ESTABLISHMENT OF A POPULATION MONITORING PROGRAM FOR THE ENDANGERED STEPHENS' KANGAROO RAT

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Abstract: Twenty-nine study plots were established throughout western Riverside County to examine Stephens' kangaroo rat (*Dipodomys stephensi*) populations and habitat relationships. Trapping results over 6-night periods demonstrate that five nights are necessary for obtaining an average of 90% of the trappable population. Studies based on shorter trapping intervals are highly questionable. Density estimates, based on live trapping, were significantly correlated with active burrow counts. A linear regression model was generated that allows the estimation of Stephens' kangaroo rat densities from active burrow counts. The basic protocol entails counting the active Stephens' kangaroo rat burrows in a 3-m swath along the right side of each of four transect lines. This technique provides a rapid method of monitoring populations annually to follow population trends as part of a permanent monitoring system in established reserves. Permanent monitoring of Stephens' kangaroo rat population trends will be critical to long-term survival in reserve settings.

The California threatened and federal endangered (U.S. Fish Wildl. Serv. 1988) Stephens' kangaroo rat (*Dipodomys stephensi*) has been the object of considerable study over the past three years, although most of the work is unpublished either because the studies are in progress or they have been written as non-refereed technical reports. Much of this work has focused on distribution and abundance throughout the animal's range (O'Farrell and Uptain 1989) as well as on the current preparation of a Habitat Conservation Plan for Riverside County (see O'Farrell 1990 for a review). The ultimate aim of the latter effort is to determine the minimum number and size of permanent preserve sites to ensure the long-term survival of the species.

Stephens' kangaroo rat is a colonizing species that occupies intermediate seral grassland habitat dominated by annual forbs (O'Farrell 1990). As disturbed grassland matures towards climax shrub association, this species is excluded. This relationship is apparent for dense stands of either brome grass or perennial bunch grass. Because *D. stephensi* inhabits disturbed habitat with final climax vegetation that is unsuitable, establishing a viable preserve network would require a means of monitoring habitat quality and kangaroo rat population trends. Early identification of declining population trends will allow proper habitat manipulation essential to maintaining occupied habitat in optimal conditions.

The purpose of the present study is to provide a monitoring methodology which allows a rapid yet accurate means of determining population levels of *D. stephensi* at discrete points in time. A monitoring protocol is presented that provides a rapid determination of *D. stephensi* population densities. The technique is advantageous in that: 1) it results in minimal disturbance to the species, 2) it may be conducted every year regardless of climatic conditions, and 3) an adequate number of plots may be examined in a manner that is not prohibitively time-intensive, thereby maximizing cost-effectiveness.

STUDY AREA

The 30 plots in the present study were selected to represent the range of habitats *D. stephensi* is known to inhabit throughout western Riverside County, California. The habitats consisted of highly variable, non-native grassland, ranging in composition from areas dominated by grasses to those dominated by herbaceous annuals. A detailed floristic analysis is in preparation (Bradney et al., unpubl. data). Some locations contained remnants of Riversidean sage scrub and chamise chaparral, but occupied habitat never exceeded 30% aerial cover by shrubs.

Active agriculture limited the extent of suitable habitat in Domenigoni Valley. Dryland agricultural practices were responsible for the current conditions found on study plots at Potrero Creek, San Jacinto Wildlife Area, and Skinner Reservoir. Cattle grazing influenced conditions at Vail Lake and Crown Valley, whereas fire produced vegetation conditions at Perris Reservoir and some areas at Skinner reservoir. Most plots at Lake Mathews occurred in grassland protected from grazing, fire, and other mechanical disturbances.

METHODS

The accurate determination of density requires consideration of a variety of factors including the shape of the sampling grid, trap type, bait, weather, moon phase, season, habitat, and the range of a species behavioral response to traps (Smith et al. 1975). Trapping activities in the present study were curtailed during the full moon phase due to reduced kangaroo rat movement patterns (O'Farrell 1974, Kaufman and Kaufman 1982). Additionally, trapping was initiated in late summer/early autumn to correspond to the lowest standing crop biomass of herbaceous material and therefore the greatest trap success for *D. stephensi* (O'Farrell and Uptain 1987). Moreover, reproductive recruitment is expected to be achieved by late summer, yielding peak population

