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RELATIONSHIPS OF THE BURROWS OF BAJA CALIFORNIA KANGAROO RATS TO ECOGEOGRAPHIC AND MORPHOLOGIC VARIATION

Geographic variation of rodent burrows has not been studied previously. The agile kangaroo rat, *Dipodomys agilis*, inhabits much of Baja California from the mountains of the north through the desert areas that cover most of the peninsula (Best, 1978). I chose to study burrow variation of this species because of the diversity of habitats it occupies and its large geographic range on the peninsula. The purposes of this study were to determine if geographic variation in kangaroo rat burrows exists, and whether the variation was correlated with that observed for morphologic and ecogeographic variables.

Burrows were studied at ten localities in Baja California during June and July 1972. I placed traps directly outside burrow entrances; animals caught were assumed to live in the burrow. Three to 11 burrows ($\bar{X} = 8$) were excavated at each locality (see Best, 1976, Appendix V, for means, standard deviations, and sample sizes for each site). The 17 burrow characteristics studied are listed in Table 1.

For each locality, altitude, latitude, longitude, temperature, and precipitation were taken from the nearest weather station as determined from the maps in Hastings and Humphrey's (1969) report on the climate of Baja California (see Best, 1976, Appendices II and III, for temperature and precipitation means used in this study). With one exception, collecting localities were within 20 km of a weather station. For Santa Catarina Landing, which is located on the west coast, the nearest weather station is approximately 35 km inland at an elevation of 450 m. At each locality I used a line-intercept method to characterize the vegetation (see Best, 1976, Appendix IV, for characters derived and their mean values for each locality).

For this study, correlation and distance matrices (Sneath and Sokal, 1973) were calculated from the standardized locality means of burrow data for each site; matrices were calculated previously for the morphologic, temperature, precipitation, and vegetation variation (Best, 1982). Clusters of localities from

TABLE 1.—*Character loadings of the first three principal components of interlocality burrow variation.*

Char. no.	Character	Principal components I	II	III
1	Height of opening	.803	−.463	.210
2	Width of opening	.099	−.906	.219
3	Number of surface openings	−.510	−.539	−.031
4	Greatest depth of system	.784	−.036	−.571
5	Average depth of system	.574	−.114	−.677
6	Number of nests	.838	.324	.039
7	Average depth of nests	.876	.294	−.024
8	Average diameter of main burrow	.737	−.183	.313
9	Average diameter of side burrows	.669	−.334	.457
10	Average length of side burrows	−.116	−.255	−.203
11	Number of side burrows	−.149	−.802	.175
12	Greatest length of system	.077	−.830	.184
13	Greatest width of system	.203	−.796	−.480
14	Location[1]	−.565	−.199	−.421
15	Mound present	−.609	.287	−.347
16	Number of food caches	.794	−.035	.129
17	Average depth of food caches	.647	−.113	−.593
Percent of total variance explained		36.1	22.6	12.9

[1] Burrow under vegetation or not.

the original matrices of distance and correlation coefficients were obtained with the unweighted pair-group method using arithmetic averages (UPGMA). Principal components (P.C.) were calculated from a matrix of correlations among characters and locality means. The projections of the localities were plotted onto the first three principal components. A shortest minimally connected network computed for the original matrix of distances was superimposed on this three-dimensional plot. Analyses were performed using the IBM 370 computer at the University of Oklahoma Computation Center. Bivariate correlations were determined with a program (BIVAR) written by D. M. Power, and multivariate analyses were conducted using the NT-SYS series of programs (Rohlf et al., 1972).

Two main clusters appear in the phenogram derived from the correlation matrix of burrow characters (Fig. 1A). Generally, these represent a separation of northern (upper cluster) from southern locations. In the distance phenogram (Fig. 1B), the localities are arranged somewhat in north to south order. Locality 9 (R. Alegre) is separate from the other localities, 1 and 3 (from northwestern Baja California) are grouped together, and the remaining localities form a large central cluster.

