DENSITIES AND HABITAT AFFINITIES OF THE CHISEL-TOOTHED KANGAROO RAT *(Dipodomys microps leucotis* Goldman)

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C SUMMARY

The Houserock Valley chisel-toothed kangaroo rat (*Dipodomys microps leucotis*) is found within three habitat types (shadscale, blackbrush, four wing saltbush). Three 6.25-ha (15.3-acre) replicate study plots were established in each habitat type. Each plots was systematically traversed on foot to identify and mark all active kangaroo rat burrow mounds. The position of each mound was mapped to scale for determination of nearest neighbor distances and overall dispersion patterns. Mounds were characterized by maximum length, width, and number of active entrances. Habitat around each mound was quantified (i.e., ground cover, aerial cover, shrub height profile) by plant transects radiating from the center of the mound in the cardinal directions. Live-trapping was conducted to determine the number of individuals using the available mounds and yield a density estimate for each plot. Secondarily, I examined the influence on the presence of *D. m. leucotis* by livestock disturbance around established water sources (the bulls-eye effect. Step-toe walking transects were conducted in the cardinal directions from water sources in each habitat type. Thus, I obtained a frequency distribution of bare ground perennial plant species and the distance to the nearest active mound.

Shadscale and four wing saltbush habitats tended to support greater numbers of *D. m. leucotis* than blackbrush, although densities were generally low when compared to values reported in the literature for other geographic areas. Within each habitat type, the highest densities were found on plots with the least amount of livestock sign (e.g., relative amount of tracks, scat, browsed shrubs). There was a significant correlation between the number of active mounds and the number of individual *D. m. leucotis* on a plot. A linear regression model was generated which will allow future density estimation by counting the active mounds in similar sized plots.

Significant differences were found among habitat types with respect to mound dimensions. Longer and wider mounds, and those with more active entrances, were found in four wing saltbush habitat. Habitat features varied among plots both within and between habitat types. Four wing saltbush plot 3 and the lowest percentage of bare ground and the highest annual vegetation cover, supported the highest number of *D. m. leucotis*, and had the least amount apparent livestock use. Similarly, the greater the aerial shrub canopy occurred on this plot. Overall, a significant relationship was found between mound length and annual ground cover. A significant stepwise regression model indicated that kangaroo rat abundance increased with increasing shrub cover and mound length.

Bare ground predominated the areas within the first 50-100 m of an established water sources. Vegetation within this area was primarily introduced, disturbance species. Native vegetation first appeared between 80 and 160 m from a water source. *D. m. leucotis* mounds did not appear, on average, less than 200 m from a water source. A highly significant logistic

regression model indicated that 89% of the variance in the probability of encountering a mound was explained by the model. At a distance of 200 m from a water source, there was only a 55% probability of encountering a mound. A conservative estimate of the quantity of habitat incapable of supporting *D. m. leucotis* is 12.6 ha (30.9 acres) representing a radius of 200 m from a water source.

The current distribution and population status of *D. m. leucotis* indicates no immediate concern for an upgrade in sensitive status. However, overall low densities and the apparent negative response to livestock pressure suggests vulnerability. Based upon the present study, I recommend that concentration of livestock use within the blackbrush, shadscale, and four wing saltbush habitats should be avoided. Reduction in general use or a more frequent shift of use among existing pastures would increase the carrying capacity for D. m. leucotis. Avoid placement of new water sources within the three suitable habitat types. Future periodic monitoring of kangaroo rat population levels and general vegetation trends should be conducted. The recovery rate and success of vegetation and subsequent re-colonization of abandoned water sources would be instructive for future management decisions.

INTRODUCTION

The chisel-toothed kangaroo rat (*Dipodomys microps*) is a Great Basin desert species mostly distributed in Nevada and with limited distribution in adjoining states (Hayssen 1991). Of the 13 subspecies currently recognized, two (*D. m. leucotis* and *D. m. celsus*) occur in the extreme northwestern portion of Arizona known as the Arizona Strip. The Arizona Strip lies north and west of the Colorado River and the Grand Canyon. The river and canyon serve as a barrier to distribution of many species of terrestrial small mammals in Arizona, including *D. microps*. *D. m. leucotis,* the Houserock Valley chisel-toothed kangaroo rat, is confined to the Houserock Valley in the eastern end of the Arizona Strip.

Chisel-toothed kangaroo rats are specifically adapted for feeding on leaves of saltbush (*Atriplex* spp.; Kenagy 1972). They occur in a variety of habitats but tend to be most abundant in saltbush/shadscale associations or in higher elevation transitional communities dominated by blackbrush (*Coleogyne ramosissima*; see Hayssen 1991 for a review). The Houserock Valley supports such habitat types. Physical barriers (Colorado River, Vermilion Cliffs, Paria and Kaibab plateaus) and vegetation barriers (pinyon-juniper woodland and sagebrush communities) appear to have effectively isolated *D. m. leucotis* within the valley. Surveys to determine a connection with *D. m. celsus* or a more widespread distribution proved negative (Spicer and Johnson 1988). Although Hoffmeister (1986) expressed some reservation as to its subspecific status, The Houserock Valley population of kangaroo rats is currently recognized as a distinct taxonomic entity.

The occurrence of *D. m. leucotis* within the Houserock Valley poses questions regarding initial colonization and subsequent isolation. Paleoclimatic records of the last glacial period, the Wisconsin (Cole 1990), indicate that the eastern Grand Canyon supported a pinyon pine-dominated woodland approximately 800 to 1000 m elevation lower than the modern lower limits of such vegetation. The entire Houserock Valley would have been covered with coniferous woodland, a habitat unsuitable for *D. microps*. If *D. microps* had been present in the valley during a previous interglacial, it seems likely that it would have been extirpated during the Wisconsin. The presence of the canyon walls should have precluded the species from persisting on the lower margins of the valley during the Wisconsin glacial period. Development of suitable habitat within the Houserock Valley would have occurred during the Wisconsin-Holocene transition between 11,500 and 8500 years before present (BP). Colonization of the Houserock Valley by *D. microps* may have occurred during a warmer, drier period of the Holocene some 8000 BP (Antevs 1948) that allowed development of a corridor of suitable habitat along Coyote and Houserock washes (Figure 1) connecting the northwestern corner of the Houserock Valley with suitable habitat in the vicinity of Kanab, Utah, currently occupied by *D. m. celsus*. Subsequent cooler climatic conditions have resulted in the northwestern portion of the Houserock Valley presently occupied by pinyon pine woodland.

As a taxon of limited distribution, *D. m. leucotis* is a candidate species for listing as Threatened in Arizona (AGFD, 1988) and was listed as a Category 2 federal candidate prior to

1996 (USFWS 1994; USFWS 1996). The taxon is still considered a Species of Special Concern by the USFWS. Virtually all of the Houserock Valley is within state (Arizona State Lands) or federal (National Park Service, U.S. Forest Service, Bureau of Land Management) ownership (Figure 1). The status of *D. m. leucotis* mandates that the jurisdictional agencies address potential impacts to the species. Although the current status of the species is in question, recent work (O'Farrell, 1995) suggests that the species can avoid listing if an adequate management plan is developed and implemented.

The purpose of the present study was to provide an assessment of densities supported by the various vegetation types currently occupied by the species. Actively used burrow mounds were characterized by physical dimensions, number of active entrances, and surrounding vegetation structure. The relationship between number of individuals captured and the number of active mounds provided the basis for a density estimation regression model. An attempt was made to quantify the relationship between livestock grazing and the density of *D. m. leucotis*.

