 and some of those died subsequent to the 1988 census. Data for these two species were eliminated from statistical comparisons. Data on growth of individual shrubs were convereted to volumes (maximum measures of length*width*height); differences were compared using the two-tailed, independent t-test. Volumes measured in this way reflect above-ground space occupied by shrubs by are not an accurate measure of biomass.

Organic Litter

The objectives in sampling plant litter were twofold: 1) obtain a measure of the total amount of organic material on the soil surface; and 2) determine the amount of herbaceous material remaining at the end of the annual grazing season. Samples of organic litter collected in 1987 were not completely processed until 1988, and results are report d and compared herein. In August 1988 200 samples of litter, stratified a follows, were obtained: 25 each from the steep rocky hillsides (hill), ephedra association (slope), grassland association (plains), and arroyo association, in grazed (pasture) and ungrazed (reserve) areas. Williams and Tordoff (1988) described these associations in detail. Sample sites were chosen randomly and at each site all organic material was collected from within a 0.25 m^2 sampling frame by scraping the surface of the ground with the edge of a sharp-bladed trowel.

In the laboratory, larger pebbles were picked from samples. Samples were placed in 100-mesh soil sieves and partly immersed in a bucket of water to float off organic material. The material was thoroughly rinsed in clean water prior to collection. This process resulted in separation of dirt from all organic material from soil-sized particles of organic duff to large pieces of wood and dung. The collected material was returned to labeled paper bags and dried in a 40°C drying box. When dried to uniform weight, weight was recorded.

RESULTS

Small Mammals

Captures and Population Estimates

Numbers of small mammals captured on experimental and control plots in 1987 and 1988 are listed and compared in Table 2. Numbers of all three species differed significantly between years by plot, but numbers between plots within either year were not significantly different for any species.

Table 2. Captures of small mammals by year, species, and plot on the Elkhorn Plain during 1987 and 1988. Lines connecting values show probability values for x^2, based on goodness-of-fit tests.

	Plot 1 (Reserve)		Plot 2 (Pasture)	
Species	1987	1988	1987	1988
Ammospermophilus nelsoni	13	29	19	32
	└─0.0124─┘		└─0.0672─┘	
Dipodomys ingens	49	88	48	81
	└─0.0007─┘		└─0.0035─┘	
Dipodomys nitratoides	23	12	29	14
	└─0.0607─┘		└─0.0208─┘	
Perognathus inornatus	0	2	0	0
Onychomys torridus	0	0	1	1

Numbers of individuals captured increased for *D. ingens* and *A. nelsoni* on both plots between 1987 and 1988, but declined for *D. nitratoides* (all values but two exceed the 5% probability level). Furthermore, the magnitude of change between years was nearly identical on each plot for each species (Fig. 2).

Although numbers of individuals by species captured did not differ significantly between experimental and control plots, there were more overall captures on the experimental plot in both years, when captures from simultaneous censuses are compared. In 1987 there were 424 captures in the reserve and 411 captures in the pasture; in 1988 there were 1357 captures in the reserve and 1123 in the pasture. The difference for 1987 was insignificant (3%), but in 1988 there were 17% more captures on the reserve, a highly significant difference ($P < 0.000002$, $G = 22.113$).

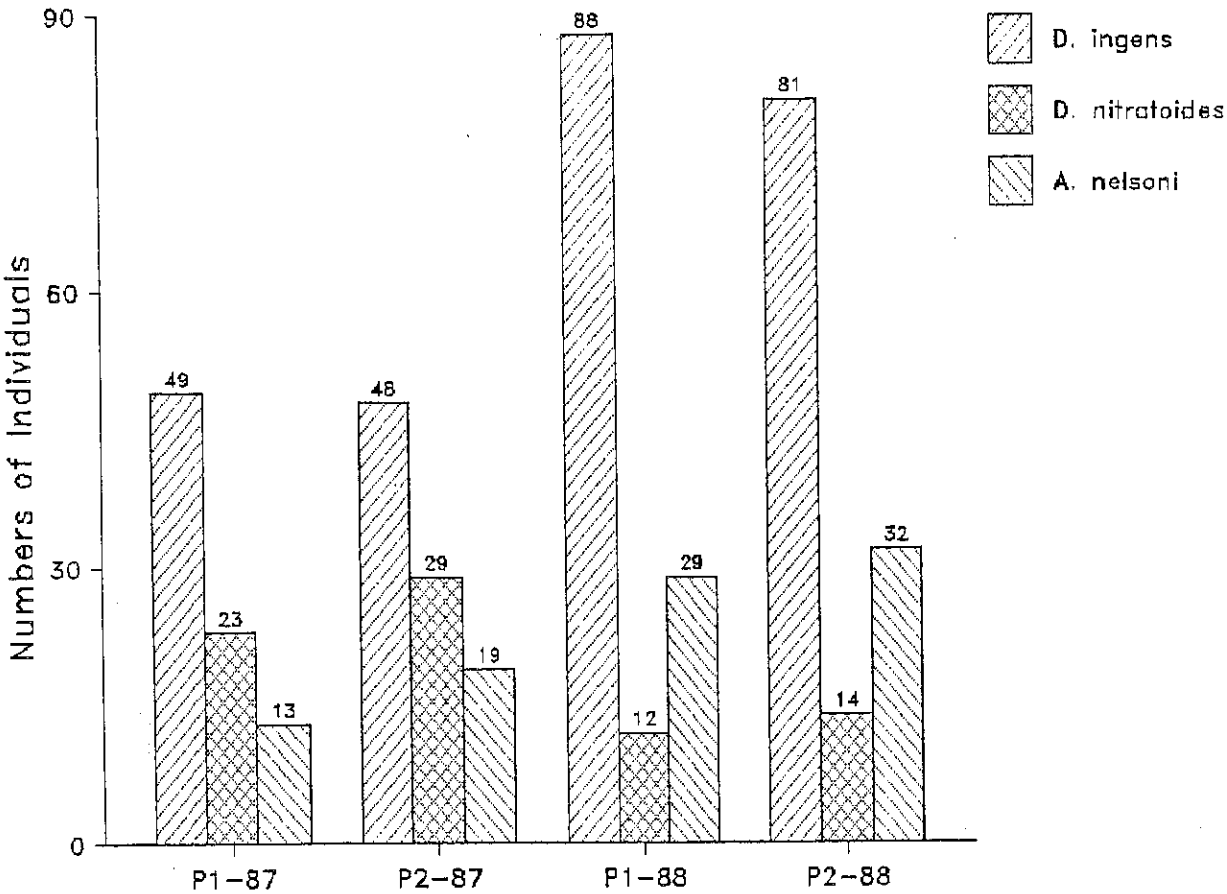

Figure 2. Numbers of individuals captured by species, plot and year. P1 = plot 1 (reserve); P2 = plot 2 (pasture). Numbers at tops of bars are total numbers marked. Refer to Table 2 for significance values.

Estimated population sizes and densities for four census periods are given in Table 3. Numbers and captures refer to the number of individuals captured during the session and total captures of all individuals during a session, respectively. Estimated 95% confidence intervals are determined using the methods of Otis et al. (1978).

Tests of significance by species, plot, and year are shown in Table 4. Only relevant comparisons of the same plot by sessions or between plots within sessions were made.

Movements

Maximum distances between captures of individuals on plots within sessions, distances moved from point of capture on a plot to a burrow outside the plot boundaries upon release from traps, and distances from

Table 3. Estimated population sizes, densities per ha, and effective sampling areas (strip-width) of 1-ha experimental and control plots on the Elkhorn Plain. Only data for simultaneous census periods of ≥ 6 days were used. No. = number of individuals; captures = total captures of all individuals. Standard errors of the estimates are given as ±; 95% confidence intervals are shown for population size estimated for plots (which includes entire effective sampling area).

Census		*A. nelsoni*	*D. ingens*	*D. nitratoides*
8 - 19 July 1987				
Plot 1:	No. and Captures	12, 17	45, 186	18, 49
	Density	13.3±7.9	40.5±1.1	22.6±7.7
	Strip Width	1.3±11.0	8.1±0.0	14.3±2.5
	Population Size	20±6.2 7-33	45±1.1 44-46	19±0.9 16-21
Plot 2:	No. and Captures	18, 33	40, 161	21, 37
	Density	21.8±8.8	30.3±3.1	22.0±4.6
	Strip Width	1.8±8.9	14.3±2.5	7.3±3.7
	Population Size	21±2.2 16-26	41±1.8 37-45	26±2.7 20-31
27 July - 2 Aug 1987				
Plot 1:	No. and Captures	5, 5	31, 78	13, 41
	Density	----	31.9±4.0	15.9±2.3
	Strip Width	----	7.03±1.74	0.0±3.2
	Population Size	----	35±2.5 30-41	13±0.5
Plot 2:	No. and Captures	4, 5	29, 63	20, 63
	Density	3.8±3.7	30.3±0.1	20.2±16.3
	Strip Width	8.0±26.6	1.48±	4.0±12.2
	Population Size	4±0.7 3-6	31±1.5 28-34	20±0.6 18-22
24 March - 5 April 1988				
Plot 1:	No. and Captures	8, 11	67, 418	14, 35
	Density	7.4±5.2	58.2±5.7	17.8±5.7
	Strip Width	0.0±14.4	5.3±1.4	2.3±6.7
	Population Size	8±1.3 5-11	74±5.0 64-84	16±1.7 12-20
Plot 2:	No. and Captures	1, 1	79, 381	3, 9
	Density	----	63.2±5.5	----
	Strip Width	----	11.4±2.0	----
	Population Size	----	85±3.3 79-92	----
8 - 15 August 1988				
Plot 1:	No. and Captures	7, 10	61, 204	13, 30
	Density	7.8±7.6	56.9±7.6	10.9±2.9
	Strip Width	9.7±7.2	11.1±3.0	9.7±7.2
	Population Size	8±1.2 5-11	71±4.1 62-79	13±1.0 10-16
Plot 2	No. and Captures	15, 18	51, 168	11, 23
	Density	18.2±3.2	49.6±7.6	9.5±6.6
	Strip Width	0±3.6	10.3±3.5	2.8±3.8
	Population Size	15±0.7 13-17	60±3.9 52-68	12±1.3 9-15

Table 4. Values of _z_ and probability levels (_P_) for relevant comparisons of estimated population size on 1-ha experimental (P1 = reserve) and control (P2 = pasture) plots by species, year, and plot. Sessions are: S1 = 8-19 July 1987; S2 = 27 July - 2 August 1987; S3 = 24 March - 5 April 1988; S4 = 8 - 15 August 1988.

Species	Plots	Sessions	_z_-value	_P_
Ammospermophilus nelsoni:	P1-P2	S1	0.15	0.8808
	P1-P2	S2	----	
	P1-P2	S3	----	
	P1-P2	S4	5.04	0.0000
	P1	S1-S2	----	
	P1	S3-S4	0	1.0000
	P2	S1-S2	7.36	0.0000
	P2	S3-S4	----	
	P1	S2-S4	----	
	P2	S2-S4	11.1	0.0000
Dipodomys ingens:	P1-P2	S1	1.90	0.0574
	P1-P2	S2	1.37	0.1706
	P1-P2	S3	1.84	0.0658
	P1-P2	S4	1.94	0.0524
	P1	S1-S2	4.00	0.0000
	P1	S3-S4	0.46	0.6456
	P2	S1-S2	4.27	0.0000
	P2	S3-S4	4.89	0.0000
	P1	S2-S4	7.50	0.0000
	P2	S2-S4	6.94	0.0000
Dipodomys nitratoides:	P1-P2	S1	2.46	0.0138
	P1-P2	S2	8.96	0.0000
	P1-P2	S3	----	
	P1-P2	S4	0.61	0.5418
	P1	S1-S2	5.82	0.0000
	P1	S3-S4	1.52	0.1286
	P2	S1-S2	2.16	0.0300
	P2	S3-S4	----	
	P1	S2-S4	0	1.0000
	P2	S2-S4	----	

nearest point of capture on a plot to point of capture off of plots are given in Table 5. Movements on and around plots during trapping sessions probably represent normal population movements within home ranges.

Other data on movements derive from captures of individuals marked on plots and subsequently captured elsewhere (Table 5). These may represent normal movements within a home range or dispersal. All three _D. nitratoides_ captured off of plots in June were subsequently captured on

Table 5. Known distances (m) moved on and off of experimental (P1) and control (P2) plots during 1987 and 1988 by species. Sessions are: S1 = 8-19 July 1987; S2 = 27 July - 2 August 1987; S3 = 24 March - 5 April 1988; S4 = 8 - 15 August 1988. Means for on-plot movements are mean maximum distances between capture points for all individuals; ranges are range of all capture points. Distances for individuals are minimum distances between nearest points of capture on and off of plots.

Species	Plots	Sessions	n	Mean	Range
Ammospermophilus nelsoni:	P1	S1	12	26.1±26.3	0-30
	P1	S2	5	0	----
	P1	S3	8	63.6±63.6	0-70
	P1	S4	10	21.8±23.9	0-14
	P2	S1	18	28.2±13.3	0-82
	P2	S2	4	28.0 ----	----
	P2	S3	1	----	----
	P2	S4	18	18.7±21.4	0-36
Distance to burrows upon release			12	5±1.2	1-15
Dipodomys ingens:	P1	S1	45	18.0±4.5	0-61
	P1	S2	31	17.6±5.8	0-57
	P1	S3	67	14.1±2.9	0-36
	P1	S4	61	15.1±4.0	0-36
	P2	S1	40	17.3±4.8	0-82
	P2	S2	29	14.2±5.6	0-20
	P2	S3	79	15.6±3.4	0-80
	P2	S4	51	11.4±2.9	0-36
Distance to burrows upon release			96	4.5±0.3	1-17
# 76 from P1 to point off of plot					40
# 91 from P1 to P3				160	
# 250 from P1 to point off of plot					30
Dipodomys nitratoides:	P1	S1	18	20.7±11.1	0-80
	P1	S2	13	21.3±11.8	0-61
	P1	S3		19.1±10.4	0-42
	P1	S4	30	23.3±17.0	0-30
	P2	S1	21	18.1±8.5	0-50
	P2	S2	20	27.1±12.4	0-64
	P2	S3	3	----	----
	P2	S4	23	9.0±6.6	0-20
Distance to burrows upon release			44	6±0.5	1-30
# 9 from P1 to point off of plot					32
# 11 from P1 to point off of plot					35
# 13 from P1 to point off of plot				20	

plot 1 in August or October, and probably represent normal day-to-day movements. For D. ingens, number 76 was last caught on plot 1 on 5 April 1988 and was taken off of the plot on 27 June 1988. This probably represents a dispersal movement. Number 91 was last captured on plot 1 on 15 August 1988 and was taken on plot 3 on 26 and 27 August 1988, a minimum distance of 160 m between closest trapping points. Because of the great distance compared to normal movements (Table 5), this probably represents dispersal. Number 250 was captured off of plot 1 on 27 July 1988, but was subsequently captured on Plot 1 in August and October 1988.