Results of the principal components analyses of interlocality burrow variation are presented in Table 1. Only 36.1% of the variance is explained by the first principal component. Eleven of the 17 characters have high correlations with P.C. I. This component appears to represent general size and complexity of the burrow systems: localities are plotted on the three-dimensional model (Fig. 1C) with smaller, less complex burrow systems on the left, and larger, more complex systems on the right. Principal component II accounts for 22.6% of the variance. Highest loadings are for characters which primarily represent diameter of the burrow system. This component places locality 9 (with larger diameter burrows) toward the back and the other localities toward the front of the model. P.C. III represents 12.9% of the variation and has highest loadings for characters measuring depth characteristics; localities depicted by longer sticks in Fig. 1C generally have deeper burrows.

Results of covariation analyses of the first two principal components of *Dipodomys* burrow variation with ecogeographic variables and morphologic principal components are presented in Table 2. P.C. I of male *D. agilis* morphologic variation (primarily indicative of body size; Best, in press) covaries significantly with P.C. II of burrow variation (system diameter; Table 2); i.e., larger males have larger diameter burrow systems. No morphologic component for females was associated with the burrow variation; this lack of significant covariation might be due to a small sample size for females (localities compared, n = 9).

Principal component I of burrow variation covaries significantly with latitude, longitude, July mean temperature, P.C. I of temperature (annual mean), January mean precipitation, and P.C. I of precipitation (winter and spring means). The most complex burrows are in the northern parts of the peninsula. This region has the lowest temperatures throughout the year and the greatest winter-spring precipitation. P.C.