MATERIALS AND METHODS

Density and Dispersion of *D. m. leucotis*

Of the seven plant communities described within the Houserock Valley, three vegetation types (shadscale, SS; four wing saltbush, FWSB; and blackbrush, BB) support *D. m. leucotis* (O'Farrell 1995):. Three study plots were established in each of the three designated habitats types (Figure 2). Each study plot was 250 m on a side for a total of 6.25 ha (15.3 acres). The boundary of each was measured and marked incrementally at 15 m intervals. The entire area of each was traversed on foot by three observers at 15 m intervals, thereby providing 100% coverage. All active kangaroo rat mounds were marked with pin flags. Distribution of the mounds was mapped using a method similar to that used by Schroder and Geluso (1975). All

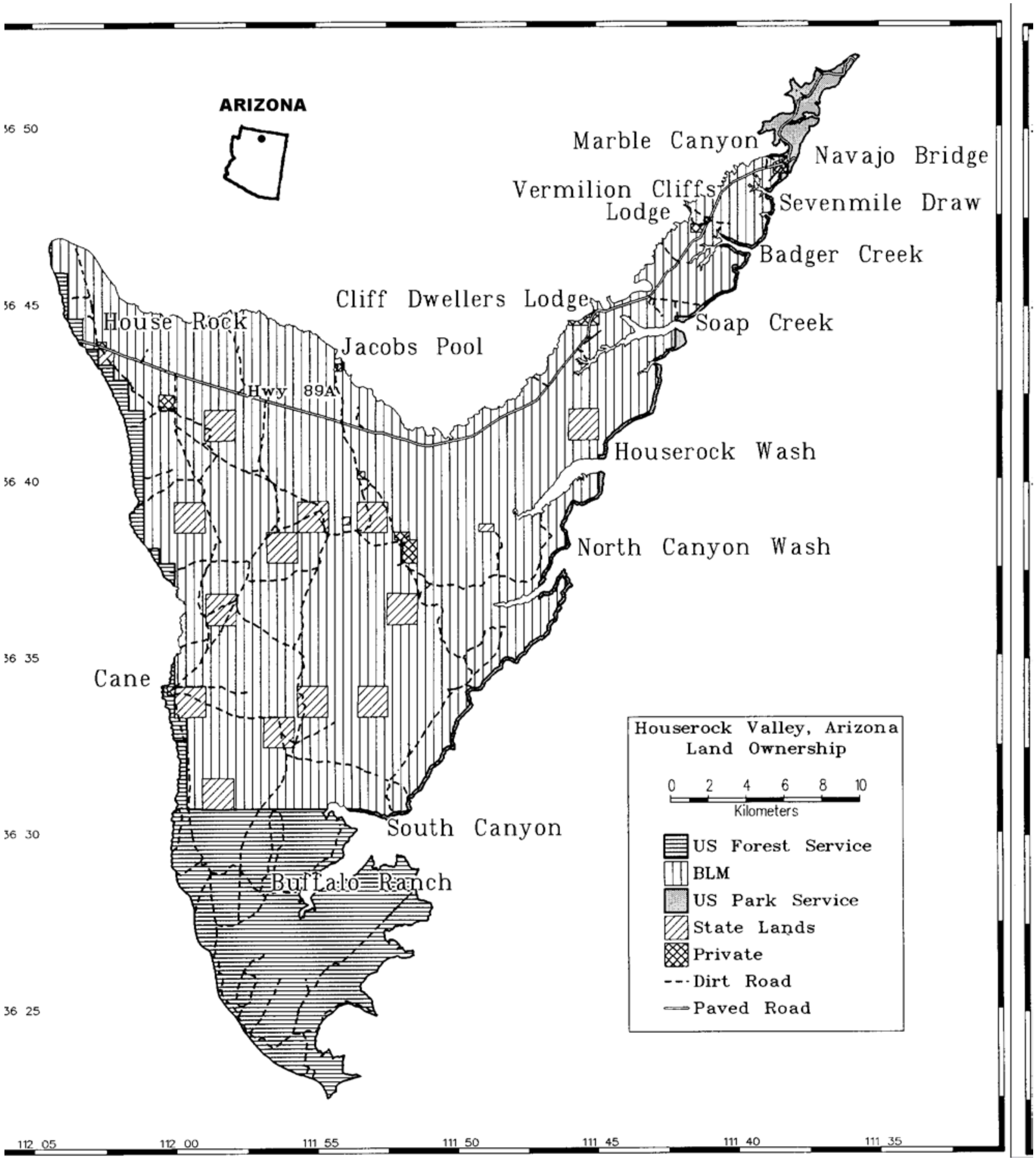

Figure 1. Ownership and jurisdictions within the Houserock Valley, Coconino Co., Arizona.

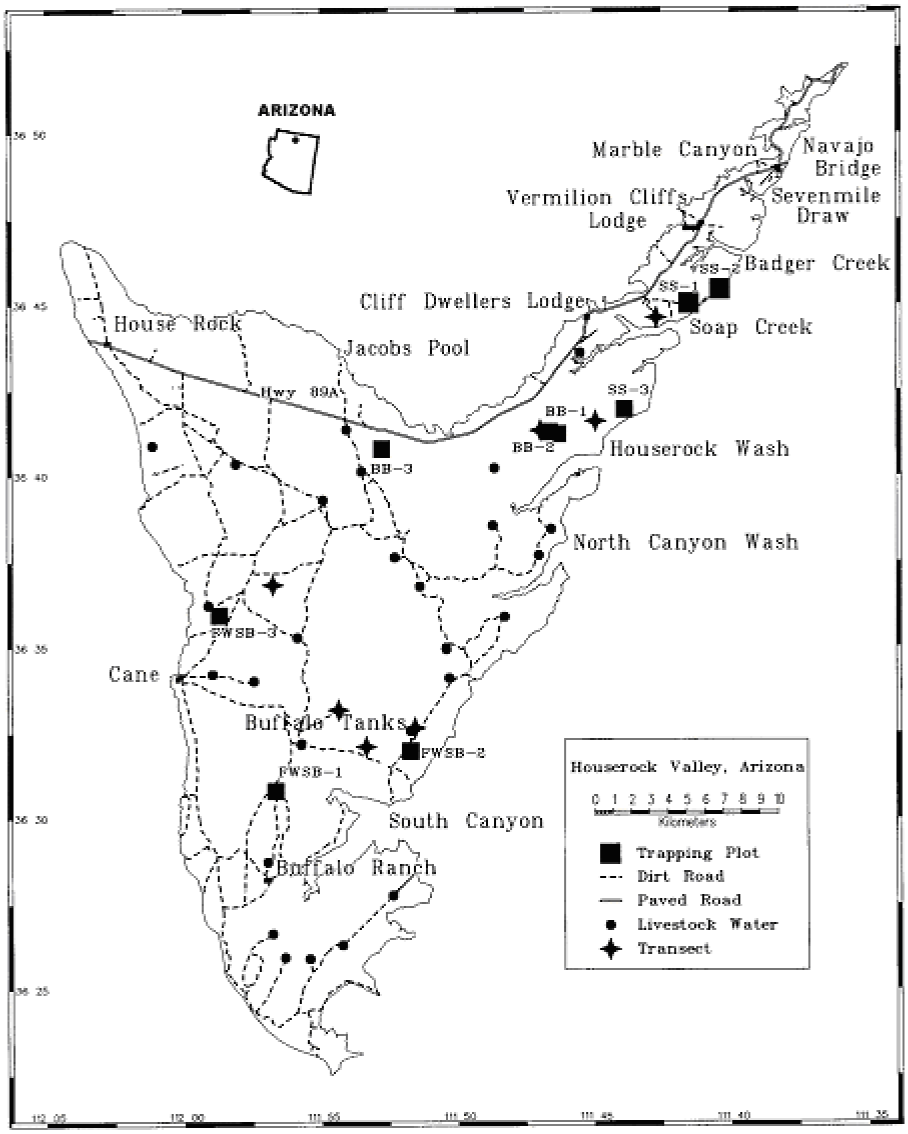

Figure 2. Location of live-trapping plots and vegetation transects in the Houserock Valley, Coconino Co. Arizona