Reproduction and Longevity

Data on reproduction and population biology are incomplete because the project commenced in July when it was not possible to accurately distinguish kangaroo rats born in 1987 from those born in previous years. Complicating development of information was the irregular sampling schedule. Data are sufficient to outline the seasonal patterns of reproduction for the three common species, but some details must still be developed.

Ammospermophilus nelsoni males had fully enlarged testes on 13 February, and females showed evidence of lactation by the first week in April. Juveniles weighing between 50 and 65 g were first trapped on 1 May. By 1 June, most animals caught were subadults weighing between 95 and 115 grams; none lighter than 95 g were captured in June. By the August census period (8-15 Aug.) the lightest individuals weighed more than 100 g. There was no evidence of an extended reproductive season or more than a single litter of young produced by a female.

Fifteen of 25 (60%) antelope squirrels first captured as adults were never recaptured. The mean duration on plots from first capture of adults was 46.4 days (S.D. 117.8); the longest time between first and last capture was 458 days. Excluding animals that were not recaptured, the mean duration between first and last capture of adults was 115.9 days (S.D. 158.9).

For antelope squirrels first captured as young, 39 of 67 (58.2%) were never recaptured. Mean duration from first capture was 24.4 days (S.D. 68.0); the mean duration excluding animals never recaptured was 58.3 days (S.D. 94.5). The longest time between first and last capture was 398 days.

The greatest proportion of both adult and young antelope squirrels become trap shy after their initial capture, complicating the acquisition of data on population structure.

Dipodomys ingens females showed evidence of pregnancy and lactation on 13 February 1988 and males had fully developed testes. Two individuals captured at that time may have been born in late December or early January, as they weighed 95 and 105 g, and were not reproductively active, whereas all others weighed more than 123 g (mean 137.9, S.D. 9.18). However, occurrence of several lightweight individuals (100, 102, 104, 107, 109 g) in the 25 November sample suggests that some individuals may either take longer to reach adult weights or are simply smaller than typical. Nearly equal numbers of females were pregnant and lactating.

One female was in estrus and two were pregnant on 25 March, but most females were either lactating or post-reproductive. The testes of males were shrinking in size by late March. Several juveniles weighing between 60 and 90 g were captured between 25 March and 5 April, although most were taken the last few days of the census period. By 1 May, no adult females showed evidence of pregnancy or lactation and the testes of all but one male were no longer scrotal. The lightest juvenile taken on 1 May was 72 g. By 1 June there was no evidence of reproduction and the lightest individual weighed 91 g. On 9 October, the testes of males were beginning to enlarge again, but were less than half of their maximum size. By 26 November, most males had testes about half of their maximum size, but there was no evidence of reproduction in females.

Examination of records of individual females produced no evidence for more than a single pregnancy, although the possibility that some females bred twice cannot be ruled out. There also was no evidence that females born early in the season reproduced during the year of their birth, although this remains a possibility too. Either possibility seems remote for the animals monitored in 1987-1988, however.

The inability to positively distinguish young from older animals in 1987 precludes comparisons of duration by age classes for D. ingens. Thirty-seven of 265 individuals (14%) were never recaptured. Average duration on plots from first capture was 110.8 days (S.D. 125). One individual was still present after 506 days. Mean duration of individuals recaptured at least once was 128.8 days (S.D. 126.0).

Dipodomys nitratoides commenced reproduction later than D. ingens. The testes of males were scrotal on 12 February and two females were in estrus; one had a plug of semen in her vagina. Another female may have been pregnant, but there was no evidence of lactation. Four adult females captured on 12 March and held in captivity for 2 months were not pregnant when captured. By the 25 March-5 April trapping session, two females were in estrus, two were pregnant, and one was lactating. The testes of all males were scrotal and of maximum size. No young animals were captured until the 31 May-3 June session, when a 32 g subadult was found. The testes of males had begun to regress in size and no females evidenced pregnancy or lactation by 1 June. A few more subadults were captured in the 8-15 August period. Two adult males still had scrotal testes in August. By 9 October, testes were no longer apparrent, except for one individual. By 26 November, the testes of males were enlarging again, but they were only about half of their maximum size. Females showed no evidence of reproduction between May and November.

The data at hand do not suggest more than a single pregnancy nor reproduction by young-of-the-year for D. nitratotides.

Of 84 individual San Joaquin kangaroo rats captured and marked, 21 (25%) were not recaptured. Mean duration from first capture of all individuals on plots was 122.8 days (S.D. 165). Four individuals were still present after 506 (2) and 507 (2) days. The time between the first and last trapping sessions in 1987 and 1988 was 507 days. Mean duration for individuals recaptured at least once was 163.8 days (S.D. 172.7).

The differences in average duration of all individuals of D. ingens and D. nitratoides were not significant either for all captures or for all individuals recaptured at least once (two-tailed z-test, P = 0.48 and P = 0.43, respectively), even though San Joaquin kangaroo rats persisted on plots 12 days longer for all captives and 35 days longer for individuals recaptured at least once.

Seed Caches of Dipodomys ingens

Numbers of seed caches showed remarkable consistency between the four plots: 31 and 32 on 1-ha experimental and control plots and 33 and 30 for the 1.2 ha transects in reserve and pasture, respectively. One precinct had two discrete caches located about 2 m apart, but all others had a single area for caching seeds. Numbers of caches probably signify number of active precincts.

Values for area and volume of seed caches for plots in grazed and ungrazed areas are listed in Table 6. Statistics represent pooled values for all caches in the reserve and pasture, respectively. These data are displayed in Fig. 3. The volume of surface caches in the reserve averaged significantly greater than those in the pasture, but surface area covered by caches was significantly greater in the pasture.

Table 6. Surface area covered (area) and volume (vol.) of surface seed caches of D. ingens on the Elkhorn Plain during May 1988. Values are in square (area) and cubic (volume) centimeters. Values of t and P are from 2-tailed t-tests.

Statistic	Area-Reserve	Area-Pasture	Vol.-Reserve	Vol.-Pasture
n	64	62	64	62
minimum	2400	1500	0	0
maximum	53200	81000	153000	72000
mean	18570.8	23953.1	29012.3	12402.3
standard deviation	10773.9	18018.6	39171.8	18047.7
t	2.063		3.085	
P	0.041		0.002	

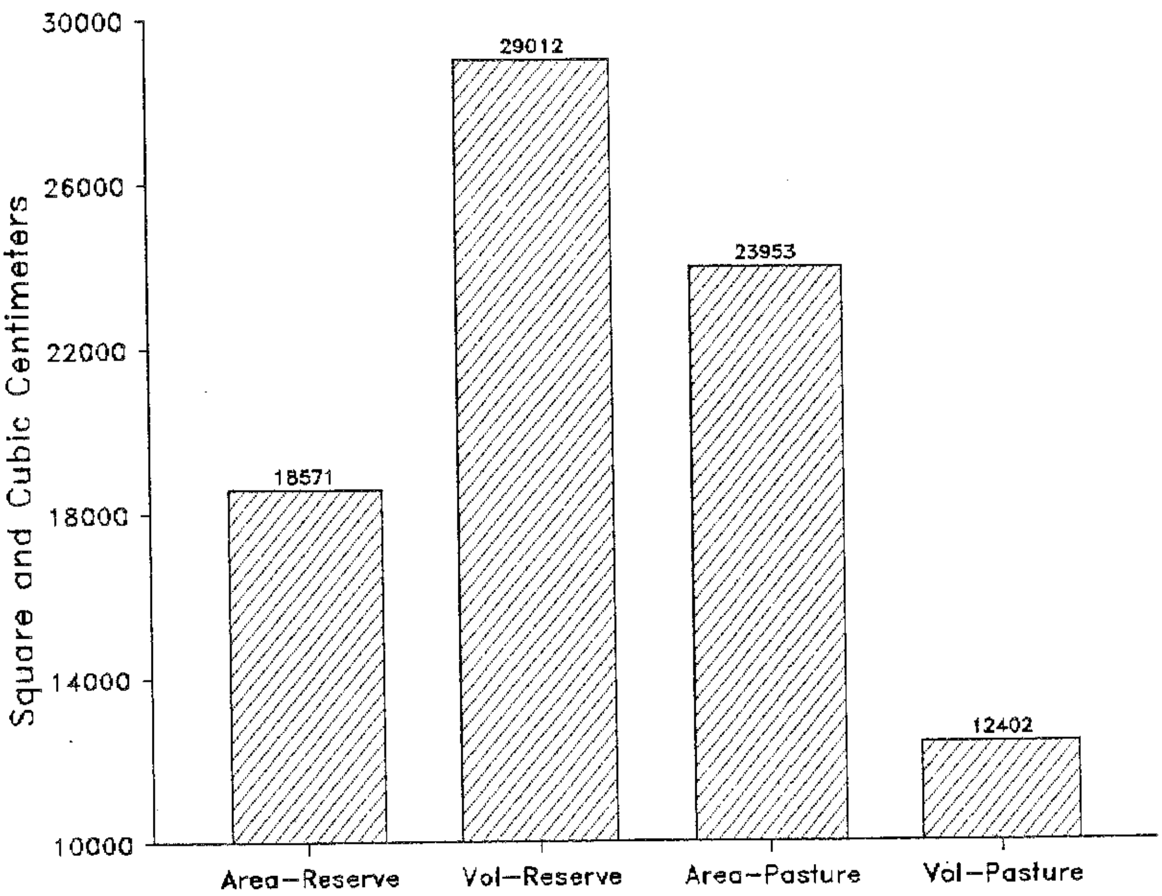

Figure 3. Surface area covered by seed caches of giant kangaroo rats and volume of seedheads in surface piles or haystacks. Measurements were made the first week in May 1988. Values in reserve and pasture differ significantly (Table 6).

During inspection of caches a few haystacks were found that overlapped the boundary of the reserve. The portions inside the fence were intact while outside the fence only traces of seedheads were found scattered on the surface. The portions outside the fence presumably were eaten by cattle. Consumption by cattle explains the significantly greater volume (57%) for caches in the reserve compared to those in the pasture. The significantly greater area covered by caches (36%) in the pasture might have been due to scattering of seedheads as cattle ate the haystacks or it might represent greater numbers of pit caches with traces of seedheads on the surface.

Trap Bias

Results of tests for trap bias between extra-large and large folding Sherman livetraps are presented in Table 7. Tests for homogeneity of variances of results on experimental and control plots found no significant difference; thus data from the two plots were pooled.

Numbers of captures were significantly greater for the larger (ELFA) trap, amounting to about 25% more captures over the 66-day period.

Table 7. Summary statistics for test of trap bias between extra-large (ELFA) and large folding Sherman livetraps. Longer and shorter traps were placed on alternate columns and switched every 7 days during sampling periods for July 1987 to October 1988. Values of *t* and *P* are from a two-tailed, paired *t*-test. Statistics were computed from daily captures; *n* is number of days.

Statistic	ELFA Trap	LFA Trap
n	66	66
total captures	1644	1238
minimum	3	4
maximum	56	47
mean captures per day	24.9	18.8
standard deviation	14.9	9.4
t	4.54	
P	0.0001	

Blunt-nosed Leopard Lizards

Figures 4 and 5 show the sites and dates of all observations during the June sampling period for the on-reserve and off-reserve plots, respectively. No figure is included for the August sampling period because of the low number of sightings. The results of the 10-day leopard lizard sampling period (June 2-9) are presented in Table 8. Table 9 presents the results of paired *t*-tests conducted on the data from the June surveys. Comparisons were made for on- and off-reserve for all encounters and for each sex. Comparisons were also made for males and females on each plot. Results of the 6-day sampling period during August (Aug. 10-15) are presented in Table 10. Paired *t*-tests were not conducted for the August data because of the paucity of sightings. No lizards were

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

INTRODUCTION

The desert shrub and arid grassland communities of the San Joaquin Valley region of central California comprise one of the two areas of highest endemism at the mammalian species and subspecies level in California (Kilburn and Williams, in press). Additionally, it has high endemism for flowering plants, is the home of the endemic blunt-nosed leopard lizard (Gambelia silus), and represented an important foraging area for the California condor (Gymnogyps californianus).

Rapid reduction in extent of natural areas in the San Joaquin Valley followed completion of the Central Valley Project (Delta Mendota Canal) and the California Water Project (California Aqueduct) in the early 1970's. Loss of habitat jeopardized those members of the unique San Joaquin Valley biotic communities that were dependent upon habitat on the valley floor and piedmont slopes (Williams, in press). Six resident species of vertebrates from this area dependent upon desert and arid grassland habitats are classified as threatened (T) or endangered (E) by state (S) or Federal regulations (F): blunt-nosed leopard lizard (FE, SE), Fresno kangaroo rat (Dipodomys nitratoides exilis, FE, SE), Tipton kangaroo rat (D. n. nitratoides, FE), giant kangaroo rat (Dipodomys ingens, FE, SE), San Joaquin antelope squirrel (Ammospermophilus nelsoni, ST); San Joaquin kit fox (Vulpes macrotis mutica, ST, FE). Several others are listed as U.S. Category 2 species or state Species of Special Concern.

The largest remnant block of valley aridland communities with habitats for blunt-nosed leopard lizards, giant kangaroo rats, short-nosed kangaroo rats (D. nitratoides brevinasus), San Joaquin antelope squirrels, and San Joaquin kit foxes is located on the Elkhorn and Carrizo plains in eastern San Luis Obispo County.

Where habitats for these endangered species persist, livestock grazing is the principal use of land. In many places grazing is intense and prolonged, and has extirpated the more palatable woody shrubs as well as many elements of the native herbaceous flora. The Carrizo Plain region (including the Elkhorn Plain) has been designated as an Area of Critical Environmental Concern (ACEC) by the U.S. Bureau of Land Management (BLM), requiring that management goals give priority to maintaining populations of the endangered species (BLM, 1988).

Federal legislation recently provided funds for acquisition of private lands to maintain endangered species and their supporting aridland communities in the Carrizo Plain region. These funds, together with money from The Nature Conservancy, California Department of Fish and Game, and California Energy Commission have resulted in the recent collective purchase of thousands of acres on the Carrizo and Elkhorn plains for inclusion in the Carrizo Plain Natural Heritage Reserve (CPNHR). Most land acquired so far has been severely degraded by livestock grazing and cultivation, does not support most elements of the native communities, and will require revegetation and restoration of microrelief to make it suitable as habitat for the species that formerly lived there. The native lands with the highest values for endangered animal species are still in private ownership or are BLM lands surrounded by private lands where control of livestock grazing is complicated by long-standing practices of overstocking and grazing for too long during the year. Most of this remaining land is on the Elkhorn Plain.

Before restoration and recolonization of animals can be achieved, information on distribution of native communities must be developed, revegetation and reintroduction processes determined, and on-going management protocols established. Research is required into each phase of these processes. In order to develop management protocols, the effects of livestock grazing on endangered elements of these communities must be determined because it is the principal land-use activity, and some level of grazing may be important in optimizing populations of some of the endangered species.