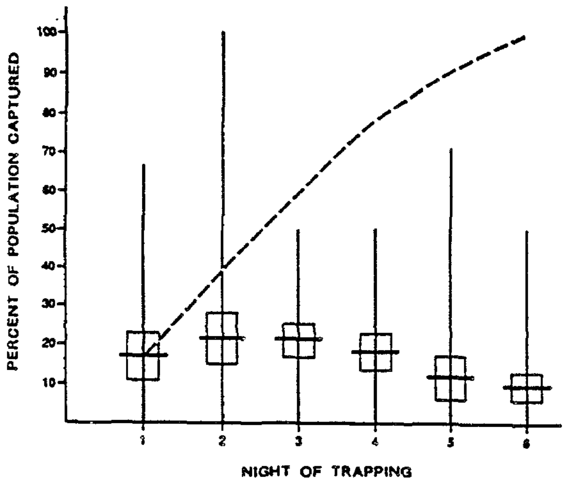

Fig. 1. The percent of Stephens' kangaroo rat populations captured each night of live trapping effort. Vertical lines = range, horizontal lines = mean, open box = 2 standard errors above and below the mean, dashed line = cumulative mean percent.

densities by early autumn. Trapping dates are provided in Table 2.

Experience suggested that an effective grid configuration consisted of a rectangle four stations wide and ten stations long with station intervals of 15 m (O'Farrell and Clark 1987). This area (45x135 m) allowed a standard-ized sampling of the range of occupied patch sizes encountered. In 1989 and 1990, a single Sherman live trap was placed at each station and baited each day with a mixture of crimped oats, mixed bird seed, and peanut butter. Traps were modified to prevent the door from closing completely, thus avoiding damaged or severed tails. To optimize trap success, each trap was placed next to an active burrow providing one occurred within 7.5 m of the station stake.

Trapping was conducted for six consecutive nights because of earlier indications of poor trappability (O'Farrell and Clark 1987, O'Farrell and Uptain 1987). Traps were opened and baited each afternoon and checked each morning at sunrise. On cool and/or foggy nights, traps were checked 2 to 4 hours after sunset to lessen animal exposure to stressful conditions. For each capture, the following data were recorded: station number, species, animal number, sex, reproductive condition, relative age, weight. Kangaroo rats were marked with a 3-digit aluminum fingerling tag attached to an ear; other species were toe-clipped. All animals were released at point of capture.

Table 1. Summary of total new captures per night of trapping for Stephens' kangaroo rat on sampling plots throughout Riverside County (mean = mean percent of total new individuals captured for each specific night of trapping, SE = standard error of mean, mean cum % = mean cumulative percent for each night of trapping).

	Night of Trapping					
Year	1	2	3	4	5	6
1989						
N captures	67	84	92	73	43	30
N plots	26	26	26	26	26	26
Mean	16.9	19.4	25.3	18.1	11.6	8.7
SE	3.3	2.9	2.7	2.3	2.8	2.2
Mean cum %	16.9	36.3	61.6	79.7	91.3	100
1990						
N captures	25	29	20	22	20	15
N plots	11	11	11	11	11	11
Mean	16.9	26.6	12.8	18.9	13.1	11.5
SE	5.4	8.7	3.4	5.8	6.4	2.8
Mean cum %	16.9	43.5	56.3	75.2	88.3	100

In 1989 and 1990, density was estimated using a modification of the assessment line technique (O'Farrell et al. 1977). Stephens' kangaroo rat movements documented in 1989 and 1990 indicated that a border strip of 7.5 m conservatively estimated the area being effectively sampled, yet was small enough not to require the adjustment of grid-caught animals (N_G) by the proportion of new to old animals within the border strip. The area of effect (A_E) was calculated by the equation of O'Farrell et al. (1977) using a width of the area of effect (W_A) equal to 7.5 m. Therefore, density = N_G/A_E.

In 1991, two plots (26 and 30) were subjected to a crossover experiment whereby density estimates were obtained independently with Sherman and custom-made, hardware cloth, mesh live traps. Each grid was 4 by 10 stations with four assessment lines extending ten stations beyond the edge of the grid, equally spaced along each long side. Trapping was conducted on the grids for 4 consecutive nights then the traps placed on the assessment lines and checked for an additional two consecutive nights, following the methodology and calculations of O'Farrell et al. (1977). Initial trapping was conducted from 20 through 25 November 1991 and the secondary trapping was conducted from 2 through 7 December 1991. The first trapping set occurred through the full moon phase which introduced an additional, unwanted

Table 2. Summary of Stephens' kangaroo rat density (individuals/ha) and active burrow counts for line transects and habitat cells on sampling plots throughout Riverside County (WA = Wildlife Area).