measures and compass coordinates were taken from a single corner of a plot (Appendix A). A latitude/longitude fix was taken at this corner, designated as the control point (CP), with a Trimble Navigation GPS Model Scout.

Each study plot was selectively trapped. Two or three mesh live traps were placed at each mound, depending on the number of active entrances. Traps were situated in runways near active entrances. Trapping was conducted for three consecutive nights. Sampling on FWSB plots 1, 2, 3 occurred from 21 to 23 August 1995; BB plots 1, 2, 3 and SS plot 3 from 24 to 26 August 1995; and SS plots 1 and 2 from 30 August to 1 September 1995. Stoddard mesh live traps were opened in late afternoon and baited with a mixture of crimped oats, mixed bird seed, and peanut butter. Traps were checked and closed each morning at sunrise. For each capture, mound number was recorded and the animal was identified to species and sex, marked by clipping hair on the right flank for future identification, assessed for relative age and reproductive condition, weighed, and released at point of capture. Density was calculated for each species as the number of individuals captured divided by 6.76 ha. The area effectively sampled (6.76 ha) was calculated by adding a buffer strip of 15 m around the basic plot following the method of O=Farrell et al. (1977).

The distance between mounds was measured and distribution of burrow mounds was examined by computing all inter-mound distances for each plot. Inter-mound distances and nearest mound distances were then compared with >null= distributions of mounds. That is, a uniform random number generator was used to place mounds within a hypothetical plot in which all portions of the plot were equally likely to support a mound. Each null distribution of mounds was simulated 10 times for plots containing 7, 10, 11, 21, 22, 29, 30, and 35 mounds. Thus, 80 null plots were simulated. Inter-mound distances were then computed and compared graphically with the actual distribution of mounds for each plot size (7 through 35 mounds). A second series of simulations was conducted in which nearest mound distances were computed. Here each null distribution of mounds was simulated 20 times (for a total of 160 simulations. The distribution of actual nearest mound distances were compared with the randomly generated distribution.

The distribution of inter-mound and nearest mound distances was used to evaluate the potential effects of intraspecific competition. Increasing levels of competition should result in overdispersion of actual mounds relative to the null distributions. Underdispersion of mounds would be indicative of significant selection of critical components of the habitat within each plot.

Mound and Habitat Characterization

Each mound was measured for length and width and the number of active entrances counted. Mounds were judged active if surfaces were smooth and obviously being used by small mammals and scat and/or tracks were present. Vegetation was quantified by establishing four 7.5-m transects radiating from the center of a mound in the four cardinal directions. Percent aerial cover was determined by line-intercept of shrub canopy (Mueller-Dombois and Ellenberg

1974). The length of canopy intersected and the height of each shrub intersected was measured and the species recorded. Percent ground cover was determined by the point-intercept method (Mueller-Dombois and Ellenberg 1974). A 1-m point frame, with points at 20, 40, 60, and 80 cm, was placed perpendicular to the transect line at 1-m intervals. The first feature touched by each point was recorded (bare ground, rock > 2 cm, litter, plant species.

Vegetation, mound characteristics, and trapping data were analyzed by principal components analysis (PCA) in an effort to reduce the dimensionality of the data set, and to provide a series of statistically independent predictor variables for use in stepwise regression. The PCA was based on the covariance matrix to emphasize variables which were strongly correlated with the principal axes. The resultant PCA scores were used in a canonical correlation analysis in an effort to discern general patterns within the data. Stepwise discriminant analysis was used to identify vegetation variables which provided significant discrimination between the three sampled vegetation types. Finally, stepwise regression analysis was used to construct predictive models of kangaroo rat abundance relative to the vegetation variables. The stepwise regression analysis was performed twice. First with the complete vegetation data set, and second with a reduced data set. For the latter, the vegetation data were summarized in categories (percent ground cover by bare, litter, rock, annual plants, and percent aerial cover of live and dead perennials). All percentage data were normalized using the arcsin transformation.

Bulls-eye Effect

The effect of concentrated livestock activity around established water sources on the distribution of *D. m. leucotis* was determined by quantifying the distance that the species was found from the water source. Seven representative water sources were selected (Figure 2; 1 in BB; 2 in SS, 4 in FWSB). Vegetation was characterized by the step-toe method (Cottam and Curtis 1956). From each water source, walking transects were performed in the four cardinal directions and the perennial plant species touched by the tip of the toe was recorded for every other step. This yielded a linear quantification of vegetation changes from the water source to the first mound of *D. m. leucotis*. The effective field of observation for mounds was a minimum of 15 m on either side of the observer.

Based on numerous observations in the Houserock Valley, I assumed that no mounds of *D. m. leucotis* occurred next to water and that the probability of encountering a mound increased with distance from the water source. The transect data were analyzed using a logistic model, which was regressed against distance from the water source (Neter and Wasserman 1974). Thus, the model provided a predicted probability of encountering a mound relative to distance from the water source.

RESULTS

Density and Dispersion of *D. m. leucotis*

The species composition of small mammals varied among the three habitat types (Table 1). Among heteromyid rodents, the little pocket mouse (*Perognathus longimembris*) was restricted to four wing saltbush and blackbrush habitats, whereas the long-tailed pocket mouse (*Chaetodipus formosus*) was restricted to shadscale habitat. The single Great Basin pocket mouse (*P. parvus*) on FWSB Plot 1 was probably a fugitive immigrant from the big sagebrush habitat south of the plot. Ord=s kangaroo rat (*Dipodomys ordii*), like *P. longimembris*, was absent from shadscale habitat. Among murid rodents, deer mice (*Peromyscus maniculatus*) were found in all habitat types, canyon mice (*P. crinitus*) were found only in shadscale habitat near the canyon edge, pinyon mice (*P. truei*) surprisingly were found in four wing saltbush and blackbrush as were northern grasshopper mice (*Onychomys leucogaster*). Although not captured in this study, the desert woodrat (*Neotoma lepida*) occurred in shadscale habitat associated with cactus patches (O=Farrell 1995). The one sciurid rodent captured, antelope ground squirrel (*Ammospermophilus leucurus*), was ubiquitous. Numbers of individuals captured varied among plots, and within and among habitat types.