For the blunt-nosed leopard lizard, kangaroo rats, and antelope squirrels the demographic data available are insufficient to model population dynamics and determine viable population sizes. For these species and the San Joaquin kit fox demographic data must be developed and cost-effective protocols devised for monitoring populations as a part of ongoing stewardship of lands dedicated to their preservation. Data from studies of D. n. brevinasus also will be useful for modeling and managing populations of D. n. nitratoides and D. n. exilis.

The San Joaquin antelope squirrel (A. nelsoni) is one of five species of antelope squirrels. Members of the genus Ammospermophilus are confined to desert, arid steppe, and open, shrubland communities in the southwestern United States and northern Mexico. Ammospermophilus nelsoni was described by Merriam in 1893 as a member of the genus Spermophilus; the type specimen was from Tipton, Tulare County, California. A. nelsoni has also been placed in the genus Citellus. Taylor (1916) distinguished the northern populations as a subspecies, A. nelsoni amplus, but A. nelsoni currently is considered to be monotypic (Hall, 1981).

Loss of habitat to agricultural developments, urbanization, and petroleum extraction are the principal factors threatening San Joaquin antelope squirrels. Use of rodenticides for control of ground squirrels, including San Joaquin antelope squirrels, has been a long-standing practice in California (e.g., Grinnell and Dixon, 1918), and probably has contributed to the overall decline of the species.

The greatest single threat to San Joaquin antelope squirrels throughout much of their remaining geographic range may be the long-term effects of excessive grazing by livestock. Extirpation of shrubs and soil erosion resulting from heavy use of rangeland communities by livestock are degrading their carrying capacities for most member species. First affected are those species dependent upon the plants most palatable and vulnerable to browsing by livestock. San Joaquin antelope squirrels appear to maintain good population densities on moderate-to-severely degraded rangelands where shrubs such as ephedra or saltbush are common, but it is doubtful that they could maintain viability indefinitely unless the processes of overgrazing and resulting soil erosion were halted.

Because A. nelsoni has state Threatened status, California lead agencies must consider its needs in granting development permits and authorizing other activities that might adversely impact antelope squirrels and their habitat (Schlorff, 1987). For developments that fall under the provision of state legislation protecting Threatened and Endangered Species, compensation for lost acreage of habitat is often the best mitigation measure. Because loss of habitat is considered the principal cause of decline of the species and a major continuing threat to species survival, acquisition and preservation of habitat is essential for its eventual recovery.

The needs of identifying and acquiring habitat for A. nelsoni underscore the pressing need for an efficacious method to accurately inventory for presence and relative abundance of San Joaquin antelope squirrels. Once determined, an inventory of remaining natural lands within the geographic range of A. nelsoni is needed to provide the information for mitigation and compensation efforts required by the California Endangered Species Act and Environmental Quality Act.

Development of a recovery plan for A. nelsoni also requires information on population ecology, dispersal, and effects of land-use practices such as livestock grazing, controlled burning, and use of rodenticides on populations of the species.

Background: Elkhorn Plain Ecological Reserve

In July 1987 a research program was initiated on the Elkhorn Plain Ecological Reserve by the California Department of Fish and Game. Its proximate objectives were to inventory the biota of the reserve and develop a plan for its operation and maintenance (Williams and Tordoff, 1988). From the beginning, a research program was planned that could be expanded as funding became available and carried through for a minimum of 5 years. Its long-range objectives were to obtain data on the population ecology of featured species of Endangered and Threatened vertebrates and the impact of livestock grazing on their community.

The Elkhorn Plain Ecological Reserve (Fig. 1) is a 160 acre (64.8 ha) parcel bordering both private and BLM lands on the Elkhorn Plain. A fence was constructed around the reserve, being completed in June 1987. Cattle had been removed from the area in April 1987 because of severe drought and lack of forage.

One-hectare plots consisting of 100 trap stations arrayed in a 10- by 10-meter configuration were established inside and outside the reserve boundaries. On these plots, population censuses for small mammals were conducted simultaneously on three occasions in July, August, and October 1987, prior to reintroduction of cattle to the area.

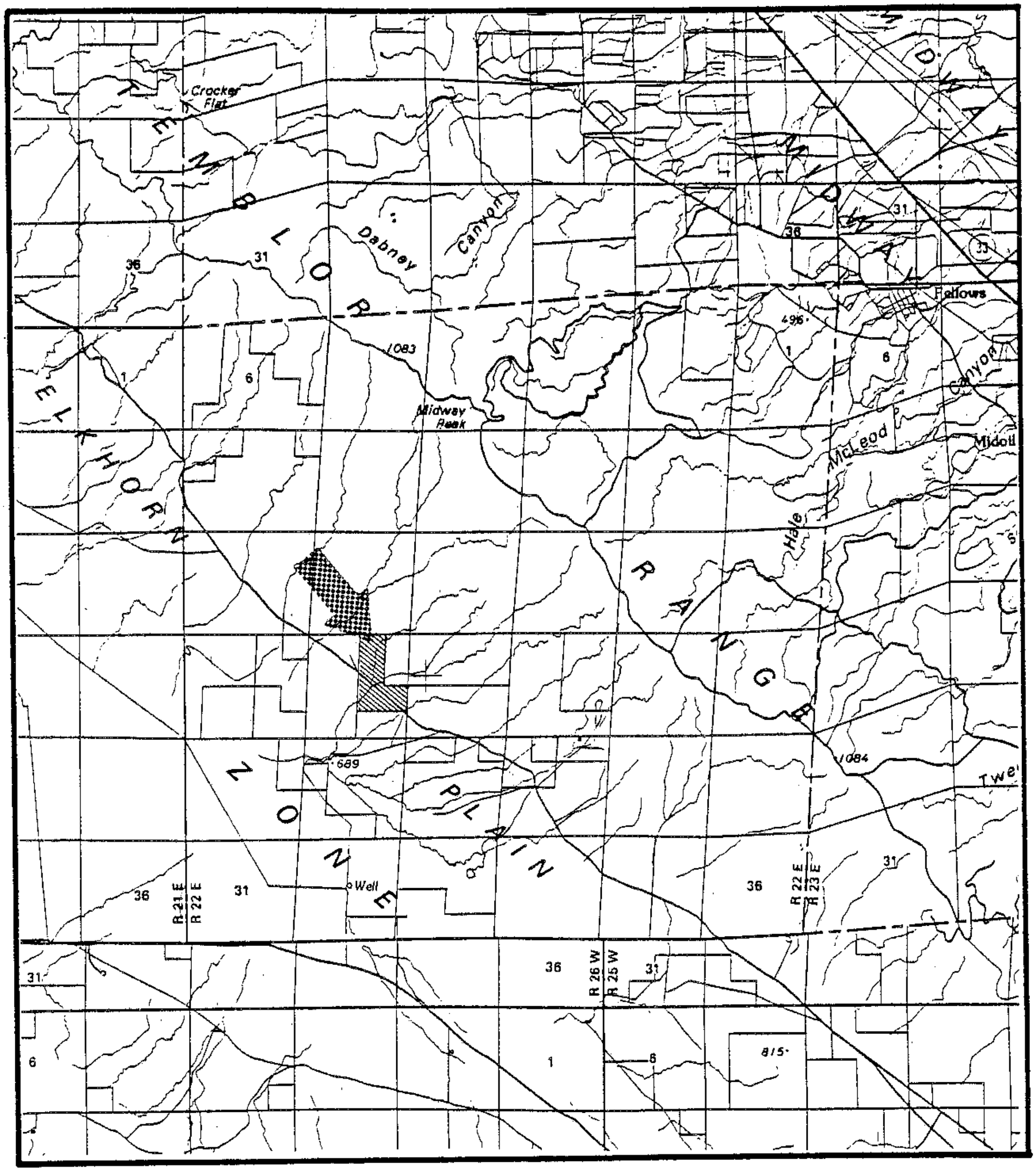

Figure 1. Location of the Elkhorn Plain Ecological Reserve (shaded parcel at tip of arrow), section 20, T32S, R22E, Mt. Diablo Baseline Meridian, San Luis Obispo County.

During August 200 samples of plant litter were collected from 0.25-m^2 quadrats inside and outside the reserve. Sixteen 50-meter transects (8 in reserve, 8 in pasture) were established in 4 plant associations and height and length of all woody and semiwoody plant species were measured using the line intercept method. For each of eight shrub species 10 individuals located on the reserve and 10 in pasture were tagged and measured in three dimensions. To provide a record of changes in plant cover in future years on and off of the reserve, 20 photo stations were established from which 30 photographs were taken during October 1987.

During July and August 1987, each plot was bisected at 1-m intervals and all active and inactive burrow openings, segments collapsed by cattle, depressions, seed caches, and other surface features were mapped. These maps provide a detailed record of burrow features, shrub cover, and disturbances by cattle against which future changes can be measured.

The project was initiated too late in 1987 to determine with certainty the relative ages of kangaroo rats. Young kangaroo rats had reached adult proportions and could not be distinguished reliably from adults. Leopard lizards could not be censused because most adults had become dormant by the time the project was initiated.

Species inventories, censuses, maps, and measures of litter and shrub cover during 1987 established baseline data on control and experimental plots at a time when all plots had been subject to grazing.

Population estimates for small mammals showed no significant differences between experimental and control areas (these data are presented and compared with data from 1988 herein).

The initial method of permanently marking animals with tattoos was shown to be inefficient, resulted in unacceptable numbers of errors in reading marks, and contributed to mortality and injuries to animals during handling. It was decided not to tattoo animals in 1988.

Background information on historic land use on the Elkhorn Plain, summaries of the known biological information on featured endangered species, summaries of preliminary inventories and censuses on the plots, and a program for research required to develop management protocol was presented in the Elkhorn Plain Ecological Reserve Operations and Maintenance Schedule (Williams and Tordoff, 1988).

Cattle returned to the area surrounding the reserve after the final small mammal census in October 1987 and were present through October 1988.

Study Objectives

The goals of this project are twofold: 1) continuation of research on the Elkhorn Plain Ecological Reserve initiated in 1987 -- i.e., develop information on the population biology of *A. nelsoni*, *D. ingens*, *D.*

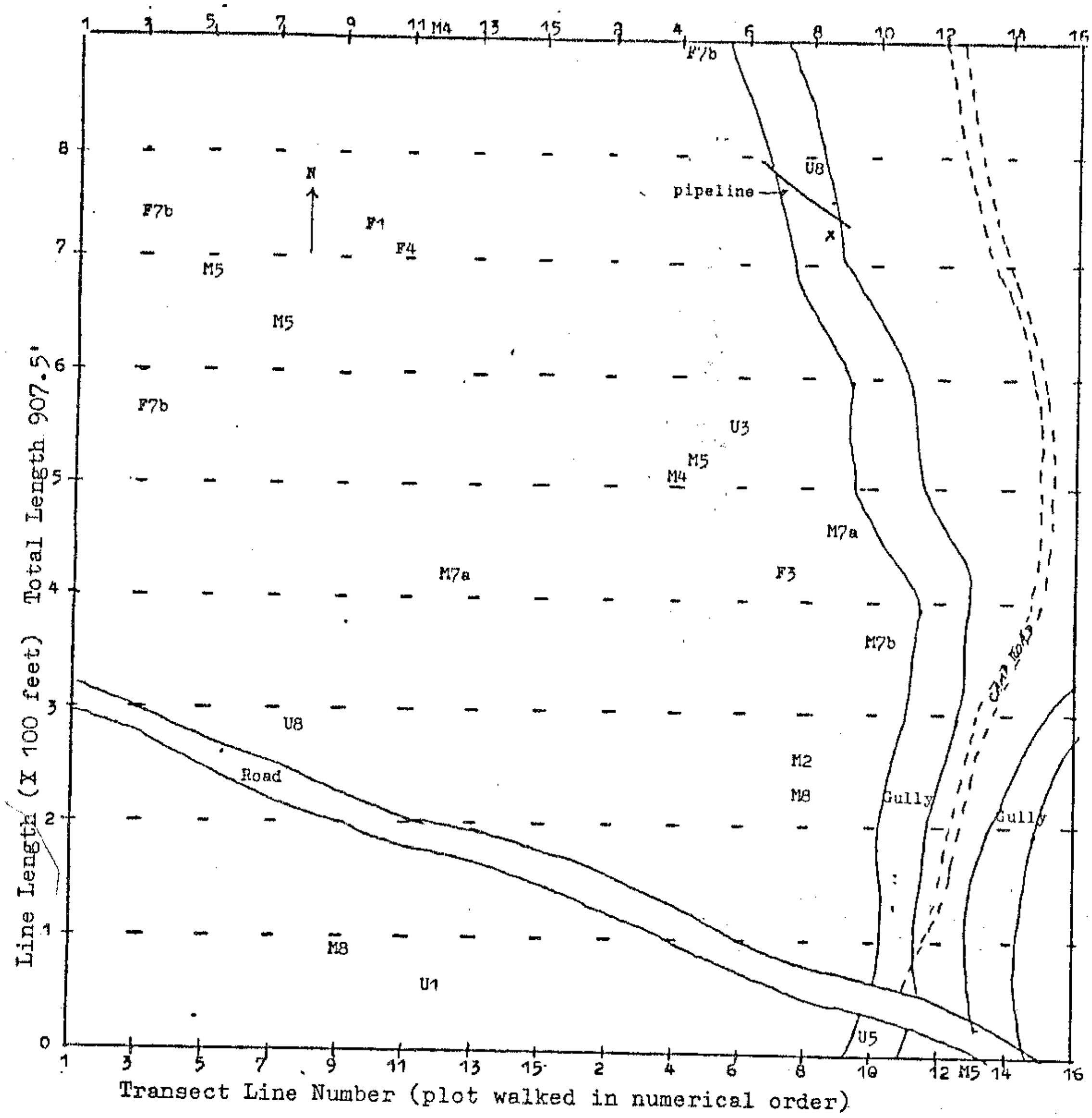

Figure 4. Location of leopard lizards encountered during the June 1988 sampling period on the plot on the reserve. Key: F = female; M = male; U = adult sex unknown; x = rocks present as landmarks. Numbers reference day of sighting in June; a or b indicates AM and PM, respectively.

encountered on the one survey of the on-reserve plot in October although a few juveniles were observed elsewhere during that weekend.