Year, Plot	Location	Date	Density	Active burrows	
				Line	Habitat cell
1989					
01	Domenigoni Valley	5-10 Sep	12.6	88	288
02	Domenigoni Valley	5-10 Sep	5.8	62	222
03	Domenigoni Valley	5-10 Sep	8.7	66	227
04	Potrero Creek	19-24 Sep	14.6	37	171
05	Potrero Creek	19-24 Sep	20.4	84	259
06	Potrero Creek	19-24 Sep	19.4	111	396
07	Potrero Creek	19-24 Sep	15.5	80	194
08	Potrero Creek	19-24 Sep	15.5	97	459
09	San Jacinto WA	25-30 Sep	17.5	129	547
10	San Jacinto WA	25-30 Sep	20.4	64	273
11	San Jacinto WA	25-30 Sep	13.6	40	145
12	Perris Reservoir	25-30 Sep	27.2	124	496
13	Perris Reservoir	25-30 Sep	25.2	66	242
14	Perris Reservior	25-30 Sep	20.4	62	338
15	Skinner Reservoir	4-9 Oct	17.5	19	146
16	Skinner Reservoir	4-9 Oct	15.5	76	303
17	Skinner Reservoir	4-9 Oct	15.5	91	360
18	Vail Lake	17-22 Oct	1.9	26	91
19	Vail Lake	17-22 Oct	19.4	43	158
20	Vail Lake	17-22 Oct	5.8	64	281
21	Lake Mathews East	26-31 Oct	1.9	14	99
22	Lake Mathews East	26-31 Oct	1.9	44	173
23	Lake Mathews East	26-31 Oct	5.8	32	174
24	Lake Mathews West	5-10 Nov	15.5	135	621
25	Lake Mathews West	5-10 Nov	13.6	80	327
26	Lake Mathews West	5-10 Nov	28.2	168	773
1990					
05	Potrero Creek	11-16 Jul	1.9	51	190
06	Potrero Creek	11-16 Jul	5.8	120	474
07	Poterro Creek	11-16 Jul	24.3	33	152
08	Potrero Creek	11-16 Jul	19.4	50	255
21	Lake Mathews East	23-28 Jul	1.0	48	190
22	Lake Mathews East	23-28 Jul	5.8	27	230
23	Lake Mathews East	23-28 Jlu	6.8	50	299
25	Lake Mathews West	23-28 Jul	13.6	95	370
27	Crown Valley	17-22 Jul	16.5	78	322
28	Crown Valley	17-22 Jul	5.8	82	453
29	Crown Valley	17-22 Jul	26.2	202	876

Table 3. Summary of 1991 estimates of Stephens' kangaroo rat density (individuals/ha) using mesh live traps (S = use of Sherman traps), number of individual animals captured on grid and assessment lines, and number of active burrows for line transects at Lake Mathews, Riverside Co. Density estimated from the calculations of O'Farrell et al. (1977).

Plot	Density	N individuals	N burrows
22	6.5	15	27
23	29.4	61	69
25	37.9	98	139
26S	40.9	91	218
26[a]	65.0	113	218
30S[a]	54.4	68	316
30	63.8	203	316

[a] Trapping conducted during full moon, late November 1991

variable. Two Sherman live traps were placed at each station on Plot 30 and two mesh traps were placed on each station on Plot 26 during the first trapping set. After the hiatus, traps were shifted to opposing grids for the second trapping set. Subsequently, Plots 22, 23, and 25 were sampled with the assessment line method using the mesh live traps. Density estimates for 1991 followed the adjusted N_G (N_A) calculations of O'Farrell et al. (1977).

All active *D. stephensi* burrow entrances were counted within a 3-m swath along the right side of each of the transect lines (number of kangaroo rat burrows/1620 m^2). Active burrows were those that showed obvious signs of ingress and egress and contained kangaroo rat scat at or near the entrance. Throughout the trapping effort, released animals were followed to determine the range of burrow entrance types used. To compare different levels of sampling effort, all active burrows were counted within each habitat cell. A habitat cell consisted of the area within a 7.5 m radius circle centered at each trap station.