By design, *D. m. leucotis* was found on all plots and within all habitat types examined (Table 1). Generally, shadscale and four wing saltbush habitats supported larger numbers of the species than blackbrush. Plots BB-1 and BB-2 supported fewer individuals than BB-3. Visible

Table 1. Summary of live trapping results within each habitat type sampled. Estimated density (# individuals/ha) and number of individuals captured (Male/Female)

	FOUR WING SALTBUSH			BLACKBRUSH			SHADSCALE		
SPECIES	PLOT 1	PLOT 2	PLOT 3	PLOT 1	PLOT 2	PLOT 3	PLOT 1	PLOT 2	PLOT 3
Perognathus longimembris	0.89 (3/3)	0.74 (4/1)	0.74 (2/3)	0.44 (3/-)	0.59 (2/2)	1.18 (4/4)	-	-	-
Perognathus parvus	0.15 (-/1)	-	-	-	-	-	-	-	-
Chaetodipus formosus	-	-	-	-	-	-	1.78 (5/7)	3.11 (10/11)	0.44 (1/2)
Dipodomys microps leucotis	0.89 (2/4)	1.04 (3/4)	2.67 (7/11)	0.30 (-/2)	0.59 (2/2)	1.33 (5/4)	1.93 (5/8)	1.33 (4/5)	0.59 (2/2)
Dipodomys ordii	1.18 (4/4)	0.74 (3/2)	3.11 (11/10)	0.74 (4/1)	-	0.15 (1/-)	-	-	-
Onychomys leucogaster	0.15 (1/-)	0.15 (1/-)	0.44 (2/1)	-	-	0.30 (1/1)	-	-	-
Peromyscus crinitus	-	-	-	-	-	-	-	0.15 (-/1)	-
Peromyscus maniculatus	1.33 (5/4)	1.48 (5/5)	0.59 (2/2)	0.15 (1/-)	0.30 (1/1)	1.63 (5/6)	-	-	0.74 (4/1)
Peromyscus truei	0.44 (1/2)	0.44 (2/1)	0.30 (-/2)	-	-	0.15 (-/1)	-	-	-
Ammospermophilus leucurus	-	0.30	0.30	0.74	0.59	0.89	1.18	1.04	0.74

	(1/1)	(1/1)	(3/2)	(1/3)	(4/2)	(4/4)	(3/4)	(2/3)

differences among these plots included: 1) greater livestock activity was evident on the first two plots (i.e., relative quantity of droppings and tracks), possibly due to proximity of a periodically used water source; and, 2) BB-1 occurred at an ecotone with ephedra/yucca habitat (O=Farrell 1995). Plots SS-1 and SS-2 showed less evidence of livestock activity than SS-3, which supported far fewer kangaroo rats. The same pattern was evident for four wing saltbush. FWSB-3 supported not only more *D. m. leucotis* but far more rodents of all species and had much less evidence of livestock activity than the other two plots.

The number of active burrow mounds exceeded the number of individual *D. m. leucotis* captured on all plots (Tables 1-2; Appendix I). No differences were found between the actual dispersion of mounds and the simulations based on randomly generated distributions (see Appendix I for actual plots of mound dispersion). Likewise, no significant difference was found between the actual and randomly generated nearest neighbor distances. In six of the nine cases, actual nearest neighbor distances between mounds were smaller than the null distributions, suggesting some clumping of mounds. Likewise, simulations of the median nearest neighbor distance showed no significant difference between the actual distribution of mounds and the null distribution. The distance between mounds tended to decrease with increasing numbers of mounds present (Figure 3).

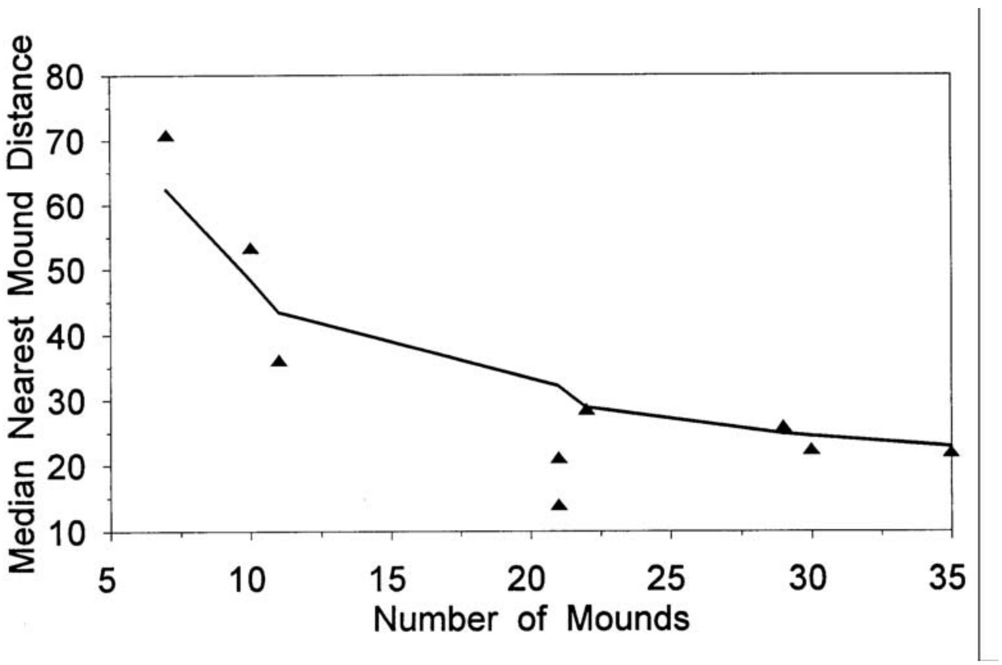

Figure 3. Plot of the median nearest neighbor distance in relation to the number of mounds found on a trapping plot.

A significant correlation was found between number of active mounds and number of individual *D. m. leucotis* on a plot ($R = 0.775$; $P < 0.05$). A linear regression model was generated without a constant because theoretically the intercept must be 0. No animals should be

present without the presence of mounds. The regression model (Figure 4) was:
N = (0.355)M (1)
where N is the number of *D. m. leucotis* and M is the number of active mounds within a 6.25 ha plot (the standard error of the regression coefficient = 0.043 ; R_2 = 0.894; t = 8.233; P < 0.001; $F_{df = 1,8}$ = 67.778; P < 0.001).

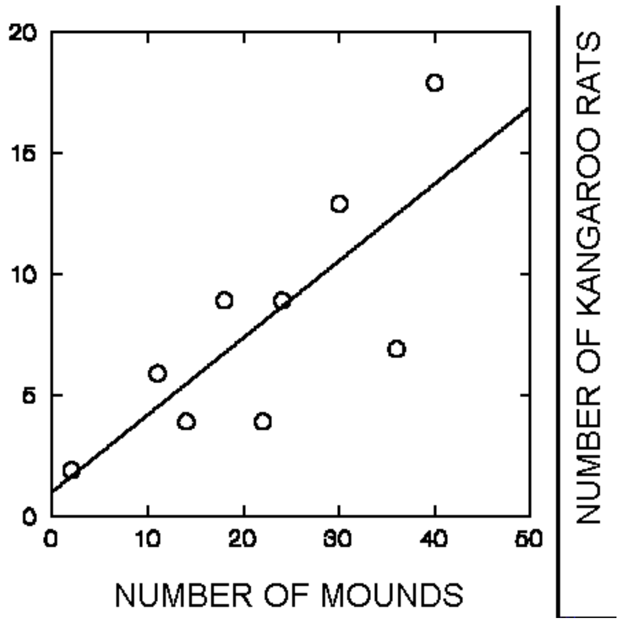

Figure 4. Scatter plot of the number of *D. m. leucotis* individuals captured in relation to active burrow mound counts for the 6.250-ha trapping plots.