No attempt has been made to estimate densities from the data included in these tables. Average encounters per survey indicate 2.6 and 1.9

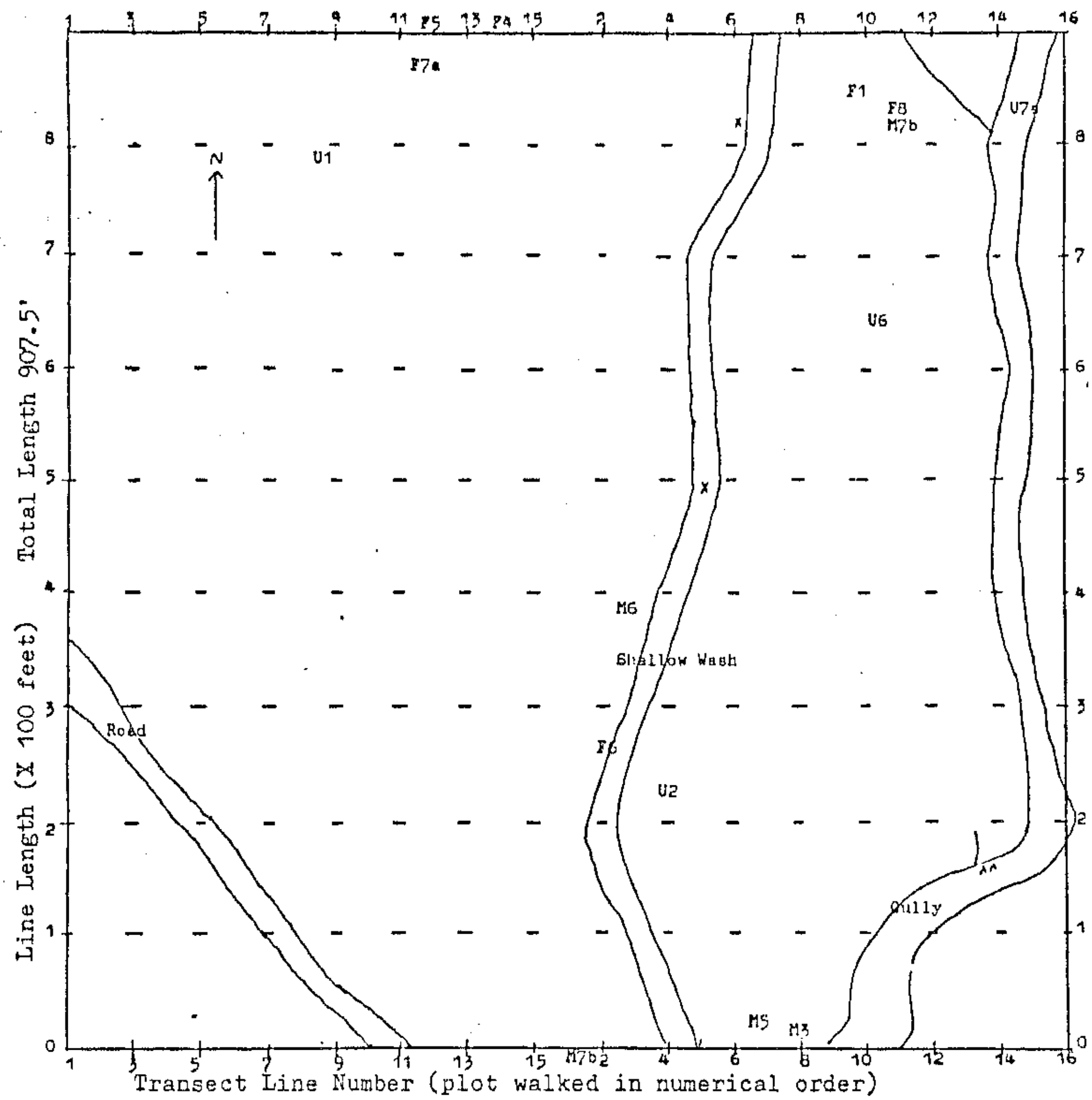

Figure 5. Location of leopard lizards encountered during the June 1988 sampling period on the plot in pasture. Key: F = female; M = male; U = adult sex unknown; x = rocks present as landmarks.

observed in a single day on the plots, respectively, the averages are obviously gross underestimates. On the other hand, without having the permission to capture and mark the animals, we cannot determine whether animals observed on successive days in close proximity are the same or different lizards. In any event, the densities of adults on the Elkhorn Plain are low and when more data are available they will probably fit individuals per plot but since as many as 5 and 3 individuals were

Table 8. Results of surveying plots for Blunt-nosed Leopard Lizards during June, 1988.

	On Reserve				Off Reserve			
Date	Male	Female	Unknown	Total	Male	Female	Unknown	Total
June 1		1	1	2	1		1	2
June 2	1			1			1	1
June 3	1		1	2	1			1
June 4	2	1		3		1		1
June 5	4		1	5	1	2		3
June 6				0	1	1	1	3
June 7 (AM)	2			2	2			2
June 7 (PM)	1	3		4		2	1	3
June 8	2		2	4		1		1
June 9	2	1		3		2		2
TOTALS	15	6	5	26	6	9	4	19
COMBINED TOTALS	21 males		15 females		9 sex unknown		45 total	

within the 0.5 to 3.0 animals per acre which other researchers usually have reported (Sheppard, 1970; Tollestrup, 1979).

There were no significant differences between the two plots in total number of lizards observed, in number of males, or in number of females observed. Although this may be due partly to the low numbers involved, it

Table 9. Results of paired *t*-tests comparing on reserve and off reserve survey results for the June sampling period.

Comparison	*t*-value	d.f	*P*
all captures (on versus off)	1.35	9	0.2
males (on versus off)	2.08	9	0.07
females (on versus off)	1.00	9	0.33
male versus female (on reserve)	1.71	9	0.12
male versus female (off reserve)	0.71	9	0.5

Table 10. Results of surveying plots for Blunt-nosed Leopard Lizards during August, 1988.

Date	On Reserve				Off Reserve			
	Adult	Juv.	Unknown	Total	Adult	Juv.	Unknown	Total
August 10		6		6				
August 11					1(F)			1
August 12		3		3				
August 13								0
August 14		3		3				
August 15						1		1
TOTALS	0	12	0	12	1	1	0	2
COMBINED TOTALS	1 adult (female)				13 juveniles			14 total

is also what was expected for this year since the two plots were located in what was supposed to be comparable habitats and the effects of enclosing the reserve would not be expected to show yet. In succeeding years, as the habitat differences increase between the two plots, the results will probably differ more.

Plant Growth and Productivity

Herbaceous Productivity

Data on mean net above-ground primary productivity of 200 0.25-m^2 plots are shown in Fig. 6. Samples were stratified into units of 50 on and off precincts of giant kangaroo rats in the reserve and pasture, respectively. Values for plots in the reserve represent above-ground primary productivity minus any material eaten by insects, rodents, or rabbits. Sampling frames were repositioned, however, if a randomly chosen site showed evidence of grazing. Except for a centimeter or two around exit holes, there was little evidence of grazing by rodents. Values for plots in the pasture represent material remaining after grazing by cattle. Cattle were present in the pasture when the samples were taken in the first week of April 1988 and were still in the area in October.

Plants represented in samples were recorded and relative abundance noted, but no attempt was made to quantify abundance by species. One of the 200 samples was dominated by red brome (Bromus rubens); all others consisted primarily of Arabian grass (Schismus arabicus), with small

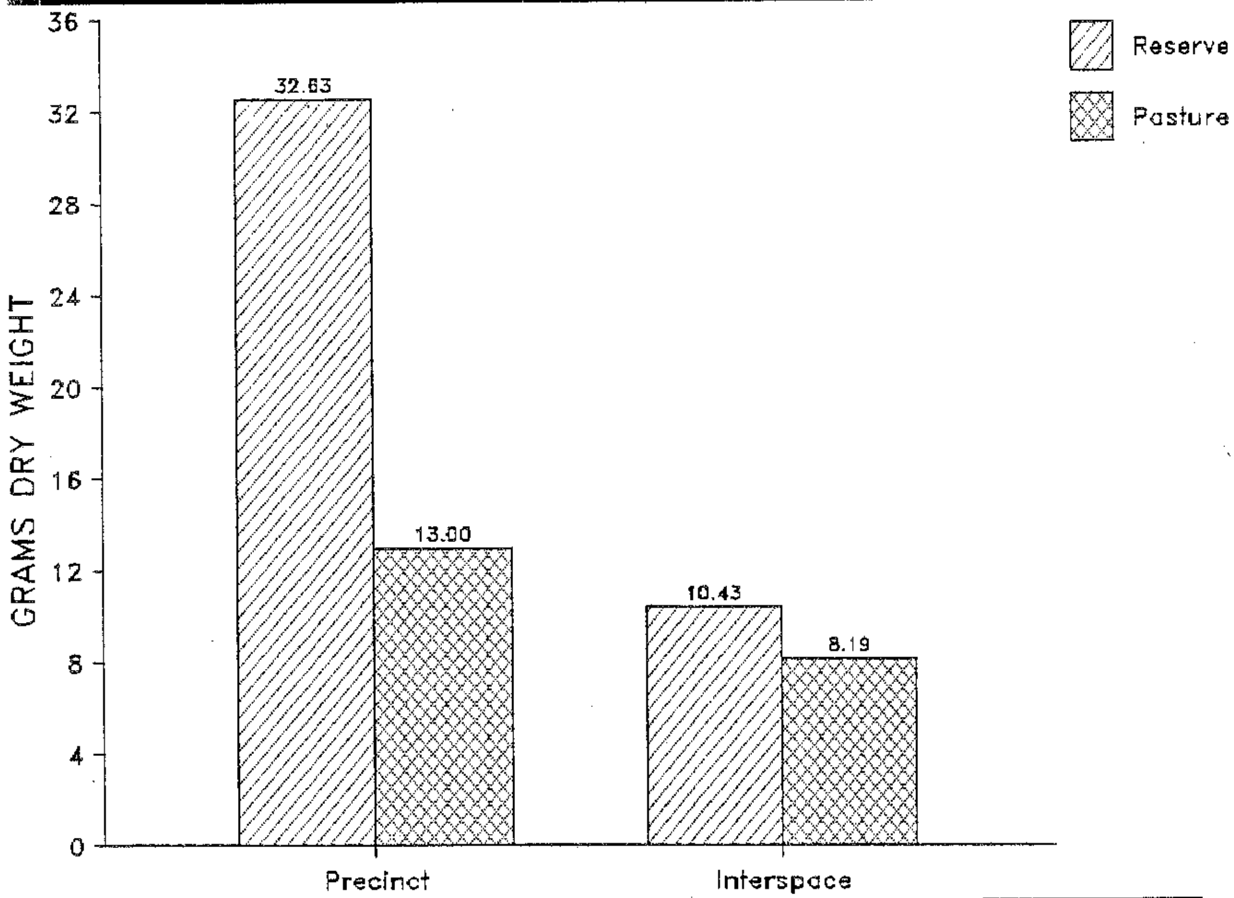

Figure 6. Net above-ground primary productivity (gm dry weight per 0.25-m^2) on (precinct) and off of precincts (interspace) of giant kangaroo rats, measured during April 1988. The reserve samples were from ungrazed areas; those from pasture had been grazed by cattle.

amounts of filaree (Erodium cicutarium), and, less often, lesser quantities of Vulpia microstachys, V. Myuros, or Hordeum leporinum.

Data shown in Fig. 6 were converted to kilograms per hectare and pounds per acre and are listed in Table 11. There was 3.1 times more dry biomass on precincts than on the ground between precincts. This difference is due to the activities of giant kangaroo rats. Probably most important is the digging and loosening of soil on precincts so that rainwater penetrates the soil rather than runs off. Greater productivity may also be due to more organic material and nutrients in the soil on precincts. Precincts are apparently occupied for decades or longer by successive generations of rats. The seed hulls, feces, and other organic material incorporated into the soil probably contribute to the increased productivity.

Table 11. Net above-ground primary productivity of herbaceous plants, primarily Arabian grass (*Schismus arabicus*), during 1988. Matched samples were taken on and off of precincts of giant kangaroo rats on the reserve and in grazed pasture nearby. Values of *t* and *P* are from a two-tailed, paired *t*-test (for within reserve and pasture comparisons) and independent *t*-test (for between reserve and pasture comparisons). Basic statistics are given in gm/0.25 m^2, dry weight.

	Reserve		Pasture	
Statistic	Precinct	Off Precinct	Precinct	Off Precinct
n	50	50	50	50
minimum	13.65	1.59	2.23	1.15
maximum	93.03	35.56	38.31	19.52
mean	32.63	10.43	13.00	8.19
standard deviation	15.40	6.78	8.85	4.34
t (Reserve Precinct vs. Off Precinct)	9.737			
P	< 0.0001			
t (Pasture Precinct vs. Off Precinct)			3.792	
P			0.0006	
t (Reserve Precinct vs. Pasture Precinct)	7.814			
P	< 0.0001			
t (Reserve Off Precinct vs. Pasture Off Precinct)	1.971			
P	0.052			
kg per ha	1305.2	417.2	520.0	327.6
lb per acre	2878.0	919.9	1146.6	722.4

The difference in dry biomass on precincts in the reserve and pasture was 785.2 kg/ha (1731.4 lb/ acre). Cattle had eaten about 60% of the forage from precincts by the first week in April. In comparison, they ate only 89.2 kg/ha (197.6 lb/ac; 21.5%) from the spaces between precincts. Although no samples were taken later than April, the same pattern of differential grazing by cattle persisted into May. By the first week in May, cattle had virtually denuded all herbaceous material on precincts, but had grazed only lightly on grasses in the intervening areas. By this time all of the annual grasses were dead and dry.

Growth of Shrubs and Subshrubs

Mean measurements of volumes occupied by individual shrubs (maximums of length x width x height) are given in Table 12. Differences in volumes between 1987 and 1988 were calculated for individual shrubs. Summary statistics for differences in volumes between 1987 and 1988 are given in Table 12. Volume of shrub growth increased both in grazed and ungrazed areas, but the increase was significantly greater on the reserve compared to pasture. Differences between reserve and pasture by species showed the same general trends, although small sample sizes precluded statistical comparisons. Some shrub species evidenced little or no browsing by cattle and the slight differences in reserve and pasture probably were due to normal variation and sampling errors. Measurements on line transects have not been analyzed yet, but will be summarized in a future report.

Organic Litter

Plant litter samples proved difficult to process in a time- and cost-effective manner. The 400 samples have been cleaned of dirt and organic material dried and weighed, but herbaceous litter has not been separated yet from dung, woody litter, and duff. Data by plant association and year are given in Table 13.

Apparent from the summary statistics (Table 13) are that there were no consistent trends between treatments (years) and place (plant associations), and that variance in many samples was unacceptably high. One-way ANOVA's and tests for homogeneity of variance showed that it was inadmissible to group samples by place to obtain larger samples to reduce intrasample variance and compare treatments. Results of independent *t* tests found significant differences ($P \leq 0.05$) between years for plains samples on the reserve, plains samples in pasture, slope samples on the reserve, slope samples in pasture, and hill samples in pasture; and significant differences were found within years for plains samples in reserve and pasture in 1988 and ephedra samples in reserve and pasture in 1987 and 1988.

The lack of consistent trends and high intrasample variance make interpretations of these data difficult. Most variance within samples appears to be due to three factors: 1) large quantities of woody litter in those few samples taken from randomly selected sites near or under shrubs; 2) large quantities of organic duff in a few samples, the origin of which also was typically under or near shrubs; and 3) large quantities of cattle dung in some samples. These materials represent components of the organic litter available to protect soil and serve as sources of nutrients for the soil community, and they are unequally distributed in space, being found in greatest abundance under shrubs and closest to resting areas for cattle near water troughs.

The major sources of intrasample variance that prevent reliable interpretations of differences between years and grazing treatment will be excluded when herbaceous litter is sorted from other organic materials.