Reliable identification of a burrow is paramount to the accuracy of the technique. First, it is critical to know the species composition of the small mammal community for the habitat being sampled. Then it is important to know the size and shape range for the target species and the microhabitats in which the burrows may be found. Kangaroo rats have fecal pellets of a characteristic "jelly bean" shape; the pellets are smooth, rounded on both ends, and firm due to lack of moisture. The genus appears to deposit fecal pellets along surface trails, at dust bath areas, and within the cleared apron at burrow entrances. Within the range of *D. stephensi*, there is only one other species of kangaroo rat of comparable size, the Pacific kangaroo rat (*D. agilis*). These species are contiguously allopatric, except for a few ecotonal situations between sage scrub and non-native grassland habitats (Lackey 1967, O'Farrell 1990). When they are sympatric, both species may be found to use the characteristic burrow ascribed to *D. stephensi*. As long as the target species is using the burrow, it does not matter what other species also make use of it.

RESULTS

Yearly trends in total new captures per night of trapping for Stephens' kangaroo rat show few differences (Table 1). Results from both years were combined for visual presentation (Fig. 1). Three nights of trapping yielded an average of 60% of the trappable population. The range of variation among plots was sufficiently large from night to night to negate the ability to predict trap response for any specific trap site.

An examination of density and active burrow entrance counts, both for line transects and habitat cells, indicates a positive relationship among these factors (Table 2). Linear regression models were generated, both with and without a constant. Addition of a constant contributed little to increasing r^2 values and produced a model not consistent with biological fact (e.g., a transect plot with no perceivable Stephens' kangaroo rat burrows will not contain 5 individuals/ha). Therefore, a model with the Y-intercept at 0 was selected. The linear regression equation to estimate density of *D. stephensi* from the 1989 and 1990 transect line counts is:

$$D = (0.164)B \qquad (1)$$

where D is density (the number of individuals/ha) and B is the number of active burrows in all 4 transect lines (the standard error of the regression coefficient = 0.015, r^2=0.78, t=11.3, P<0.001, $F_{df=1,36}$=126.6, P<0.001). The linear regression equation to estimate density of *D. stephensi* from habitat cell counts is:

$$D = (0.038)B \qquad (2)$$

(the standard error of the regression coefficient = 0.004, r^2=0.76, t=10.8 P<0.001, $F_{df=1,36}$=115.6 , P<0.001).

The r^2 values for both equations appear higher than warranted by the variation observed in the data (Fig. 2). The lack of a constant accounts for the artificially high r^2 values.

Density estimates obtained from using Sherman live traps differed from those obtained with the mesh live traps (Table 3). Estimates were 37.1% and 14.7%