Mound and Habitat Characterization

Mean dimensions and number of entrances varied among habitat types (Table 2). A one-way analysis of variance revealed significant differences among the three habitat types for length, width, and number of active entrances (Table 3). Tukey Tests of pairwise differences in means indicated significantly larger burrow mounds in four wing saltbush habitat than in shadscale or blackbrush habitats.

Table 2. Summary of burrow mound characteristic for *Dipodomys microps leucotis* in the Houserock Valley, Coconino County, Arizona. Mean values, plus or minus

N = (0.355)M

one Standard Error, for length and width are given in meters; # ENTRANCES = number of active burrow entrances on the mound.

HABITAT/PLOT	N	LENGTH	WIDTH	# ENTRANCES
Four Wing Saltbush				
Plot 1	11	3.75 " 0.49	2.54 " 0.39	12.5 " 1.9
Plot 2	10	4.88 " 0.40	2.99 " 0.48	11.2 " 2.3
Plot 3	29	4.75 " 0.41	3.08 " 0.23	11.7 " 1.1
Blackbrush				
Plot 1	7	2.29 " 0.22	1.70 " 0.15	6.0 " 1.5
Plot 2	21	2.76 " 0.25	2.05 " 0.15	9.5 " 1.2
Plot 3	19	2.13 " 0.18	1.60 " 0.14	6.8 " 1.0
Shadscale				
Plot 1	35	2.89 " 0.19	2.25 " 0.18	8.3 " 0.7
Plot 2	30	3.44 " 0.25	2.22 " 0.13	9.5 " 0.8
Plot 3	22	2.61 " 0.24	1.78 " 0.23	9.2 " 1.4

Habitat features varied among plots within a habitat type as well as among habitat types. Percentage of bare ground was lowest and annual vegetation cover highest on Plot 3 in four wing saltbush habitat (Table 4). Shrub cover and height were similar for all three plots. Blackbrush plots (Table 5) showed similar ground cover and bare ground proportions and similar shrub parameters but Plot 2 had a greater proportion of ground cover than the other two plots. Shadscale plots (Table 6) showed similar shrub cover but Plot 2 had greater ground cover by annual plants and litter, with consequently reduced bare ground.

Table 3. ANOVA results of burrow mound characteristics (length, width, entrances) by habitat type. SS = Sums of squares; MS = Mean square.

Source of Variation	*df*	SS	MS	*F*	*P*
Length	2	121.308	60.658	30.159	< 0.001
Error	181	364.016	2.011		
Width	2	34.394	17.197	16.808	< 0.001
Error	181	185.195	1.023		

Entrances	2	400.410	200.205	7.308	< 0.01
Error	181	4958.525	27.395		

Table 4. Summary of ground cover [mean percent of bare ground (BARE),

	PLOT 1	PLOT 2	PLOT 3
BARE	62.86	68.53	51.62
ROCK	0	0.07	0.88
LTTR	14.02	13.74	8.22
ANNUALS	22.23	17.64	30.28
SHRUB COVER	18.32	14.78	15.06
MEAN SHRUB HT	81.2	71.1	85.5

Table 5. Summary of ground cover [mean percent of bare ground (BARE),

	PLOT 1	PLOT 2	PLOT 3
BARE	75.11	73.72	73.09
LTTR	16.06	18.75	15.84
ANNUALS	8.15	7.53	10.85
SHRUB COVER	24.07	24.50	28.04
MEAN SHRUB HT	111.2	78.2	51.0

Table 6. Summary of ground cover [mean percent of bare ground (BARE),

	PLOT 1	PLOT 2	PLOT 3
BARE	75.63	57.49	72.80
ROCK	0	2.67	0.25
LTTR	14.06	24.97	16.19
ANNUALS	10.34	14.55	10.80
SHRUB CV	18.13	17.92	16.23
SHRUB HT	64.4	69.6	49.0

In general, shadscale and blackbrush plots showed similar ground cover parameters. Both habitats demonstrated a greater proportion of bare ground than four wing saltbush plots. Litter on all plots was of the same order of magnitude but four wing saltbush plots had greater annual plant cover than the other two habitats. Blackbrush habitat had greater shrub cover and had the tallest shrubs. Shrub cover on the remaining plots was similar but shadscale had the shortest shrubs.

The first five PCA axes explained 96% of the variance in the vegetation data. Interpretation of the first three axes was straightforward. The first principal component was loaded most heavily for blackbrush (*Coleogyne ramosissima*) aerial cover. The second principal component was dominated by shadscale (*Atriplex confertifolia*) aerial cover. The third principal component contained two variables with high loading, four wing saltbush (*Atriplex canescens*) and green rabbitbrush (*Chrysothamnus viscidiflorus*) aerial cover. The fourth axis was a mix of both *Atriplex* species cover and the dead shrub cover variable. The fifth axis was dominated by dead shrub cover. Aside from assuring that the principal axes were independent, the PCA demonstrated the obvious that blackbrush habitat was dominated by blackbrush, shadscale habitat was dominated by shadscale, and four wing saltbush habitat dominated by four wing saltbush and green rabbitbrush.

The PCA on the reduced vegetation data base provided a different perspective. The first three axes explained 85% of the variance in the data. The first principal component was annual ground cover (grasses and forbs). The second axis was dominated by litter cover. The third axis was loaded most heavily for shrub cover. These principal components were used in later analyses.

When applied to the reduced vegetation and mound databases, canonical correlation revealed a significant ($p < 0.05$) relation between mound length and annual ground cover. Small mounds associated with greater annual cover were found predominantly in four wing saltbush habitat. Long mounds with little annual cover were found predominantly in blackbrush habitat. Mound length and annual cover were intermediate in shadscale habitat. The stepwise regression model, significant at the 5% level, explained 11% of the *D. m. leucotis* abundance data (Table 7). Abundance increased with increasing shrub cover and mound length. Greater overall *D. m. leucotis* abundance was found in four wing saltbush plots.

Table 7. Stepwise regression results of *D. m. leucotis* abundance and the mound/vegetation databases. SE = Standard error; SHRUB = aerial cover; LENGTH = mound length; FWSB = Four wing saltbush plots. $R^2 = 0.112$.

VARIABLE	PARAMETER ESTIMATE	SE	*F*	*P*
INTERCEPT	-0.556	0.310	3.22	0.075
SHRUB	1.560	0.573	7.40	0.007
LENGTH	0.083	0.032	6.57	0.011
FWSB	0.261	0.113	5.33	0.022

Bulls-eye Effect

Logistic regression analysis of the bulls-eye transect data resulted in a sigmoidal regression curve, significant at the $P < 0.001$ level (Figure 5). The R^2 was 0.892, indicating that more than 89% of the variance in the probability of encountering a mound is explained by the regression model. Although the remaining unexplained variance may be spurious, there is probably another factor influencing the probability of encountering a mound. When there was considerable difference among distances to a mound among the four transect lines at a water source, I found significant change in topography, substrate, and vegetation on one or more of the transect lines. Generally, when the surrounding habitat was uniform there was corresponding agreement with the distance to first mound.