Table 12. Summary statistics for differences in volumes of individual shrubs measured in 1987 and 1988. Shrubs in the reserve were not available to cattle in 1988. Statistics are in cubic meters. Values of *t* and *P* are for the 2-tailed, independent *t*-test. Only mean differences are given for individual species.

Shrub Statistic	Reserve Difference (1988-1987)	Pasture Difference (1988-1987)
Lycium andersoni	0.124	-0.043
Eriogonum fasciculatum	0.031	0.034
Hymenoclea Salsola	0.309	0.166
Eastwoodia elegans	0.029	0.045
Ephedra californica	1.293	0.317
Eurotia lanata	0.067	0.051
All Shrubs (pooled)		
n	60	60
minimum	-0.331	-0.932
maximum	4.566	3.490
mean	0.312	0.097
standard deviation	0.725	0.330
t	2.069	
P	0.041	

This will be accomplished as soon as funds are available. The herbaceous litter present in grazed and ungrazed areas will reflect the intensity of grazing by cattle. Comparison of values on herbaceous litter and herbaceous productivity from the ungrazed reserve will provide a measure of grazing by rodents, rabbits, and insects.

Table 13. Statistical summaries of dry weight of all organic litter collected on 0.25-m^2 plots in August 1987 and 1988 on the Elkhorn Plain. Both treatments (Reserve and Pasture) were grazed in 1987; in 1988 the Reserve was not grazed.

	Reserve		Pasture	
Statistic	1987	1988	1987	1988
	PLAINS GRASSLAND ASSOCIATION			
n	25	25	25	25
minimum	8.40	40.45	1.41	35.53
maximum	61.32	155.22	110.07	166.75
mean	31.54	92.26	31.83	73.18
standard deviation	13.15	30.75	22.72	35.04
	SLOPE EPHEDRA ASSOCIATION			
n	25	25	25	25
minimum	5.48	20.45	5.57	35.53
maximum	53.05	87.14	112.57	43.71
mean	29.76	40.32	53.34	22.18
standard deviation	13.35	17.36	29.44	10.50
	HILL SHRUB/SUBSHRUB ASSOCIATION			
n	25	25	25	25
minimum	2.06	6.95	2.48	6.00
maximum	142.77	76.47	56.84	220.01
mean	34.20	27.72	24.00	47.12
standard deviation	32.95	17.43	14.84	50.37
	ARROYO ASSOCIATION			
n	25	25	25	25
minimum	0.12	0.80	2.23	1.95
maximum	173.47	123.97	138.24	309.43
mean	30.44	36.35	28.51	43.42
standard deviation	40.69	33.52	33.70	81.95

List of Plants on the Elkhorn Plain Ecological Reserve

The following plant list was developed from observations in 1987 and 1988. It is incomplete because there was no activity on the reserve prior to late March 1988. A portion of the list was provided by Ann and Doug Chadwick under the supervision of George Sheppard of the BLM.

Amaryllidaceae

Brodiaea pulchella

Boraginaceae

Amsinckia vernicosa
Amsinckia tessellata
Pectocarya penicillata
Plagiobothrys sp.

Compositae

Achyrachaena mollis
Chaenactis stevioides
Coreopsis calliopsidea
Eastwoodia elegans
Eatonella Congdonii
Gutierrezia bracteata
Haplopappus acradenius
Hymenoclea Salsola
Lasthenia coronaria
Microseris sp.
Monolopia lanceolata
Monolopia stricta
Senecio vulgaris

Cruciferae

Brassica geniculata
Erysimum capitatum
Lepidium nitidum
Sisymbrium sp.
Thelypodium lasiophyllum
Tropidocarpum gracile

Ephedraceae

Ephedra californica

Fabaceae

Astragalus didymocarpus
Astragalus lentiginosus var. *nigricalycis*
Lotus humistratus
Lupinus ruber
Lupinus horizontalis
Trifolium depauperatum

Geraniaceae

Erodium cicutarium

Gramineae

Bromus rubens
Hordeum leporinum
Poa scabrella
Schismus arabicus
Stipa speciosa

Vulpia microstachys
Vulpia Myuros

Hydrophyllaceae
Pholistoma membranaceum
Phacelia tanacetifolia

Onagraceae
Camissonia Boothii decorticans
Camissonia campestris campestris

Papaveraceae
Eschscholzia Lemmonii
Platystemon californicus
Stylomecon heterophylla

Plantaginaceae
Plantago erecta

Polemoniaceae
Eriastrum pluriflorum
Gilia clivorum
Gilia minor
Linanthus Bigelovii
Linanthus liniflorus
Microsteris sp.

Polygonaceae
Eriogonum angulosum
Eriogonum fasciculatum var. polifolium
Eriogonum roseum
Eurotia lanata

Portulacaceae
Calandrinia ciliata
Montia perfoliata

Scrophulariaceae
Orthocarpus densiflorus

Solanaceae
Lycium andersonii

Ranunculaceae
Delphinium gypsophilum
Delphinium Parryi
Paeonia californica

Umbelliferae
Lomatium utriculatum

DISCUSSION

Small Mammals

Estimates of density on plots were less precise than desirable because there were too few columns and rows to use the nested subgrid method of estimating strip width effectively (White et al., 1982). Estimates of total population size on grids provided a better measure than density, because strip width was not part of the computation procedure. For this reason, statistical comparisons between plots and years were limited to data on population size (Table 4).

Additional undesirable variance was introduced into capture statistics from several sources. At the beginning of each trapping session in 1988 significantly fewer animals were captured on plot 2 in pasture than on the reserve. After 2 or 3 days of trapping in each session, however, captures on the two plots were nearly equal. The probability of capture increased for most individuals of both species of kangaroo rats after their first capture, and to a greater extent after their second capture; a majority of the population became habituated to traps. Considering this factor and the great sensitivity of the auditory systems of kangaroo rats (Webster and Webster, 1975), a reasonable hypothesis to explain the differential rates of capture is that the animals heard our activities on their burrow systems and responded by emerging in greater numbers than they would have in our absence. Animals in pasture, being habituated to cattle walking around on their precincts, did not respond as readily to the noises made by our activities.

Another source of undesirable variance in capture data derived from the inability of some researchers to handle giant kangaroo rats effectively and to read numbers correctly. Reading tattoos and small ear tags and inspecting animals for signs of reproductive activities required that animals be restrained by hand. The animals are strong and their loose skin makes it difficult to obtain a proper hold that will restrain the animal without injury to itself or its handler. An unacceptable number of animals escaped restraint prior to reading their numbers. This introduced heterogeneity into the data that could not be compensated for in statistical computations. A small percentage of obviously misread tags was also a source of heterogeneity. These data had to be discarded, but at the cost of additional heterogeneity.

Heterogeneity in captures also stemmed from trap bias (Table 7). This bias was anticipated, and procedures instituted to negate its effects in comparing experimental and control plots. Nevertheless, heterogeneity from this source affected selection of population estimation models and increased the variance of computations.

Visual observations of animals released on plots and measurements of distance traveled to burrows off of plots upon release suggest that the effective sampling area of plots was about 1-ha. Trap stations arrayed in a 10- x 10-m grid means 90 m between end traps in columns and rows. Assuming that the traps sample a 5-m band on the perimeter of the grid, the plot size is 1 ha. The mean distance individuals were observed to move to burrows off of plots was 5 m for A. nelsoni, 4.5 m for D. ingens, and 6 m for D. nitratoides (Table 5), suggesting an effective sampling area of about 1 ha. However, other observations show that A. nelsoni and D. nitratoides make longer movements in their day-to-day activities than giant kangaroo rats; thus the effective sampling areas of the plots is probably greater than 1 ha for these two species.

In addition to the larger size of home ranges, the low numbers of antelope squirrels and San Joaquin kangaroo rats captured on plots makes plots of 1-ha size too small to effectively estimate densities (Table 3). However, comparisons of total numbers marked in 1987 and 1988 are statistically valid. Also complicating the censuses for A. nelsoni was the habituation to traps by giant kangaroo rats. Some giant kangaroo rats often returned to traps after their release in the morning, and some were found in traps at subsequent checks during the day. One animal died from heat stress in a shaded trap by entering the trap between 1100 and 1200 h when the air temperature did not exceed 33°C. After this incident traps were closed during the first morning check, and not reopened until between 1700 and 1800 h, providing little opportunity to capture antelope squirrels.

Numbers of A. nelsoni and D. ingens marked on plots increased on both plots in 1988, but the increase in pasture was not significant at the 0.05% level for A. nelsoni (Table 2). Numbers of D. nitratoides decreased in 1988 on both plots. Changes in estimated population sizes showed the same trends between 1987 and 1988 as numbers marked.

In 1987 there were no significant differences in estimated numbers of D. ingens on plots 1 and 2 (tables 3 and 4). The March-April 1988 census found greater numbers on the plot in pasture than on the reserve (Table 3), although the difference was not quite significant (Table 4). By August 1988, estimated population sizes of D. ingens on the reserve and pasture had reversed, with greater numbers on the reserve, and the difference was highly significant. The initial increases on both plots probably were due to a common environmental factor. The increase probably was sustained on the ungrazed plot by higher survivorship and greater recruitment. However, data are not sufficient yet to make conclusive comparisons and have not been analyzed to determine if there are differences in survivorship and recruitment.

The increases in estimated densities of A. nelsoni and D. ingens may have been due to more and better timing of rainfall in 1988. The 1986-1987 wet season resulted in a severe drought on the Elkhorn Plain. By the first week of April 1987 most plants had started to dry and only Erodium cicutarium had produced a noticeable crop of seeds (Williams and Tordoff, 1988). In contrast, the 1987-88 wet season, while probably average or below in total precipitation, produced a large crop of grass seeds. The increased availability of food may account for the greater numbers of these species on plots.

The increases in numbers of A. nelsoni and D. ingens in 1988 were in marked contrast to the nearly 50% decrease in numbers of D. nitratoides (Table 2, Fig. 2). The low number of captures of San Joaquin kangaroo rats in the March-April session was noted and presumed to be due to trapping during the period of full moon. The May and June 1988 sessions also coincided with full moons. The low rate of capture of D. nitratoides did not increase substantially, however, during the later sessions that were timed to be at or near the new moon. It is doubtful that the reduced numbers captured can be attributed solely to moon phase. Captive San Joaquin kangaroo rats showed no significant curtailment of activity during times of full moon (Lockart and Owings, 1974).

Excluding the November 1988 trapping session, 7 of 30 (23%) San Joaquin kangaroo rats were judged to be young when first captured in 1988. In contrast 82 of 169 (48.5%) giant kangaroo rats were considered to be young when first captured in 1988. The numbers of young are probably underestimated because animals first captured in August and October could not be reliably aged. Even so, these data suggest greater productivity or survivorship of young D. ingens.

The decrease in numbers of D. nitratoides may have been due to an increase in the numbers of D. ingens. D. nitratoides has a much larger home range than D. ingens (Braun, 1985) in which to gather food and requires less food due to smaller size than D. ingens (mean body weights of about 40 and 130 g for D. nitratoides and D. ingens, respectively). The drought in 1986-1987 may have adversely affected D. ingens, reducing population size and thereby allowing the number of D. nitratoides to increase. Greater moisture and seed production in 1988 probably was responsible for a significant increase in numbers of giant kangaroo rats, which in turn may have reduced the number of San Joaquin kangaroo rats.

That competitive superiority and aggressiveness of giant kangaroo rats probably are factors affecting the abundance of San Joaquin kangaroo rats has support from a variety of observations. Giant kangaroo rats appear to exclude most other small mammals from their better-quality habitats. Both Grinnell (1932) and Hawbecker (1951) remarked on the general absence of other small mammals in areas inhabited by D. ingens. Wherever Grinnell (1932) found giant kangaroo rats, they dominated the community to the exclusion of all other rodent species. He wrote, "Over thousands of acres the 'colonies' are spaced out over the level or rolling cattle range, this being here apparently the only rodent, taking the place of the ground squirrels elsewhere." Hawbecker (1944, 1951) and Tappe (1941) corroborated some of these observations, finding that giant kangaroo rats excluded all other nocturnal rodents from areas where they occurred. On the Elkhorn Plain, San Joaquin kangaroo rats were most abundant in arroyos and on steep slopes and narrow ridgetops where giant kangaroo rats were few or absent. Giant kangaroo rats were the only nocturnal small mammals occupying the shrubless, nearly level ground (Williams and Tordoff, 1988). We have not found extant colonies of D. ingens elsewhere where no other species of rodents occurred, although in large colonies, giant kangaroo rats were the predominant species. Williams (in press) attributed this to the fact that most extant habitat for giant kangaroo rats was of lower quality than areas study by Grinnell and Hawbecker.

Giant kangaroo rats also apparently are aggressive toward other small mammals. Shaw (1934) reported one aggressive encounter between a giant kangaroo rat and a small mouse, and speculated that exclusive occupancy of expanses of ground by giant kangaroo rats was maintained by interspecific aggression. Hawbecker (1944) reported that a giant kangaroo rat chased an antelope squirrel out of a burrow entered by the latter. On the Elkhorn Plain Ecological Reserve we saw giant kangaroo rats emerge from their burrows during daytime and chase antelope squirrels away from their precincts. We witnessed several such incidents in June, August, and October at times after seed caches had been removed from the surface of precincts and stored in larders within the burrows of giant kangaroo rats. It appears that giant kangaroo rats vigorously defend their precincts from trespass by other small mammals, even when food caches are not vulnerable to raiding, and may be the principal reason for the general absence of other small mammals where giant kangaroo rats are found.

Seed Caches of *Dipodomys ingens*

Aspects of seed caching behavior of giant kangaroo rats was first reported by Shaw (1934). Shaw described in detail the small, thimble-sized pits on the surface of precincts that result from caching seeds. He also measured underground larders, and described the sequence of cutting and curing seedheads in surface pits, then moving the caches to underground larders. Later, Hawbecker (1944) described seedhead caches placed in large piles on the surface of precincts to dry in the sun. Surface piles that Hawbecker measured averaged about 5 x 10 x 61 cm, considerably smaller than the surface caches found in this study (Table 6).

There appears to be considerable individual and geographic variation in seed-caching behavior of giant kangaroo rats. On the Elkhorn Plain, pit caches of giant kangaroo rats typically were closely spaced and were always covered with a layer of loose dirt. Some caches consisted of a mixture of several liters of loose dirt and seedheads piled on the surface and others contained only seedheads. These caches were not disturbed so it is not known if pit caches were always located under the pile, but sometimes traces of pit caches could be seen under surface piles. Some caches consisting primarily of pits had scattered seedheads on the surface; others had piles of seedheads from 0.1 to several centimeters deep covering portions of the pit caches. In any area of about a hectare could be found caches consisting wholly of closely spaced pits, mixtures of dirt and seedheads piled on the surface, and large haystacks. In some parts of their geographic range, surface piles or haystacks were seldom observed. This may have been due to depredation by livestock or to differences in caching behavior.