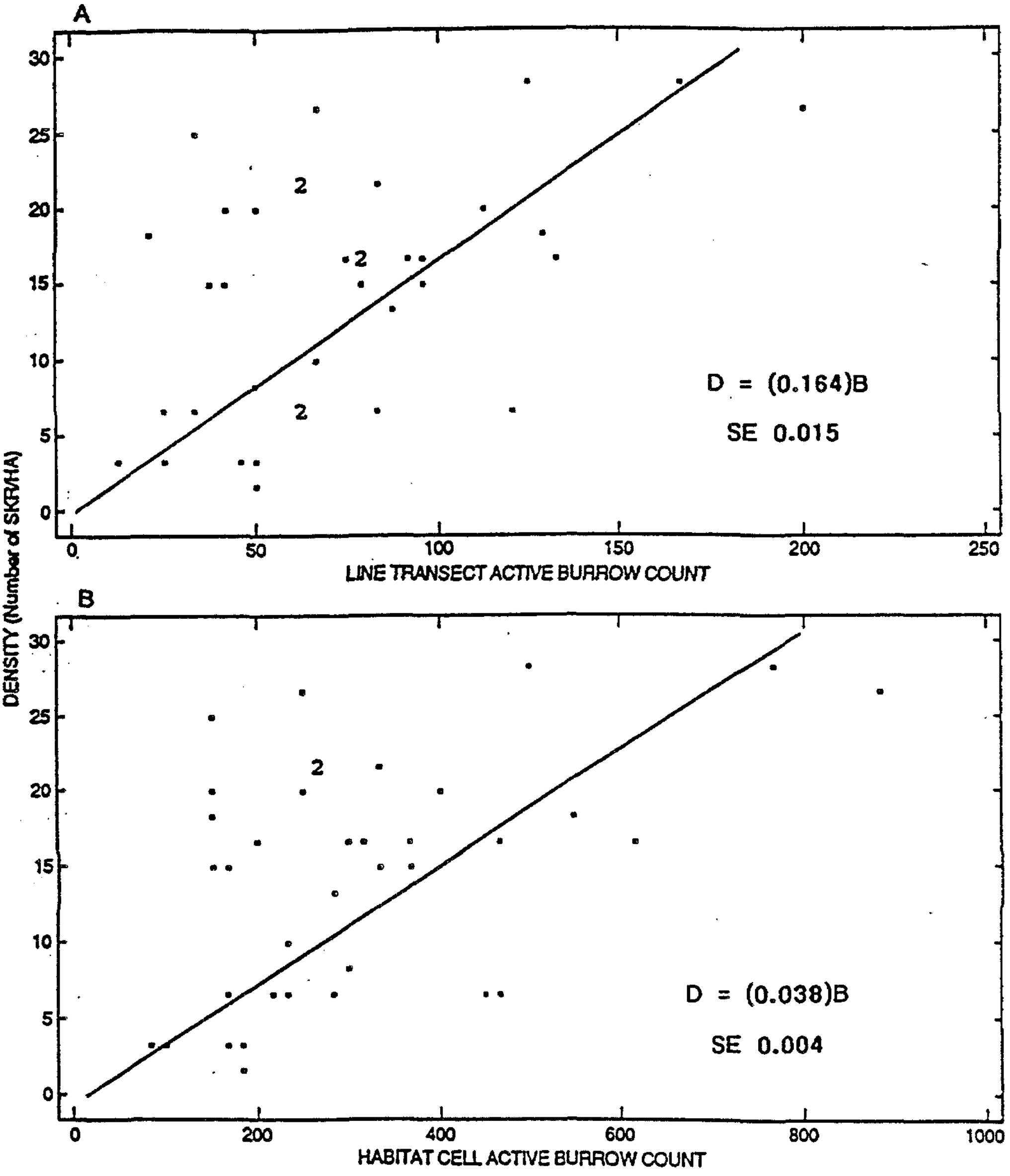

Fig. 2. Scatter plots of Stephens' kangaroo rat density (individuals/ha) in relation to active burrow counts from the line transect (A) and habitat cell methods (B) in 1989 and 1990. For the linear regression equation, D is density (the number of individuals/ha) and B is the number of active burrows in all four transect lines.