There were obvious, subjective vegetation changes with increasing distance from a water source (Table 8). Directly around a water source vegetation was non-existent or extremely sparse. In general, the first vegetation encountered was an introduced disturbance species (e.g., Russian thistle, *Salsola tragus*; FWSB). *Atriplex canescens* and *S. tragus* both appeared at about the same time and both tended to be greater than 50m from a water source. However, *S. tragus* appeared to dominate. The area around a water source was significantly altered by livestock concentration, resulting in marked reduction of vegetation within the first 100 m from the water source. *D. m. leucotis* mounds did not appear, on average, until 200 m from a water source.

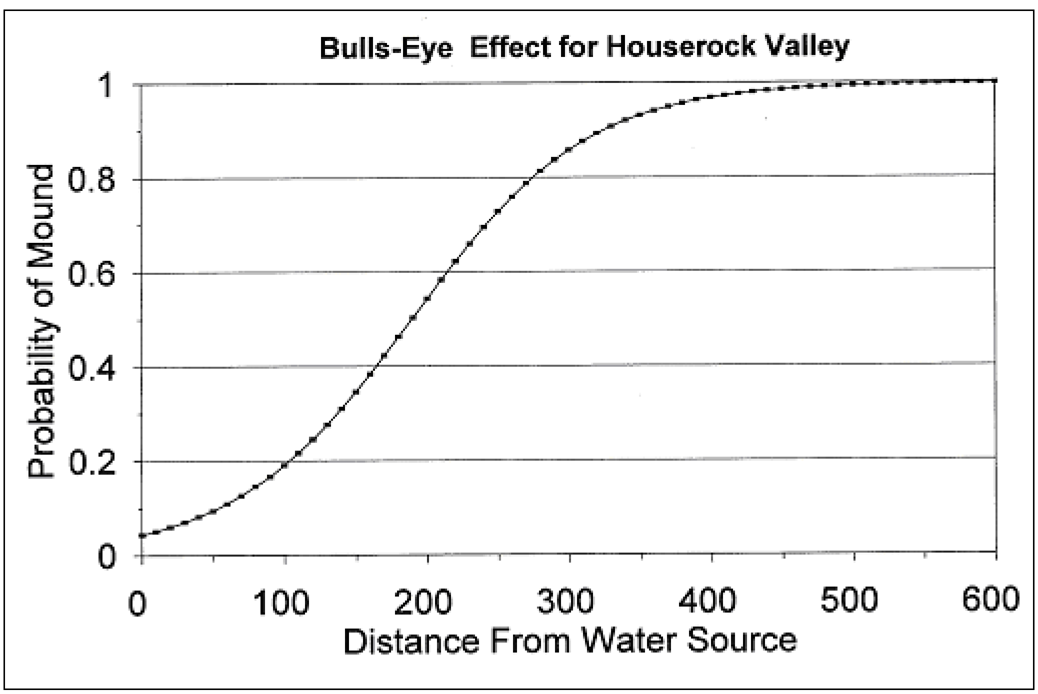

Figure 5. Logistic regression of the probability of encountering a mound of *D. m. leucotis* with increasing distance from a water source.

DISCUSSION

Chisel-toothed kangaroo rats are known to form mounds associated with a concentration of burrow entrances (Hayssen 1991). These mounds are similar to but less substantial than those produced by larger, grassland kangaroo rats (Best 1988; Williams and Kilburn 1991). Studies on these latter species indicate estimates of density can be provided by quantifying the number of mounds per unit area because a single adult was resident in each mound. At present it is suspected but not verified that a single adult *D. m. leucotis* occupies each mound (Spicer and Johnson 1988; O'Farrell 1995). It is clear from past studies that *D. m. leucotis* does not trap readily and that the sparse distribution through portions of the range preclude the use of standard trapping configurations to determine density.

This study supports the contention that chisel-toothed kangaroo rats form mounds (Hayssen 1991). During the initial marking of kangaroo rat burrow mounds, great care was taken to include any burrow used by a kangaroo rat as evidenced by presence of characteristic scat and tracks. Subsequent trapping verified the exclusive use of non-mound complexes by *D. ordii*. In most cases, there were more mounds than individual *D. m. leucotis* (see Appendix I). The

Table 8. Summary of Bulls-eye transects with distance (m) of key features from select water sources in four wing saltbush (FWSB), shadscale (SS), and blackbrush (BB) habitats. SATR = mean distance of last occurrence of *Salsola tragus*; ATCA = mean distance of first occurrence of *Atriplex canescens*; ATCO = mean distance of first occurrence of *Atriplex confertifolia*; CORA = mean distance of first occurrence of *Corethrogyne ramosissima*; DIPMIC = mean distance of first occurrence of *Dipodomys microps leucotis* mound. The symbol > indicates at least one of the four transects for a plot had a kangaroo rat mound before the target plant species was encountered.

TRANSECT	SATR	ATCA	ATCO	CORA	DIPMIC
FWSB 1	73	>110			233
FWSB 2	55	33			178
FWSB 3	35	58			233
FWSB 4	165	120			218
SS 1			20		125
SS 2			305		335

BB 1				>65	155
MEAN	82	80	163		216

proximity of apparently unoccupied but active mounds to those that were occupied suggested use of multiple mounds. The movements documented during the trapping further supported this idea. The trapping results further revealed that only a single adult uses a mound at any given time. Occasionally, both sexes were encountered at a mound but in the context of a male traveling from a nearby mound (BB-3, FWSB-3, SS-1; Appendix I). These observations are similar to those made for *Dipodomys spectabilis* (Best 1988). The presence of young associated with adult females was observed but the timing of the trapping occurred when most young had already dispersed. It is also possible that some of the active mounds had resident individuals that simply were not trapped. A comprehensive trapping effort over multiple seasons will be required to clarify spatial and social interactions.

The significant correlation of the number of active mounds and the number of *D. m. leucotis* present provided the basis of a predictive model. Enumeration of active mounds within a 6.25-ha plot requires no more than half a day. Use of equation 1 with this enumeration will provide a reasonable estimate of the number of resident animals. A trapping effort to determine abundance or density would require a minimum of 3 nights of intensive trapping thereby reducing the number of areas that can be sampled in a short time frame.

Chisel-toothed kangaroo rats occur in a wide variety of habitats, including creosote bush, saltbush, and blackbrush types (Hayssen 1991). However, key features in the habitat that effect abundance have not been determined. Within the Houserock Valley, *D. m. leucotis* occurs in several distinct habitat types (O'Farrell 1995). A combination of soil and vegetation factors appear to determine suitability for occupation. Specific features enhancing or restricting occupation have not been described. Although both species of kangaroo rats within the Houserock Valley do use mound-like burrow complexes, we have found that qualitative differences are sufficient to distinguish which species is the primary occupant (O'Farrell 1995). *D. m. leucotis* produces and occupies readily apparent, raised mounds containing multiple entrances whereas *D. ordii* uses a range of dispersed burrow entrances ranging from single, isolated entrances to clusters of entrances that do not form a discrete, raised mound.