Although it is clear that cattle ate haystacks of giant kangaroo rats (Table 6), there is no direct evidence that loss of these caches reduced survivorship of owners. Other methods of curing seedheads in pits covered over with loose dirt or mixing seedheads with loose dirt on the surface of the precinct probably do not result in loss to cattle. Our observations suggest that giant kangaroo rats experiencing loss of surface piles may have responded by increasing the amount of seedheads placed in pits. This hypothesis can be tested by sweeping the surface of precincts clear of loose dirt in June after caches have been moved to larders in burrows and counting numbers of seed pits in reserve and pasture.

Individuals which experience significant losses to depredating cattle may also be able to compensate by continued seed gathering during summer and fall. This likely takes much greater effort per unit of seeds gathered because seedheads have shattered and dispersed their seeds, and fewer seeds are available due to competition with ants, birds, and cattle. Evident from our observations, however, is that giant kangaroo rats continue to gather seeds throughout the year, even after their main harvest has been stored and their larders filled.

Numbers of active precincts as evidenced by their seed caches, primarily in April and May, is probably the best measure of the number of adult animals, and may be the most efficacious method of estimating populations without the need for trapping. In all but one case out of 126 precincts examined in a 4.4-h area, there was only a single area on precincts devoted to seed caches. In that one case, two large surface piles were separated by about 2 m. On many precincts, haystacks started out from two or more small, independent piles located less than 1 m apart, but eventually merged as they grew. It is not known if resident young assist their mother with seed harvest, or if they disperse in time in spring to cut and cure seedheads before they dry and shatter. If they do not, then number of precincts with active seedhead caches would directly measure the size of the adult population.

Although not reported in the literature, some populations of D. heermanni also cut and cache seedheads in large piles. This has been noted in the southern San Joaquin Valley in the vicinity of the Elk Hills (R. Anderson and L. Spiegel, pers. comm.), and in western and central Merced and Madera counties (unpubl. data). Surveys and population censuses for giant kangaroo rats that depend solely or mainly on the presence of haystacks to identify giant kangaroo rats are likely to be unreliable.

Blunt-nosed Leopard Lizards

Surveys on the two plots need to be continued on a yearly basis. Despite the fact that unseasonably cold weather in 1988 prevented a 10-day sampling period at the beginning of May, a sampling regime of multiple 10-day periods (beginning of May, June) probably is the proper way to conduct this study and we plan to have both May and June surveys in 1989. The fact that we were able to identify individual lizards seen on successive days by their locations indicates that this survey is preferable to scattered days during a 2-month period. However, without being able to mark lizards for positive identification upon later encounters, we will not be able to positively determine densities, territories, or movements. Our maps for 1988 show clusters in which all sightings occurred within a 50-ft radius which probably represent the same lizard. However, we also have multiple sightings on a single day within a comparable area which obviously represent two lizards. Only through marking animals will we be able to know the true situation. We therefore will request permission to noose and mark leopard lizards for 1989. Markings need to be both permanent and legible without multiple recaptures (i.e. optically from a distance). Sewing colored beads seems to be the ideal way to do this. However, should permission for this not be forthcoming, temporary marking with colored ink for visual identification coupled with toe-clipping for long-term identification would be acceptable. The long term nature of this study offers an ideal opportunity to learn about population dynamics but this can only be done through marking individuals.

Plant Growth and Productivity

Data from this study show that activities of giant kangaroo rats benefit livestock production by increasing the productivity of grasses and forbs on their precincts. Cattle were the primary beneficiaries of this increased productivity (Fig. 6 and Table 11), focusing their grazing in the greener, lusher-appearing growth on precincts. Williams (1985) reported similar results in a preliminary study involving the fencing of individual precincts to exclude sheep. Productivity on precincts averaged 1.8 times greater than in intervening areas. Williams (1985) believed that in areas or years with lower rainfall, the productivity on precincts would be greater in comparison to interprecinct spaces. In unfenced areas, sheep focused grazing on precincts and left the growth of grasses in intervening spaces largely untouched. Hawbecker (1944) measured 560% more plant biomass on precincts in the Panoche area, but data sufficient to make statistical comparisons were not reported.

The growth on precincts also may be more nutritious with larger quantities of nitrogen and other nutrients. It appeared to be darker green, stayed green longer, and was obviously preferred by livestock even when grazed to a level below surrounding grasses of the same species. The samples taken in 1988 have been stored until they can be analyzed for nitrogen. In future years, soil samples will be taken from the same plots where herbaceous samples are collected, and both the plant and soil samples will be analyzed for nitrogen content.

Our observations convince us that the kangaroo rats and antelope squirrels eat an insignificant amount of green herbaceous material and do not adversely impact livestock by competing for green forage. If livestock were removed from the range at the time when annual grasses ripened and dried, their grazing probably would have little impact on small mammals because of the abundance of seeds remaining. Removal of livestock upon ripening of the annual grasses is also good animal husbandry because once California annual rangelands dry out, the nitrogen content of forage drops precipitiously and cattle do poorly and often loose weight on this range unless given high-nitrogen supplements. Cows held on dry annual rangelands are thin, producing fewer and smaller calves that weigh less at weaning and bring a lower price per pound than calves from cows fed supplements or pastured elsewhere (Wagnon et al., 1959).

Cattle also exhibited a significant impact on woody shrubs on the Elkhorn Plain during 1988 (Table 12). Buckwheat (Eriogonum fasciculatum), winterfat (Eurotia lanata), and bandergee (Eastwoodia elegans) apparently were not browsed significantly by cattle in 1988. Buckwheat and winterfat are relished by cattle, but bandergee is not considered to be a plant that they normally eat (Sampson and Jespersen, 1963). Buckwheat and winterfat grew almost exclusively on the steep slopes and narrow ridges uphill from the watering trough. Cattle rarely grazed in these areas compared to the flat and gently sloping ground downhill from the watering tank, sites where desert thorn (Lycium andersoni) and ephedra were common. Cheeseweed (Hymenoclea Salsola) grew mainly in the gravel soils along the bottoms of arroyos where slopes were gentle. The latter three species were most heavily browsed by cattle, but only ephedra was considered by Sampson and Jespersen (1963) to be palatable to livestock .

CONCLUSIONS

Numbers of A. nelsoni and D. ingens on both grazed and ungrazed plots increased in 1988 compared to the drought year, 1987. These increases probably were due to greater precipitation and plant productivity in 1988. Numbers of D. nitratoides declined nearly 50% on both grazed and ungrazed plots in 1988. The percentage of young animals marked on plots in 1988 was more than 50% higher for D. ingens, suggesting that differences in productivity and recruitment at least were partly responsible for the observed increase and decrease of D. ingens and D. nitratoides, respectively. Competition and the aggressiveness of giant kangaroo rats may have been the principal reason for decline in the population of San Joaquin kangaroo rats in 1988.

By August 1988, the estimated number of giant kangaroo rats on the ungrazed plot was significantly greater than on the grazed plot. This change needs to be confirmed by additional censuses and more detailed analyses of survivorship and recruitment.

During 1988, it appears that antelope squirrels and both species of kangaroo rats were semelparous and that young-of-the-year did not breed. The timing of reproduction for D. nitratoides appeared to be about 4 to 6 weeks behind that of D. ingens. A. nelsoni also bred later in the spring than D. ingens.

Growth of herbaceous plants was over three times greater on the precincts of giant kangaroo rats than in intervening areas. Cattle focused their grazing on the lusher, greener grass on precincts to the virtual exclusion of grass in intervening areas, only turning to the latter when the grass on precincts was nearly gone. Cattle also browsed significantly on shrub species that were readily available in areas downhill and on gentle slopes, including those that were not recorded as being regularly eaten. Shrubs on steep slopes and narrow ridgetops uphill from the water trough were browsed lightly or not at all in 1988, even species relished by cattle. This fits our observations that the cattle rarely traveled uphill from the water trough to graze in 1988. Differential use of downhill and uphill areas within the pasture complicated our comparative studies and, in our opinion, resulted in great overuse of the downhill areas. Overbrowsing by cattle may be the principal reason why the flatter areas on the Elkhorn Plain are shrubless today.

Samples of plant material obtained in 1988 and future samples of herbaceous material and soil will be analyzed for nitrogen content to determine if herbage on precincts of giant kangaroo rats has a different nitrogen content than that from intervening ground.

Cattle affected seed harvest by giant kangaroo rats by eating surface caches. The kangaroo rats may have responded by caching more seedheads in pits covered with dirt or by mixing seedheads with dirt. In the future, counts and measurements of seed pits will be made after the caches have been moved to underground larders. Numbers of seeds remaining in soil on precincts and intervening ground in grazed and ungrazed areas will also be measured in autumn to better document the effects of cattle on food resources of granivorous rodents.

Adjustments to the census protocol must be made to reduce the sources and amounts of heterogeneity in capture data, and to provide sufficient data for population estimation at the desired level of statistical precision. These adjustments include the necessity for a 2- or 3-day prebaiting period because of differential response to trapping on and off of the reserve, apparently due to the presence of cattle. Also required is the expansion of the plots from 10- x 10-trap grids to 12- x 12-trap grids to provide more captures and an additional nested-subgrid band to reduce variance in estimating plot strip widths. Other changes called for include the development of a simple restraining device to reduce handling time and the number of animals that escape restraint before they are identified. Marking animals with PIT tags (electronic microchips) should overcome the problem of high rate of ear-tag loss experienced for _A. nelsoni_ and the occasional reading errors detected for tattoos and small ear tags.

Antelope squirrels cannot be adequately censused on 1- or 1.44-h plots, and it has proved to be infeasible to study both kangaroo rats and antelope squirrels on the same plot because of the diurnal activity of giant kangaroo rats habituated to traps and their great sensitivity to high ambient temperatures. A 400- x 400-m plot (40-m spacing) may be required, although the layout of the Ecological Reserve and position of the existing plots may prevent use of the reserve as the ungrazed site. A 20-acre plot on the Elkhorn Plain was fenced during 1988 by the BLM for studies of effects of livestock grazing. This plot is only about half the size needed for a 16-ha plot, but perhaps a 250 x 250-m plot (15.4 ac) would suffice; this size of plot could be accommodated within the BLM plot.

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PART 2

SAN JOAQUIN ANTELOPE SQUIRREL:
CENSUS METHODS AND POPULATION STUDIES

by

John H. Harris
Biology Department
Mills College
Oakland, California 94613

Introduction

The San Joaquin Antelope Squirrel (Ammospermophilus nelsoni) is listed as Threatened in California (California Department of Fish and Game 1980). Habitat loss is responsible for the current status of the species and is currently the primary problem facing antelope ground squirrels. Use of rodenticides and overgrazing may also be important threats in some areas. The historical distribution of the squirrels included the southern and western portions of the San Joaquin Valley and adjoining upland habitats, Tulare Basin, and upland habitats of the Carrizo and Elkhorn Plains, Elk Hills and Cuyama Valley. About 80% of the species original range had been lost to cultivation by 1979 (Williams 1981), and most of the remaining habitat is not considered to be prime quality. The center of the species current distribution is the southwestern margin of the San Joaquin Valley and adjacent upland habitats, principally the Elk Hills and Elkhorn Plain. Small, generally isolated populations are found on the San Joaquin Valley floor, in the Cuyama Valley, and in the Panoche and Kettleman Hills.

Much of our knowledge of the basic biology of San Joaquin Antelope Squirrels is based on the work of Hawbecker (Hawbecker 1947, 1951, 1953, 1958, 1975). This body of work documented the diet, habitat use, movements and home range, and annual cycle of the species. The majority of Hawbecker's extensive fieldwork was conducted at a set of study plots on the eastern edge of Panoche Valley, in the northwestern portion of the species historic range. Recent work has been focused on determining the species status in California with reference to efforts to conserve the species. Williams (1981) conducted a survey for the San Joaquin Antelope Squirrel, documenting its contracted range. Recent surveys conducted by the California Energy Commission (Anderson et al., unpubl. data) have added to our knowledge of the species current distribution.

The current distribution and habitat relationships of San Joaquin Antelope Squirrels are known generally, but there are significant gaps in our knowledge which are of importance in determining a conservation strategy for recovery of the species. Several areas within the historic range of antelope squirrels have not been surveyed recently. Some of these sites are in the northern parts of the species range, where antelope squirrels are rare. Thus they may be critical to conserving genetic variation in the species. There is a need to refine survey and census techniques to more accurately determine the density of antelope squirrels. This information is critical for planning the acquisition of habitat for preservation and for assessing habitat management. In addition, accurate census techniques are basic to determining habitat relationships and population dynamics. There is little information on the density of antelope squirrels in different habitats in the remaining range. Furthermore, even if densities are similar in these habitats, it may be that habitats differ in productivity, or that some habitats are occupied by non-breeding dispersers (Van Horne 1983).

The purposes of this study are to locate additional populations of antelope squirrels, develop census methods for the species, and determine population densities at different sites with a range of plant communities reflecting differences in habitat quality.

Methods

Surveys

Previous studies (Williams 1981) identified several potential study areas for future surveys, based on their location within the historical range of the San Joaquin Antelope Squirrel, presence of potential habitat for the squirrels, but lack of historical records. These included the Ortigalita Mountain region (Merced Co.), Kettleman Hills (Fresno and Kings Cos.) and portions of the Cuyama Valley (San Luis Obispo Co.).

To survey these areas, we examined the general region by car, choosing sites for surveys on foot based on presence of shrub cover and lack of extreme disturbance (e.g. cultivation). While driving through survey areas, we frequently stopped to look and listen for squirrels in suitable habitat. Since our objective was simply to locate populations, attempted to cover as much ground as possible on foot, without spending time to survey transect lines or live-trap. We looked for squirrels, listened for calls, and noted any evidence of possible burrows of appropriate size. The general nature of the habitat was noted, especially where squirrels were located.

In addition to areas chosen for surveys, we also noted any squirrels seen while we worked on or travelled near live-trapping study plots. With one exception, these observations were not new locations for the species. However, they do document the continued existence of the species in these areas.

<u>Study Plots</u>

Trapping and Marking Methods

We located live-trapping study plots based on previous distributional surveys. We attempted to find sites with a range of habitat suitability within each of three general areas in the species range: northern upland, southern upland, and valley floor. Northern upland sites were located on BLM lands in the Panoche Hills, Fresno County. These plots were on a bench at the northwestern end of the Panoche Hills (Table 2). The principal vegetation on this bench is Ephedra scrub, with grass under story. Some plots which were trapped during efforts to locate plots were Atriplex-dominated communities, but these sites did not yield antelope squirrels. Southern upland sites were located in the Elkhorn Plain area on lands administered by the BLM. These sites were dominated by Ephedra, but also had significant cover of other shrubs, primarily small Eriogonum and Gutierrezia species. Valley floor sites were located in the Semitropic Ridge region, on lands belonging to The Nature Conservancy. These sites were primarily Atriplex scrub, although Salsola was prevalent, especiially in microhabitats which appear to be frequently flooded. Two additional sites were trapped briefly in the Buena Vista Valley, on lands belonging to Chevron, USA. These were in an area transitional between valley floor and upland habitats and were dominated by Atriplex scrub.