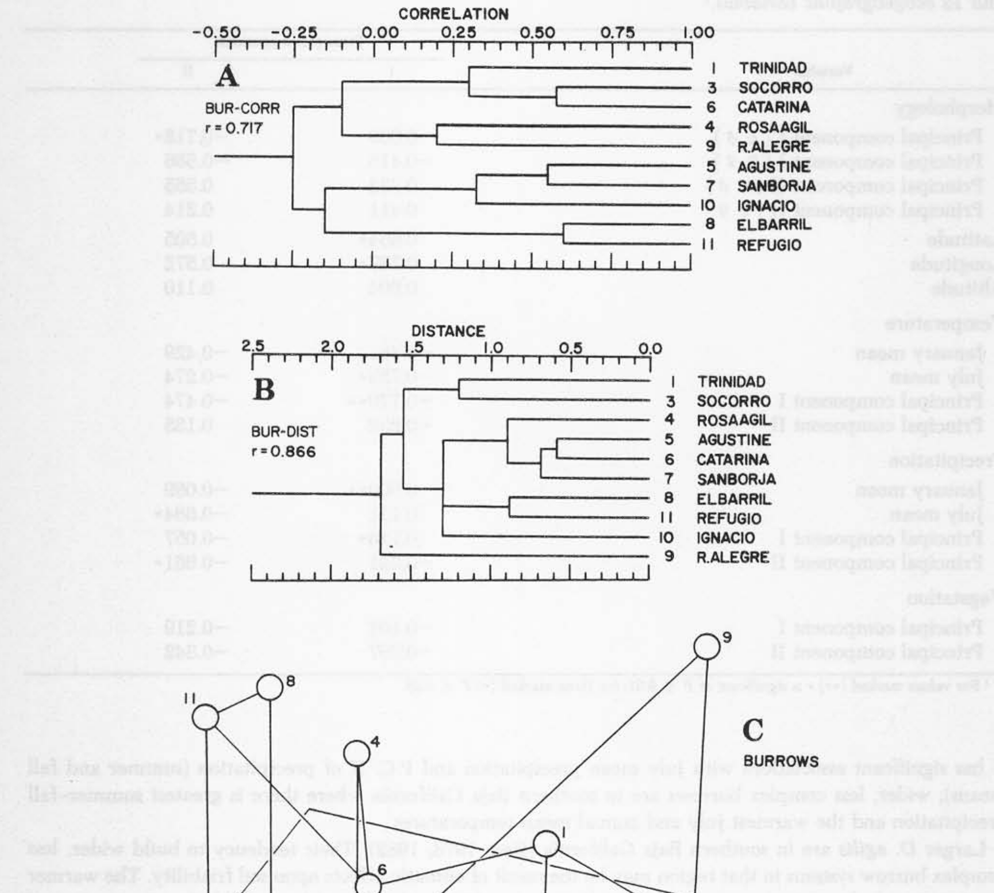

FIG. 1.—Phenograms constructed from matrices of (A) correlation, (B) distance coefficients, and (C) three-dimensional projection of the ten localities onto the first three principal component axes of variation using 17 burrow characters associated with *Dipodomys agilis* in Baja California. Cophenetic correlation coefficients (*r*) are given; accuracy of the phenograms in depicting interlocality relationships increases from left to right. The shortest minimally connected network is superimposed on the principal component space to indicate where possible distortion may be present. Numeric identifications, code names, and excavation localities are: 1) TRINIDAD, Valle de Trinidad; 3) SOCORRO, 12 mi. N El Rosario; 4) ROSAAGIL, 6 mi E El Rosario; 5) AGUSTINE, San Agustine; 6) CATARINA, Santa Catarina Landing; 7) SANBORJA, Mision de San Borjas; 8) ELBARRIL, 7 mi. W San Francisquito Bay; 9) R.ALEGRE, 2.5 mi. W Mesquital; 10) IGNACIO, 10 mi. E San Ignacio; 11) REFUGIO, 4.5 mi. N El Refugio.

TABLE 2.—*Covariation of the first two principal components of burrow variation with four morphologic and 13 ecogeographic variables.*[1]

Variable	Principal components I	Principal components II
Morphology		
Principal component I (♂♂)	−0.309	−0.718*
Principal component I (♀♀)	−0.416	−0.586
Principal component II (♂♂)	0.233	0.355
Principal component II (♀♀)	0.411	0.214
Latitude	0.654*	0.505
Longitude	0.707*	0.572
Altitude	0.304	0.110
Temperature		
January mean	−0.481	−0.429
July mean	−0.759*	−0.274
Principal component I	−0.770**	−0.474
Principal component II	−0.232	0.135
Precipitation		
January mean	0.900**	−0.089
July mean	0.131	−0.684*
Principal component I	0.716*	−0.057
Principal component II	−0.321	−0.661*
Vegetation		
Principal component I	−0.101	−0.219
Principal component II	−0.297	−0.342

[1] For values marked (**) r is significant at $P \leq 0.01$; for those marked (*) $P \leq 0.05$.

II has significant associations with July mean precipitation and P.C. II of precipitation (summer and fall means); wider, less complex burrows are in southern Baja California where there is greatest summer–fall precipitation and the warmest July and annual mean temperatures.

Larger *D. agilis* are in southern Baja California (Best, 1978, 1982). Their tendency to build wider, less complex burrow systems in that region may be the result of climatic affects upon soil friability. The warmer temperatures and greater summer–fall precipitation may help make the soil less suitable for construction of more extensive burrows. If the soils are difficult to excavate, there may be more of a tendency for kangaroo rats to construct longer tunnels and fewer of them. The soil could be more friable in the moister, cooler, northern regions allowing the generally smaller kangaroo rats to dig more; also the denser vegetation there may provide more food for storage, and therefore necessitate more side tunnels. The soil texture at each of the study sites appeared sandy. The finer-textured soils were predominately occupied by *D. merriami*, especially those areas with desert pavement, but there was considerable overlap between the two species. Unfortunately, detailed soils data are not available for Baja California. To better understand geographic variation in kangaroo rat burrows, additional studies are needed to determine their relationships with soil parameters. Many areas of the United States have detailed soils data, and wide ranging species such as *D. ordii* and *D. merriami* might be ideal for further study.

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