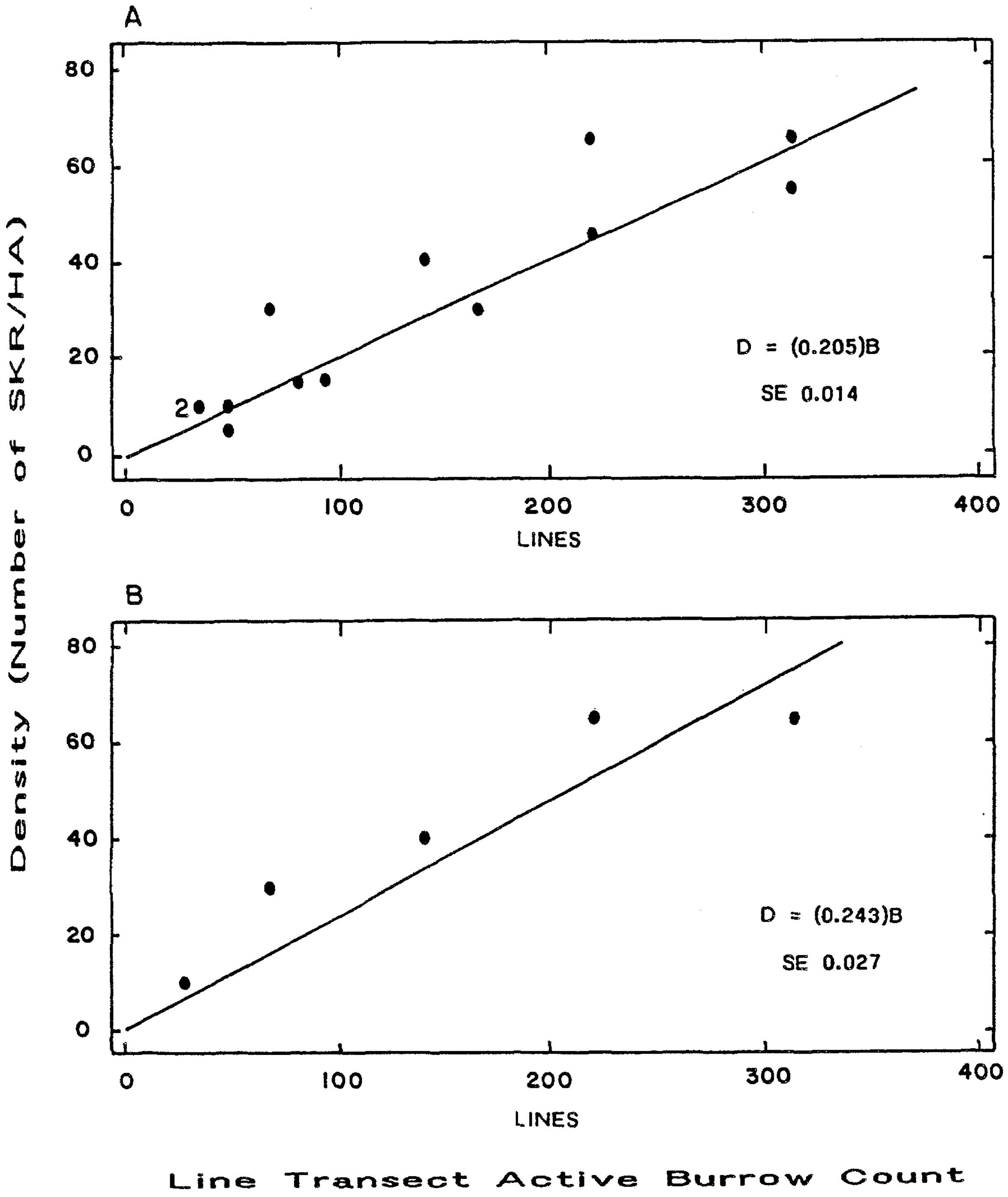

Fig. 3. Scatter plots of Stephens' kangaroo rat density (individuals/ha) in relation to active burrow counts for select plots studied in 1989-1991 (A) and for only the plots using mesh live traps in 1991 (B). For the linear regression equation, D is density (the number of individuals/ha) and B is the number of active burrows in all four transect lines.

greater with mesh traps on Plots 26 and 30, respectively. Therefore, density estimates on Plots 22, 23, and 25 should have greater reliability.

An examination the density/active burrow count relationship for the plots presented in Table 3 studied for all three years, with the addition of the new Plot 30, demonstrates less variability than the body of data obtained from the pooled 1989-1990 data (Fig. 3). The linear regression equation from this select data set is:

$$D = (0.205)B \tag{3}$$

(the standard error of the regression coefficient = 0.014, r^2=0.94, $F_{df=1,13}$=201.7, P<0.0001).

Although the number of observations is considerably reduced, an examination of only density values obtained with mesh traps (plots given in Table 3) provides a slightly better fit to the predictive equation:

$$D = (0.243)B \tag{4}$$

(the standard error of the regression coefficient = 0.027, r^2=0.95, $F_{df=1,4}$=82.9, P<0.001).

DISCUSSION

To obtain a reliable population density estimate, all or most of the trappable animals must be captured. It should follow that the greater amount of time spent trapping will yield the more accurate density estimate. In reality, most studies are limited by time, labor, and economic constraints which limit the sampling period. It is therefore important to determine the minimum time required to obtain meaningful results.

Time of year, amount of precipitation and subsequent vegetative productivity, grazing pressure, and inclement weather can significantly alter *D. stephensi* trappability (O'Farrell and Uptain 1987). Stephens' kangaroo rat trap response is low, at best, during spring months when annual vegetation production is at a peak. Trappability increases through the summer months as annual vegetation dries and disarticulates. Peak trappability occurs during the fall months prior to the onset of the rainy season which initiates another reduced trap response. This general cycle is magnified during wet cycle years; trap response will increase into the fall but is apparently not always representative of the number of animals present. When diagnostic surface sign is abundant over a trapping plot yet animals are not being captured where sign is present, little credence can be given to resulting density estimates.