At sites where we immediately observed a number of squirrels, we set out 100 Sherman live traps in a 10 x 10 grid. At our first site, near the Elkhorn Plain Ecological Reserve, we established a grid with a spacing pattern of 40 meters between traps. This grid covered 16 hectares, and would have been too large for some of the study areas on smaller parcels of land. All subsequent trapping grids had a 25 meter trap spacing. Some trapping plots were initially studied by setting out 40-100 live traps without surveying a grid. In such a case, we spaced the traps by pacing, attempting to approximate a 25 meter spacing pattern in suitable habitat. Where squirrels were located, we established grids, otherwise we continued trapping with the existing trap arrangement for 2-3 days. Grids were trapped for 3-6 days. At each trapping grid we determined the density, height and diameter of shrub species using 50 point-quarter shrub counts (Cottam et al. 1953).

Traps were opened early in the morning and checked throughout the day. On some very hot days, we closed traps for 3-4 hours during the afternoon, then opened traps for the late afternoon and early evening. In general, on very hot days the morning was a more productive trapping period. Traps were placed in the shade of shrubs where possible. A burlap shade was draped over traps which were in the open. Mixed bird seed was used to bait the traps.

For all captured animals, the weight, sex, and age were noted, as well as any unusual marks. Animals were individually marked with a numbered ear tag (size 1, National Band and Tag Co.), and the location, date and approximate time of capture were noted.

Census procedures

We attempted two general non-trapping census techniques which relied on visual and acoustic detection of the squirrels. These two methods were 15 minute point counts and transect counts. For our initial efforts, we made no attempt to estimate distances to squirrels from the point or transect line. Fifteen minute point counts were conducted by simply noting any squirrels seen or heard from a fixed point during a fifteen minute period. Transect counts were conducted using the previously established grids as a reference system. All squirrels seen or heard while walking along the grid lines were noted. We walked variable lengths of transect, depending on other activities, but we always recorded the length and time of transect counts based on our grid system.

Results

Surveys

Surveys revealed the presence of antelope squirrels in several locations (Table 1). Of particular concern is the location of additional populations in the northern part of the species' range, where there are a small number of recent locations and the squirrels do not appear to be common even where they are known to be present. We located squirrels only on the northwestern bench of the Panoche Hills, although there are recent records (Natural Diversity Data Base - NDDB) for a few locations in the northern Tumey Hills, at the east end of Panoche Valley. We were unable to gain access to BLM lands on Ortigalita Peak, which may harbor squirrels, although adjoining land of more suitable slope has been heavily grazed and has little shrub cover. We hope to be able to survey this area in 1989. Several sites in the Kettleman Hills appeared to have suitable habitat, though we did not locate any antelope squirrels. The BLM lands and adjoining private lands in the two miles south of highway 41 along the crest and slopes of the Kettleman Hills were especially promising, but we found no squirrels there. Subsequently, we have received a report (M. Wade, pers. comm.) that antelope squirrels are found on lands belonging to Chevron and lands leased from BLM by Chevron in the North Dome Oil Field, on the north end of the Kettleman Hills. We have arranged for permission to survey and trap this area during 1989. This is potentially an important population, given the paucity of antelope squirrels elsewhere in the northern part of the species' range.

The Cuyama Valley is roughly the southern terminus of the antelope squirrel's range. Parts of the valley have not been surveyed (Williams 1981). We walked several miles of seemingly suitable habitat along the Cuyama River wash without observing antelope squirrels. Probably the occasional flooding of this habitat is enough to eliminate any colonizing squirrels and prevent the establishment of populations. We also briefly surveyed the mouth of Santa Barbara Canyon. This canyon enters the Cuyama Valley opposite Ballinger Canyon, where a small population of squirrels occupies the margin of the valley. We found no squirrels in Santa Barbara Canyon, though it is possible that a low density of squirrels is found in the area. The northern margin of Cuyama Valley, between the cultivated lands of the valley and the Caliente Range, contains extensive Atriplex scrub which should be suitable for antelope ground squirrels. We examined about 9 miles of habitat along the northern edge of Cuyama Valley, locating 16 antelope squirrels at 8 locations (Table 1). There is probably a nearly continuous population of squirrels in this band of habitat, with a moderate to low density. In some areas, the valley floor is cultivated up to the edge of steep terrain. Further expansion of cultivated areas, combined with the long term effects of heavy grazing seen in some locations, may reduce this population of squirrels. We did not observe antelope squirrels while driving through the dense Atriplex scrub on the Russell Ranch, north and west of new Cuyama. It is possible that there are antelope squirrels in this habitat.

While travelling on Interstate 5, a single antelope squirrel was seen in a location not previously noted (Williams 1981, NDDB). This location, southwest of San Ridge, is within the species' historic range (Hawbecker 1953, Williams 1981). There have been other sighting reports from the Sand Ridge area (Williams, pers. comm.), and this area should be surveyed during 1989.

Study plots

A summary of live-trapping dates, trapping effort and total number of squirrels marked is shown in Table 2. At most sites, antelope squirrels were so uncommon that the number of captures was very low. At these low density sites, both trapping and transect counts are likely to be variable, creating problems for establishing a relationship between the transect index and density. Habitat variation can complicate this problem even further. For example, at the Elkhorn 2 site, shrubs were very dense, but small, such that visibility at ground level was limited. At this site, we observed only four squirrels, mostly along the roadside, but captured seven individuals. In the Panoche Hills, on the other hand, shrubs were large but more widely scattered. Here we observed 15 squirrels but captured only 2. Reasons for the low capture success at this site are not clear. As described below, we hope to use dye-marking of squirrels in combination with transect censuses to help to calibrate density estimates at the same time that we collect transect index data.

Two problems with live-trapping techniques are evident from this preliminary work. Ear tags are easily lost from these relatively small-eared squirrels. At the Elkhorn 1 study site, we captured eight animals during our second visit which had evidently lost ear tags. This represents 19.5% of the animals marked during our first visit about one month earlier. A second problem related to live-trapping methods is the apparent violation of the equal catchability assumption (Seber 1982, White et al. 1982). Juveniles appear to be more readily captured, and are also more likely to be recaptured. This represents not only heterogeneity in capture probability, but also response to trapping and an interaction between capture probability and trap response. A downward bias may result if densities are calculated under these conditions (White et al. 1982, Menkens and Anderson 1988). Methods by which we may compensate for these problems in future fieldwork are discussed below.

Table 3 shows results of vegetation surveys conducted thus far. There are large differences in shrub density, species composition and shrub size between sites. Upland sites were more similar to each other in their overall character than to valley floor sites (Paine Preserve and Semitropic Ridge). Valley floor sites included flooded areas, as indicated by extensive low-lying regions with cracked mud. Few squirrels were found in such microhabitat. At the Paine Preserve, the vast majority of captures and sightings were on raised mounds or roadside sites elevated above these periodically flooded microhabitats. At the upland sites, visual observations suggested that antelope squirrels spent considerable time at the base of shrubs, using this microhabitat for thermal cover (Heller and Henderson 1976), resting, and feeding. The majority of burrows appear to be located at the base of shrubs. There were fewer captures in large shrubless areas, though we did observe antelope squirrels living in habitats completely devoid of shrubs. Further conclusions about the relationship between habitat and density are premature at this point.

<u>Census techniques</u>

We conducted 15 minute point counts at the Elkhorn 1 and Paine Preserve study areas (Table 4). Transect counts were conducted at these study areas as well as the Elkhorn 2 and Panoche Hills study area (Table 5). Point counts were judged to be unsatisfactory after these efforts for several reasons. Although the numbers seen varied in a manner expected based on trapping results, the overall number of squirrels seen was low. This was due to the limited area observed while remaining in a fixed location, especially important where shrubs are dense and where the terrain is complex. Also, squirrels are less apt to be flushed by the observer during point counts. During transect counts, the time taken to travel one kilometer was roughly 15 minutes, thus one can compare the number of squirrels seen for the two methods by comparing point counts with squirrels seen per kilometer of transect counting. This reveals that 2-4 times as many squirrels were counted per unit time by using the transect method. Even if the two methods are equally accurate in detecting trends, the method which detects the most individuals per unit time is both more efficient and likely to be more precise (Burnham et al. 1980).

Transect methods yielded a greater number of detections per unit time because of the flushing of other wise inconspicuous animals, increased rate of calling by disturbed squirrels, the ability to traverse over hilly terrain and the increased number of visual angles on the habitat when compared to observing from a fixed point. Based on transect counts and on general observations while live-trapping, we concluded that morning censuses were preferable. The means for morning transect counts are compared with the total number of individuals marked per 100 trap days for four sites: Elkhorn 1, Elkhorn 2, Paine Preserve, and Panoche Hills (Figure 1). There is a good relation between transect counts and number of animals marked ($r^2 = .81$).

Discussion and Plan for 1989

Survey results and live-trapping results in the Panoche Hills confirm the notion that the San Jaoaquin Antelope Squirrel is rare and localized in the northern part of its range. Further efforts should attempt to determine the species' status in the northern Kettleman Hills and the surroundings of Ortigalita Peak. There may be locations on state or federal lands which would be suitable for reintroduction of the species in the northern portion of its range. For example, the Little Panoche Wildlife Area, administered by the Department of Fish and Game, has undergone a program of vegetation restoration resulting in habitat which should be suitable for antelope squirrels. This location is near a possible source population in the Panoche Hills. Another possibility would be BLM lands in the Kettleman Hills. On the floor of the San Joaquin Valley, there are few remaining populations of antelope squirrels, and those which remain are on marginal habitat (Williams 1981). We may find a few additional locations, but there is little hope for reintroduction of the species in this region other than on recent Nature Conservancy acquisitions in the Semitropic Ridge preserve. Clearly the heart of the San Joaquin Antelope Squirrel's range is in the southwestern portion of its historical range: the Carrizo and Elkhorn Plains, Elk Hills, and Buena Vista Valley. Our surveys confirmed the expected occurrence of antelope squirrels in the Cuyama Valley. BLM lands on the margin of the Caliente Range and Cuyama Valley are critical for maintenance of the species at the southwestern end of its range.

Developing census procedures which do not involve the intensive labor and expense of live-trapping are a high priority of this study. Our objective is to develop a census method or index and test it against density as determined by live-trapping. Both elements (census/index and density estimate) involve a number of assumptions and sampling problems.

Density estimation by live-trapping and marking individuals is a widely used technique with many possible approaches to estimating density from such data (see reviews of Davis and Winstead 1980, Seber 1982, White et al. 1982, Seber 1986). The most important problems (relevant to our study) with such methods are : determining whether the population is open or closed, heterogeneity of capture probabilities, heterogeneity of response to trapping, determining the actual area sampled. By sampling for density during a restricted time period (six days), we should be able to reasonably assume closure (Seber 1982, White et al. 1982). This implies separate density estimates for different seasons (e.g. before and after dispersal). We plan to use two means of estimating density from mark-recapture data. Simple Lincoln-Peterson estimates have often proved to be reliable density estimates (Davis and Winstead 1980, Menkens and Anderson 1988) when compared with other methods. By considering the first and last three days of a six day trapping period to be the first and second sample periods, the effects of trap response and heterogeneity in capture probabilities can be reduced (Seber 1986, Menkens and Anderson 1988). Models are available for closed populations which relax the assumptions of heterogeneity and lack of response to trapping. The program CAPTURE (White et al., 1982) allows one to choose such a model for analysis of mark-recapture data. We will use both the Lincoln-Peterson and CAPTURE to estimate densities for our antelope squirrel study areas, allowing us to evaluate the variability of both methods in estimating density. In addition, we will use the removal-index method (Sarrazin and Bider 1973, Eberhardt 1982) to check our density estimates. In this method, the investigator estimates density by calculating the value of a density index before and after removal of a known number of individuals. In our study, "removal" will consist of dye-marking individuals when captured, so that captured individuals can be recognized while conducting transect censuses. The ratio of an initial transect count to the true population density should be equal to the ratio of a second count (unmarked individuals only) to the true density minus the number marked during the first sample

(Seber 1982, Eberhardt 1982). Thus we hope not only to develop a reliable index, but to use the collection of data for the index to test our density estimates. A further advantage of dye-marking animals will be to help estimate the area sampled by trapping, by noting distances of marked animals from the trapping grid, and the change in proportion of marked to unmarked animals as one moves farther from the grid boundary. Such a method is similar in concept (but less time-consuming) than the method of assessment lines (Seber 1982, 1986)

The alternatives for estimating antelope squirrel density without trapping are censusing by visual and auditory detection of squirrels or by counting some indirect indicators of squirrel presence, such as burrows. Unfortunately, burrows of squirrel size are also used by kangaroo rats and perhaps other species. Thus utilizing observations of squirrels appears to be the best alternative to live-trapping. A variety of general approaches to this problem have been used by avian ecologists (Ralph and Scott 1980, Verner 1985). Most of these methods, which include variable circular plots, transect methods, and spot mapping, are intended to yield an estimate of density directly. The variable circular plot method consists of censusing from a fixed point and using distances between the observed organism and the point to estimate density. Our point count method resembles this method, though we did not estimate distances. Spot mapping involves the careful mapping of individual territorial singing birds. This method has no simple analog in the case of antelope squirrels. Transect methods involve traversing habitat along a straight line of a certain length and recording all individuals observed. It is possible to directly estimate density from transect counts if distances from the transect line are measured. However, there are a number of assumptions for such a precedure (Anderson et al. 1979, Burnham et al. 1980. These include:

1. Animals directly on the transect line are always seen.
2. Animals do not move before being seen or flushed (affects distance estimate).
3. Animals are not counted more than once.
4. The sighting of animals is independent (i.e. individuals do not alarm one another).
5. There is no error in measuring distances from a transect line.
6. Importance of defining and maintaining a straight line of travel (biases density estimate)
7. Transect lines are far enough apart to avoid overlap of observations

The last three assumptions involve measurement problems that in principal could be minimized or avoided by careful census procedures. The first four assumptions, however, are clearly a problem for censusing of antelope ground squirrels. Animals on the transect line which are in their burrows will not be observed, and there is likely to be a sizable fraction of the population which is underground at any given time, seriously biasing the estimate of density in a downward direction. In fact, animals near the transect line might be more likely to be in their burrows if they have detected the observer. Secondly, squirrels in the vicinity of shrubs may often observe the counter and move to another shrub before being observed. The majority of observed squirrels during our transect counts were moving when initialy sighted. Furthermore, some of these squirrels gave alarm calls, which violates the asssumption that the sighting of animals is independent. During some seasons, squirrels are likely to be seen in clusters, probably corresponding to family groups. The activity, and likelihood of observation, of individuals in such groups is clearly not independent. Since most observed squirrels were moving, there is a possibility that the squirrel may be counted again after making a long distance movement (squirrels frequently travelled more than 100 m while being observed). Given the densities of squirrels which we encountered, this does not seem like a major problem, but it might be more important where a dense population occurs in an area with a high percent cover of shrubs, such as the Buean Vista Valley and portions of the Elk Hills. The likelihood of violating these important assumptions renders direct transect estimates of density based on distance measurements problematic.