Dispersion of mounds did not differ from a random distribution although there appeared to be an occasional tendency towards a clustered distribution. Clustering should be associated with specific habitat features rather than intraspecific, social interactions. *Dipodomys spectabilis* demonstrated a uniform distribution presumably due to competitive interactions (Schroder and Geluso 1975). The lack of demonstrated social spacing in the present study may be due to the generally low densities supported in the Houserock Valley (Table 1). Elsewhere in the species' range, densities as high as 34 individuals/ha have been found (Hayssen 1991). This suggests that habitat conditions within the Houserock Valley are relatively poor compared to other occupied habitats. The most apparent proximal cause for general habitat degradation in the Houserock

Valley is livestock use. Precise knowledge of site-specific livestock use in relation to areas occupied by *D. m. leucotis* would help clarify this relationship.

In the Houserock Valley, mound complexes tended to be oval in shape and generally contained more than 5 active entrances (Table 2). Mounds in blackbrush and shadscale habitat were similar in dimensions and number of active entrances but differed significantly from the larger mounds found in four wing saltbush habitat. The differences may be associated with soil or vegetation factors or a combination of both.

Annual vegetative ground cover differed significantly between four wing saltbush and the other two habitat types. A significantly greater percent cover should account for the greater number of individual kangaroo rats found on the four wing saltbush plots (Table 1). However, the variability among plots within the four wing saltbush was greater than for the other two habitats. The apparent difference in livestock activity within four wing saltbush was greater than the other two types and may account for the increased variability and the observed differences in abundance of *D. m. leucotis*. Habitat systems with small patches of bare ground are considered healthy whereas those with large bare areas are less healthy (de Soyza et al. 1997). The amount of bare ground was less within four wing saltbush than for the other types examined (Tables 4-6).

I was unable to establish a correlation between kangaroo rat abundance and the level of livestock use. Part of the initial site selection criteria was to sample the range of apparent habitat variability and to sample different pastures. Information received from the BLM provided the level of livestock allocation and use by allotment, but not by pasture. Hence, all of the blackbrush and shadscale plots occurred within the Soap Creek allotment and all the four wing saltbush plots were within the Buffalo Tank allotment even though distinct differences were apparent between the amount of visible livestock sign and vegetation and individual plots within a given habitat type.

A multiple regression model, significant at the 5% level, indicated that the number of individual *D. m. leucotis* was directly related to shrub cover, the size of mounds, and habitat type. The number of individuals increased with increasing shrub cover and size of mounds which occurred in four wing saltbush habitat. It is noteworthy that in four wing saltbush habitat, areas receiving greater apparent livestock use had reduced shrub cover and a change in the proportion of dominant shrub species. *A. canescens* tend to be browsed aggressively which reduces the height and overall cover. Also, small *C. viscidiflorus* predominate in areas of apparent high livestock use which further changes the vertical profile and aerial cover.

Surface disturbance of Colorado Plateau habitats, from a variety of sources, have been found to significantly reduce soil nutrients, microflora and fauna, and soil properties such as water penetrability and erosion potential (Belnap 1995). A 60-80% reduction in nitrogenase activity was found immediately upon surface disturbance, regardless of the type (i.e., foot, mountain bike, off-road vehicle). Continued reduction, 80-100%, was found within the first year following initial disturbance. Belnap (1995) showed that livestock activity not only accounted for mechanical surface disturbance but reduced vegetative biomass further exacerbating impact to the native fauna. She indicated that recovery of soil systems required more than 100 years after disturbance is completely removed.

In order to gain a perspective of livestock impact in the Houserock Valley, the effects on perennial plants and occurrence of *D. m. leucotis* was examined in relation to distance from established water sources. Livestock concentrate around these water sources creating an immediate area virtually devoid of plant or animal occurrence. A gradient of increasing numbers of individual plants and species is evident with increasing distance from the water source. Bare ground predominates within the first 50-100 m. What vegetation occurs tends to be dominated by introduced, weedy species (e.g., Russian thistle). Native vegetation first appeared between 80 and 160 m from the water source. At a distance of 200 m from the water source, there was only a 55% probability of encountering *D. m. leucotis* (Figure 5). A conservative estimate of the area of significant habitat degradation (i.e., habitat conditions incapable of supporting *D. m. leucotis*) would be 12.6 ha (30.9 acres; a radius of 200 m). Thus, for every extant water source within suitable kangaroo rat habitat in the Houserock Valley, 31 acres are made unsuitable. New water sources will increase this acreage.

The distribution of *D. m. leucotis* in the Houserock Valley is extensive within the range of suitable soil and vegetation types (O=Farrell 1995). Approximately half the valley is currently occupied. Densities supported are relatively low for all habitat types which may reflect poor habitat conditions. I found evidence that annual ground cover and shrub structure was reduced in areas that had more apparent livestock use. The positive relationship between *D. m. leucotis* abundance and increasing shrub cover in four wing saltbush further indicates that reduced livestock impact to *A. canescens* promotes increased numbers of the kangaroo rat. Although the current distribution suggests no immediate concern for an upgrade in sensitive status, the overall low densities and the apparent responsiveness to livestock pressure suggests vulnerability.

MANAGEMENT RECOMMENDATIONS

The Houserock Valley chisel-toothed kangaroo rat is more widespread within the valley than previous studies indicated. Distribution is confined to blackbrush, shadscale, and four wing saltbush habitats. Within these habitats density levels were lower in areas receiving more concentrated livestock use, although the highest densities found were only moderate for populations of the species within the Great Basin. Although occupation was found over approximately half the valley, the taxon is restricted to the valley with no current connection with the nearest subspecies. This isolation and restriction to specific habitat and soil types infers some degree of vulnerability. In reality, minimal modification of current practices could provide important security for *D. m. leucotis*. Based on the present study, the following recommendations are made.

C. The intensity of livestock use within the blackbrush, shadscale, and four wing saltbush habitats should be avoided. A reduction in livestock use or a more frequent shift of use on existing pastures would increase the carrying capacity for *D. m. leucotis*.

C. Periodic monitoring of kangaroo rat population levels would provide trends that allow remedial action should there be a precipitous decline in kangaroo rat numbers. Monitoring of density can be accomplished using the predictive model given in equation 1. The replicate plots in each habitat type were permanently staked at the corners which will assist in using these for future trend examination. Each of the plots should be assessed, using the techniques established in this report, every other year during the late summer/early fall at the end of juvenile recruitment.

C. Detailed studies of demography and spatial use by *D. m. leucotis* are needed to gain a better perspective on critical aspects of the biology of the species and to allow a better opportunity to provide suitable management for the long-term protection of this isolated taxon

C. Avoid placement of new livestock water sources in the blackbrush, shadscale, and four wing saltbush habitats. New livestock water sources established in other habitat types should be placed away from the ecotone with the three suitable habitats types, thus avoiding kangaroo rat exclusion within the bulls eye zone.

C. When possible, the response of vegetation and subsequent kangaroo rat response in areas where livestock use has declined, especially around water sources, should be studied in detail. It is critical to understand the dynamics of habitat recovery in areas no longer used intensively.

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DENSITIES AND HABITAT AFFINITIES OF THE CHISEL-TOOTHED KANGAROO RAT *(Dipodomys microps leucotis* Goldman)

By

Michael J. O'Farrell

1997

APPENDIX I

Individual plot maps of *D. m. leucotis* burrow mounds for each of the three replicate plots within each of the habitats examined (BB = blackbrush; FWSB = four wing saltbush; SS = shadscale). Mounds where individual were captured are circled and identified as to sex. Juveniles are designated with a superscript Ay@. It is important to note that each symbol designating sex indicates a distinct individual. Mounds representing first capture of an individual contain the symbol. If the individual was later captured at a different mound, an arrow line is drawn to indicate this movement.