The nightly variation in trap success and the variation among plots emphasize the vagaries in trap response inherent in *D. stephensi* (Table 1). It should be stressed that 1989 and 1990 represented the third and fourth years of a drought affecting southern California. Trap response was at a peak that cannot be expected under normal or wet years (O'Farrell and Uptain 1987). Three nights of trapping yield a mean of only 60% of the trappable population. Variation both between and among geographic locations is large enough to preclude mathematically adjusting a 3-night estimate. Therefore, density estimation based on three nights of sampling cannot be used with any degree of accuracy. Five nights of sampling account for an average of 90% of the trappable animals and should be acceptable as a minimal trapping effort.

The quality of density estimates depend on the ability to trap a representative sample of animals. Recent findings that Sherman live traps yield significantly fewer small mammal captures than a new mesh live trap (binomial probability P<0.0001, O'Farrell et al. in prep.) raise serious questions concerning the accuracy of density estimates obtained in 1989 and 1990 in the present study. These mesh live traps proved to yield *D. stephensi* density estimates as much as 37% greater than Sherman traps (Table 3). It is clear that the calculated density estimates with mesh traps are more reliable.

It is well established that *D. stephensi* is adapted for intermediate seral stage plant communities (see O'Farrell [1990] for a review). Optimal habitat is transitory and sere persistence depends on the degree of grazing, or other surface disturbance, that helps maintain suitable conditions for the species. Consequently, the distribution and abundance of the species are dynamic. The formation of permanent preserves for the maintenance of this endangered animal will require regular monitoring of trends in both vegetation and kangaroo rat population levels. In this way, deleterious trends can be identified early and management steps taken to keep habitat within the range of optimal conditions. A detailed study of habitat use and a methodology for monitoring habitat trends will be presented elsewhere (O'Farrell and Andersen in preparation).

Stephens' kangaroo rat occupies open grasslands with sparse ground cover permitting location of diagnostic surface sign. Burrow entrances, runways, dust baths, and scat are readily visible to the trained eye throughout most of the year. At the peak of plant productivity in the spring, *D. stephensi* sign may or may not be readily detectable because of plant cover. There are also times when scat is not deposited on the surface. However, active burrow entrances can be located during most times of the year. It is not expected that a single kangaroo rat uses only one burrow entrance. This is a mobile species that occurs in a habitat principally devoid of aerial cover. It follows that there should be scattered refuges throughout a given home range. The species also is known to use a burrow complex containing a series of tunnels connecting multiple burrow entrances (O'Farrell and Uptain 1987).

A significant positive relationship exists between trappable density estimates and active burrow counts (see Table 2, eqs. 1 and 2). No significant difference exists between the predictive power of habitat cell versus line transect methodologies. However, the density estimates obtained with Sherman live traps exhibited considerable variation (Fig. 2). Examination of just the plots sampled in the 3 years of study reduced this variation (Fig. 3a). The use of 1991 results based on mesh live traps provides the model with the largest r^2 value (0.95, Fig. 3b). It is expected that a larger body of data may yield a more accurate model to estimate *D. stephensi* density from active burrow counts. However, eq. (4) provides the best model to date.

The use of active burrow counts permits a reasonable estimation of density regardless of the behavioral trap response of Stephens' kangaroo rat at any time of year. Furthermore, active burrow counts for a set of 4 transect lines requires about 40 minutes to perform using the line transect method, providing a rapid assessment of population levels.

The use of active burrow counts for estimating population density may prove to be a valuable tool for assessment and management of other sensitive kangaroo rat species. The necessary criteria involve the ability to locate the target burrows and the skill to reliably identify the species using a burrow. Thus, species that occupy open grassland habitats with few shrubs are prime candidates to examine for implementation of the active burrow count technique.

Based upon the present study, procedural recommendations are as follows: 1) establish permanent transect plots at locations representative of habitat and geographic diversity on established reserves, 2) active burrow counts should be performed in late summer or early fall, corresponding to the driest, and therefore most open ground cover allowing the most accurate detection of active burrows, 3) density should be estimated using eq. (4), 4) a method for assessing habitat condition should be performed on the same transects, and 5) additional density estimation through the use of live traps should be with mesh live traps and a duration of at least five nights.

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