Thus it seems that the best course of action is to develop a reliable index to density. Indices have been constructed for a number of species, and may include direct observations of individuals or their vocalizations (e.g. Bouffard and Hein 1978, Rotella and Ratti 1986) or indirect counts of sign such as burrows, or pellet grouping(Reid et al. 1966, Sarrazin and Bider 1973, Davis and

Winstead 1980). Unfortunately, even the most widely used indices are rarely tested against other density estimates (Eberhardt 1978, Dawson 1980, Seber 1982, 1986, Eberhardt 1987). We plan to test our index by seeking a simple relationship between the number observed during transect counts and densities determined by extensive live-trapping. Preliminary data suggests that transect counts of the number of squirrels may show a close relationship to the number of animals marked per 100 trap days (Figure 1). For this index to be successful, it must be verified against repeated, more extensive trapping censuses in a variety of habitats. We may find that the index will assume different relationships to density in different habitat types. Another important test will be to compare the ratio of the index to density at different densities (by multiple t-tests, c.f. Rotella and Ratti 1986), since a good index should show a constant proportionality to density. A simpler approach to censusing, with fewer assumptions, is more likely to meaningful and will also be more repeatable with different observers.

Summary of Study Plan: 1989

I. Surveys

1. Attempt to locate additional populations of A. nelsoni in areas not completely covered last year or in new areas based on last year's work.
2. These areas will include the North Dome Oil Field region (Kettleman Hills), Avenal Gap, Ortigalita Mountain, Sand Ridge, additional sites in the Cuyama Valley, and new Nature Conservancy acquisitions in the Carrizo Plain area.
3. Coordinate with Dept. of Energy to obtain useable data from EG+G study at the Naval Petroleum Reserves.
4. Coordinate with Cal. Energy Comm. to obtain useable data from their surveys in the San Joaquin Valley.

II. Population study areas

1. Try ear nicks as an alternative to ear tags
2. Mark squirrels with dye, then note proportion marked during visual surveys, using this as a check on trapping methods
3. Develop new trap shelters for trap stations in open microhabitat
4. Locate one additional grid in the Panoche Hills and possibly one grid in the north Kettleman Hills
5. Find an additional grid site or sites on the valley floor, perhaps in the Sand Ridge area
6. Establish three or more grids in the Buena Vista Valley, preferably before the end of June
7. Establish an additional grid at the Elkhorn Plain with shrubless habitat and one more grid in Ephedra scrub
8. Begin trapping earlier in the spring, assuming weather permits access to study areas
9. Conduct radio-transmitter studies on the Elkhorn plain to obtain the following: home range estimates, movement data, dispersal data, microhabitat use data.

III. Transect count index

1. Use only the best two or three observers to reduce observer variability
2. Conduct all transect counts between 0600-1100 or shorter period if very hot
3. Use existing grid systems or compass and rollatape; do at least 4 km of transect during each sampling period.
4. Space transect lines at least 100 m apart to reduce double sightings
5. Add sites to those censused in 1988, recensus sites censused in 1988
6. Census in a wider variety of habitats, with replicates, in order to test for differences in the relationship of index to trapping results for different habitats.

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Location	County	Legal	Date	Squirrels
Panoche Hills	Fresno	T14S R11E sec17W	6/14-15	0
Panoche Hills	Fresno	T14S R11E sec 19NE	6/14-15	0
Panoche Hills	Fresno	T14S R11E sec 20W	6/14-15	0
Little Panoche	Fresno	T13S R11E sec 30NW	6/16	0
Little Panoche	Fresno	T13S R10E sec 25NE	6/16	0
Kamm Rd.	Fresno	T16S R14E sec18SW	6/15	0
Sunflower Valley	Kings	T24S R17E sec 23E	6/28	0
Kettleman Hills	Kings	T23S R18E sec 2SE,11NE,12W	6/29	0
Kettleman Hills	Kings	T22S R18E sec 36NE	6/29	0
Pyramid Hills	Kern	T25S R18E sec 2S,3SE	6/29	0
Santa Barbara Cyn.	S. B.	T9N R25W sec 14SE, 22SE, 23NW	6/30	0
Cuyama R. wash	S.L.O.	T10N R25W sec 19,28,29,33,34	6/30	0
Cuyama Valley	S.L.O.	T10N R25W sec 13SE	6/30	3
Cuyama Valley	S.L.O.	T10N R25W sec 13SW	6/30	2
Cuyama Valley	S.L.O.	T10N R25W sec 14SE	6/30	2
Cuyama Valley	S.L.O.	T10N R25W sec 14SW	6/30	2
Cuyama Valley	S.L.O.	T10N R25W sec 16NW	6/30	1
Cuyama Valley	S.L.O.	T10N R26W sec 5NE	7/1	2
Cuyama Valley	S.L.O.	T10N R26W sec 5NW	7/1	0
Cuyama Valley	S.L.O.	T10N R26W sec 6S	7/1	0
Cuyama Valley	S.L.O.	T10N R26W sec 4N	7/1	0
Cuyama Valley	S.L.O.	T10N R26W sec 3S	7/1	2
Cuyama Valley	S.L.O.	T10N R26W sec 2SW	7/1	2
Sand Ridge	Kings	T24S R20E sec 27E	7/21	1

Table 1. Survey locations and results. County abbreviations are as follows: S.B. = Santa Barbara, S.L.O. = San Luis Obispo. Squirrels seen are the number of different individuals observed at each survey location.

Location	County	Legal	Dates	Marked	Observed
Panoche Hills	Fresno	T14S R11E sec 18NW	6/21-22	0	0
Panoche Hills	Fresno	T14S R11E sec 18SW	6/21-22	0	2
Panoche Hills	Fresno	T14S R11E sec 17W, 18NE	6/21-22	0	0
Panoche Hills	Fresno	T14S R11E sec 18SE	6/21-22	1	3
Panoche Hills	Fresno	T14S R11E sec 18SE	6/22-24 7/15-17	1	10
Semitropic Ridge	Kern	T26S R22E sec 36NW	6/7-9	0	0
Paine Preserve	Kern	T26S R22E sec 26NW	6/8-10 7/12-14	23	*
Paine Preserve, E	Kern	T26S R22E sec 26NE	7/12-14	0	0
Elkhorn 1	S.L.O.	T32S R22E sec 20NE	5/31-6/2 7/6-8	56	*
Elkhorn 2	S.L.O.	T31S R21E sec 27SE	6/12-14	7	4
Buena Vista 1	Kern	T31S R24E sec 19SW	7/19-20	5	0
Buena Vista 2	Kern	T31S R23E sec 23NE	7/19-20	0	1

Table 2. Locations of live-trapping grids. Dates of live-trapping are given, along with the total number of individuals marked and the number of additional observations of squirrels within the trapping grids. The (*) indicates two grids at which there were many observations of squirrels. At these areas, we counted squirrels by transect and point count methods, so additional observations are not included here.

Shrub Species	Elkhorn 1	Elkhorn 2	Paine Preserve	Panoche Hills
Ephedra	142.0	429.8		64.3
Atriplex			119.1	
Juniper				1.0
Eriogonum	9.4	283.0		
Gutierrizia	11.9	293.5		0.7
Salsola			134.3	
Lycium	4.3			
Other	2.6	41.9		0.3
TOTAL	170.0	1,048.2	253.5	66.3

Table 3. Densities of shrubs at selected mark-recapture sites. Density is number per 100 m^2.

Location	Date	Time	Counts	Squirrels/Count
Elkhorn 1	6/1	1000-1100	16	1.3
Elkhorn 1	6/2	0845-0915	2	1.0
Elkhorn 1	6/3	0930-1130	9	1.4
Elkhorn 1	7/9	0800-0900	8	1.1
Elkhorn 1	7/9	1900-2000	10	1.6
Elkhorn 1	Mean	0800-1130	35	1.29
Paine Preserve	6/10	0830-1000	6	0.5
Paine Preserve	6/10	1430-1530	4	0
Paine Preserve	6/10	1900-2000	7	0.7
Paine Preserve	6/11	0700-0830	5	0.6
Paine Preserve	7/14	0830-0930	6	0.2
Paine Preserve	Mean	0830-1100	17	0.41

Table 4. Results of 15 minute point counts at the Elkhorn 1 and Paine Preserve locations. The number of 15 minute counts and the average number of squirrels per 15 minute count are given for each date and time. In addition, a mean for the total of all morning counts is given for the two sites.

Location	Date	Time	Total Length (m)	Squirrels/km
Elkhorn 1	6/3	0800-1100	24,000	3.04
Elkhorn 1	7/9	0800-1100	6,400	5.63
Elkhorn 1	7/9	1600-1830	6,000	2.17
Elkhorn 1	7/10	0800-1100	4,000	4.25
Elkhorn 1	Mean	0800-1100	34,400	3.66
Elkhorn 2	7/10	0800-1100	4,000	0
Paine Preserve	6/10	0800-1100	7,500	1.07
Paine Preserve	6/10	1800-1900	4,500	1.33
Paine Preserve	6/11	0800-1100	5,000	3.00
Paine Preserve	7/13	0800-1100	1,250	2.40
Paine Preserve	7/14	0800-1100	2,500	1.60
Paine Preserve	Mean	0800-1100	16,250	1.85
Panoche Hills	7/15	0800-1100	5,500	1.09

Table 5. Results of transect censuses. The dates and total length of transects counted are given, as well as the means for all morning transects for each grid. The results are expressed as the number of squirrels per kilometer.

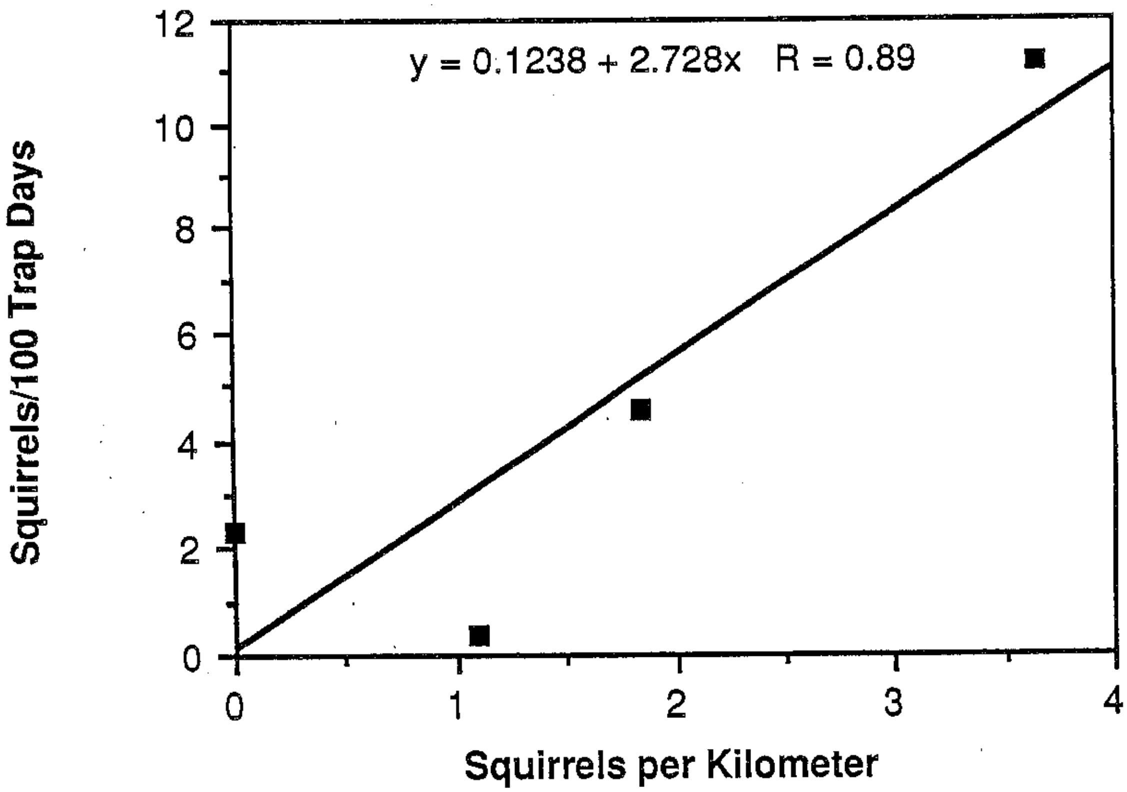

Figure 1. Relation of transect counts to number of marked squirrels. The transect count is the number of squirrels observed per kilometer of transect. The number of marked squirrels is the total number of individuals marked per 100 trap days.

Appendix 1. List of animals captured, tag number, sex, date of first capture and number of captures for each individual.

Elkhorn 1

Tag #	Sex	Date	Captures
40	F	5/31	1
41	M	"	3
42	F	"	2
43	M	"	2
44	F	"	4
45	M	"	1
46	F	"	1
47	F	"	2
49	F	"	1
50	F	"	1
101	F	"	2
103	M	"	1
104	F	"	3
802	F	6/1	1
803	M	"	2
804	M	"	3
805	F	"	5
806	M	"	4
811	M	"	1
812	F	"	2
813	M	"	2
826	M	"	1
827	M	"	2
828	M	"	2
829	M	"	2
830	M	"	2
831	M	"	1
832	M	"	1
814	M	6/2	1
815	M	"	2
816	F	"	1
822	F	"	2
823	F	"	1
825	M	"	1
835	F	"	2
836	F	"	3
837	U	"	1
838	F	"	1
839	M	"	1
840	U	"	1
841	M	"	1
844	M	7/7	1
845	F	"	1
847	M	"	2
850	M	"	2
851	M	"	2
854	M	"	1
855	M	"	2
856	F	7/8	1
878	M	"	2
879	F	"	2

882	F	"	1
883	M	"	1
884	M	"	1
885	M	"	1
886	F	"	1

Total # of captures: 23 F, 31 M, 2 U.

Elkhorn 1: retagged animals

Tag #	Sex	Date	Times captured
801	M	6/1	1
808	M	"	1
817	F	6/2	1
843	F	7/7	3
846	M	"	2
848	F	"	2
852	M	"	2
853	F	"	2
876	M	"	1
877	F	7/8	2
881	M	"	1

Total # of captures: 5 F, 6 M.

Elkhorn 2

Tag #	Sex	Date	Captures
34	F	6/3	1
35	M	6/2	1
36	F	"	1
38	M	"	1
809	F	6/1	1
810	M	"	2
833	F	"	1

Total # of captures : 4 F, 3 M.

Paine Preserve

Tag #	Sex	Date	Captures
201	F	6/8	6
202	M	"	3
226	M	"	2
227	M	"	3
228	F	"	1
203	F	6/9	2
204	F	"	1
229	F	"	3
230	M	"	3
231	M	"	2
232	F	"	3
233	F	"	4
234	F	"	2
235	F	6/10	1
236	M	"	1
205/206	F	"	1

207	F	"	2
237*	F	7/13	2
238	F	"	2
239/240	F	7/14	1
241	M	"	1
208	F	"	1

Total # of captures: 16 F, 7 M.

* This animal probably lost initial tag and was retagged.

Panoche Hills

Tag #	Sex	Date	Captures
327	M	6/22	1