Mounds where animals were not captured were obviously used as evidenced by presence of scat and tracks. The single exception is BB-1 which show interior burrow complexes originally believed to be made by *D. m. leucotis* but subsequently shown to be *D. ordii* in origin and use.

APPENDIX II. Checklist of vegetation, with habitat type, observed in the Houserock Valley, Coconino County, Arizona (1993-1994). VEGETATION TYPES: 1= Shadscale; 2 = Four-wing Saltbush; 3 = Ephedra/Yucca; 4 = Blackbrush; 5 = Buckwheat/Wolfberry; 6 = Snakeweed; 7 = Wash/Canyon; 8 = Big Sagebrush.

FAMILY/SPECIES	COMMON NAME	VEGETATION TYPE 1	2	3	4	5	6	7	8
Gymnosperms									
Cupressaceae									
Juniperus osteosperma	Utah Juniper							X	X
Ephedraceae									
Ephedra nevadensis	Nevada Ephedra	X	X	X	X				
Ephedra torreyana	Torrey Ephedra				X				
Ephedra viridis	Green Ephedra			X					
Pinaceae									
Pinus edulis	Pinyon							X	
Dicots									
Asteraceae									
Ambrosia psilostachya	Western Ragweed			X				X	

APPENDIX II. (Continued).

VEGETATION TYPE

FAMILY/SPECIES	COMMON NAME	1	2	3	4	5	6	7	8
Asteraceae (Continued)									
Artemisia tridentata	Big Sagebrush		X		X				X
Chrysothamnus nauseosus	Rubber Rabbitbrush		X	X	X			X	X
Chrysothamnus viscidiflorus	Green Rabbitbrush		X				X		
Encelia virginensis	Virgin River Encelia			X				X	
Erigeron divergens	Spreading Fleabane	X							
Grindelia squarrosa	Curly Gumweed			X				X	
Gutierrezia sarothrae	Snakeweed		X	X			X	X	
Haplopappus heterophyllus	Jimmyweed		X				X		
Haplopappus parryi	Parry Goldenbush			X			X		
Helianthus anomalus	Sand Sunflower		X	X				X	
Machaeranthera aquifolia	Aster		X		X				
Machaeranthera canescens	Hoary-Aster	X							
Pectis angustifolia	Fetid-Marigold	X							
Psathyrotes ramosissima	Turtleback	X							

APPENDIX II. (Continued).

		VEGETATION TYPE							
FAMILY/SPECIES	COMMON NAME	1	2	3	4	5	6	7	8

		1	2	3	4	5	6	7	8
Asteraceae (Continued)									
Senecio spartioides	Broom Groundsel							X	
Stephanomeria tenuifolia	Slender Wirelettuce			X				X	
Brassicaceae									
Stanleya pinnata	Prince's Plume							X	
Cactaceae									
Echinocactus polycephalus	Many-headed Cactus	X	X						
Echinocereus engelmannii	Hedgehog Cactus	X	X						
Escobaria vivipara	Viviparous Foxtail Cactus		X						
Opuntia phaeacantha	Berry Pricklypear	X	X	X					
Opuntia whipplei	Whipple Cholla	X	X						
Capparaceae									
Cleome serrulata	Rocky Mountain Bee Plant			X				X	

APPENDIX II. (Continued).

		VEGETATION TYPE							
FAMILY/SPECIES	COMMON NAME	1	2	3	4	5	6	7	8
Chenopodiaceae									

Atriplex canescens	Four-wing Saltbush	X	X	X	X		X		X
Atriplex confertifolia	Shadscale	X	X						
Atriplex garretti	Garrett Saltbush	X							
Krascheninnikovia lanata	Winterfat		X	X			X		
Salsola tragus	Russian Thistle		X	X			X		
Euphorbiaceae									
Euphorbia serpyllifolia	Spurge	X	X	X					
Fabaceae									
Astragalus lentiginosus	Freckled Milkvetch						X		
Geraniaceae									
Erodium cicutarium	Storksbill	X	X	X			X		X

APPENDIX II. (Continued).

		VEGETATION TYPE							
FAMILY/SPECIES	COMMON NAME	1	2	3	4	5	6	7	8
Lamiaceae									
Salvia davidsonii	Davidson Sage			X				X	

Malvaceae									
Sphaeralcea leptophylla	Narrow-leaved Globemallow			X				X	
Nyctaginaceae									
Mirabilis oxybaphoides	Four O'Clock	X							
Onagraceae									
Oenothera albicaulis	Evening-primrose	X							
Oenothera laciniata	Evening-primrose			X				X	
Papaveraceae									
Argemone munita	Prickly-poppy							X	

APPENDIX II. (Continued).

FAMILY/SPECIES	COMMON NAME	VEGETATION TYPE 1	2	3	4	5	6	7	8
Plantaginaceae									
Plantago lanceolata	Plantain	X	X						
Polemoneaceae									
Langloisia setosissima	Bristly Langloisia	X							

Polygonaceae									
Eriogonum corymbosum	Golden Buckwheat					X			
Eriogonum deflexum	Flat-topped Buckwheat		X						
Eriogonum hookeri	Watson Buckwheat							X	
Eriogonum inflatum	Desert Trumpet	X			X		X		
Rosaceae									
Coleogyne ramosissima	Blackbrush		X	X	X				
Fallugia paradoxa	Apache Plume							X	

APPENDIX II. (Continued).

FAMILY/SPECIES	COMMON NAME	VEGETATION TYPE 1	2	3	4	5	6	7	8
Scrophulariaceae									
Penstemon virgatus	Beardtongue		X						
Solanaceae									
Datura wrightii	Jimson Weed							X	
Lycium pallidum	Pale Wolfberry					X			
								X	

Tamaricaceae									
Tamarix sp.	Salt Cedar								
Zygophyllaceae									
Kallstroemia californica	Caltrop	X							
Monocots									
Liliaceae									
Yucca angustissima	Narrow-leaved Yucca		X	X	X				

APPENDIX II. (Continued).

FAMILY/SPECIES	COMMON NAME	VEGETATION TYPE 1	2	3	4	5	6	7	8
Liliaceae									
Yucca angustissima	Narrow-leaved Yucca		X	X	X				
Poaceae									
Achnatherum hymenoides	Indian Ricegrass	X	X	X	X		X		
Bouteloua aristidoides	Needle Grama		X						
Bouteloua eriopoda	Black Grama	X	X				X		
Bouteloua gracilis	Blue Grama		X				X		
Bromus tectorum	Cheatgrass	X	X	X	X		X		X

Bromus sp.	Brome Grass	X	X						
Enneapogon desvauxii	Spike Pappusgrass		X				X		
Erioneuron pulchellum	Fluffgrass	X	X				X		
Hilaria jamesii	Galleta	X							
Scleropogon brevifolius	Burro Grass	X	X			X			
Sporobolus airoides	Alkali Saccaton	X	X				X		

APPENDIX II. (Continued).

FAMILY/SPECIES	COMMON NAME	VEGETATION TYPE 1	2	3	4	5	6	7	8
Poaceae (Continued)									
Sporobolus cryptandrus	Sand Dropseed		X	X	X			X	

Nomenclature follows Kearney and Peebles (1960), McDougall (1973), Welsh et al. (1987).