Morphologic Variation in the San Quintin Kangaroo Rat (Dipodomys gravipes Huey 1925)

ABSTRACT: Variation was evaluated in 110 specimens of *Dipodomys gravipes* from Baja California, Mexico. There was significant secondary sexual dimorphism in size for seven of 19 characters (males were largest), and significant intersample heterogeneity for 14 of the 19 characters. Populations near El Rosario are larger than those in the northern part of the range, and are probably geographically isolated. There are habitat differences that could partially account for the observed variation.

INTRODUCTION

The San Quintin kangaroo rat (*Dipodomys gravipes*) occupies a small range within 20 km of the Pacific coast of northern Baja California, Mexico, from near San Telmo (Huey, 1925; ca. 31°N, 116°W) southward to the vicinity of El Rosario (ca. 30°N, 115°45'W). The populations found northward from near El Socorro occur on the San Quintin Plain and contiguous areas where the vegetation is short and there is little topographic relief. The southern population occurs on the floodplain of the Arroyo del Rosario near El Rosario (a relatively flat area bordered by mesas and hills). Surrounding areas with greater relief and denser vegetation are occupied by *D. agilis*, which also occur occasionally on the low areas.

Previous analyses of morphologic variation among Baja California *Dipodomys* (Best, 1978, 1981) in conjunction with karyotypic data (Stock, 1974) supports Huey's (1925) recognition of *D. gravipes* as a distinct species. Additional studies compared *D. gravipes* to other species of *Dipodomys* (Schnell *et al.*, 1978), but intraspecific morphologic variation has not been investigated. This study analyzes the degree of secondary sexual dimorphism, amount and pattern of geographic variation, and phenetic relationships among populations of *D. gravipes* using a suite of external and cranial measurements.

MATERIALS AND METHODS

A total of 138 *Dipodomys gravipes* were examined. Specimens were aged according to the criteria of Best and Schnell (1974). The 110 adult specimens used in the analyses were divided into three geographic samples: Sample 1 (14 males, 19 females) = Santo Domingo (San Diego Natural History Museum 9 males, 10 females; Museum of Vertebrate Zoology, Berkeley 0, 1); San Ramon, Mouth Santo Domingo River, 10 ft (MVZ 2, 7); 1 mile S San Ramon (SDNHM 1, 0); Colonia Guerro (Los Angeles Co. Museum, 2, 1); Sample 2 (23 males, 18 females) = 1 mile S San Quintine (University of Michigan 1, 0); San Quintin (SDNHM 1, 0; MVZ 0, 1); Mouth Agua Chicita Canyon S. Quintin Plain (SDNHM 6, 5); Agua Chiquita, 4 miles E San Quintin (MVZ 1, 0); Socorro, 20 miles S San Quintin (MVZ 0, 1); Socorro (MVZ 1, 1); Santa Maria, near San Quintin (SDNHM 1, 0); San Quintin Bay, 0 ft (SDNHM 0, 1); Agua Chiquita Canyon (SDNHM 1, 0); San Quintin Plain (SDNHM 2, 2); Bahia de San Quintin (LACM 1, 1); 8.5 miles N San Quintin (Troy L. Best Collection 8, 6); Sample 3 (19 males, 17 females) = Rosario (UM 2, 0); 6 miles E El Rosario (TLB 17, 17).

The 19 morphologic characters were described previously (Best, 1978). The heterogeneity of each character (between sexes and between the three geographic samples) was tested with a one-way analysis of variance, and a sums of squares simultaneous test procedure (SS-STP; Gabriel and Sokal, 1969) was used to determine maximally nonsignificant subsets. Correlation and distance matrices (Sneath and Sokal, 1973) were computed from the standardized locality means for each geographic sample. Clusters of populations were obtained with the unweighted pair-group method using arithmetic averages (UPGMA). Analyses were performed using the IBM computer system at the University of New Mexico Computation Center and the programs UNIVAR (D. M. Power, pers. comm.) and NT-SYS (Rohlf *et al.*, 1972).

RESULTS

Of the 19 morphologic characters, males were significantly larger than females for seven (37%) of them (Table 1). These included three external and four cranial measurements. The degree of secondary sexual dimorphism observed in *Dipodomys gravipes* may be due in part to its small geographic range, or the *D. gravipes* sample size may simply be too small to differentiate all those characters that actually are dimorphic.

Significant interlocality character variation was found in 14 of the 19 characters when the three geographic samples were examined ($P \leq 0.05$); 12 characters were significant for males and 11 for females (Table 2). Neither sex had significant differences among the three samples for body length, intermaxillary width, alveolar length, basioccipital length and nasal width. For basal length, greatest cranial length and maxillary arch width only males had differences between samples, and for interorbital width and lacrimal length only females had differences between samples. Females in Sample 3, from the vicinity of El Rosario, were the largest in all characters, while Sample 3 males were largest in 18 of 19 characters. Additionally, this southernmost sample was significantly different from both of the other samples in six characters for males and six characters for females. The general increase in size of *Dipodomys* from N to S in Baja California noted previously (Best, 1979, 1982), is evident in *D. gravipes* as well.

Correlation analyses for males and females placed the northernmost sample, from the vicinity of Santo Domingo Mission, apart from samples 2 and 3 ($r = -0.711$ for males; $r = -0.570$ for females). The correlations between the southern two samples were also low; Sample 2 was separated at $r = 0.087$ for males and $r = 0.118$ for females. The phenetic distance analyses for males and females had cophenetic correlation coefficients of 0.989 and 1.000, respectively. In both correlation and distance analyses, the southern population (Sample 3) was placed well apart from Samples 1 and 2 (phenetic distance = 1.606 for males and 1.630 for females). Although some clinal variation in size was evident among the samples, Sample 3 was morphologically distinct from the more northern populations.

DISCUSSION

The southern population of *Dipodomys gravipes,* found near El Rosario (Sample 3), may be geographically isolated from the northern populations occurring on the San Quintin Plain. Nelson (1922: 24) described the southern narrowing of the San Quintin Plain: "The low rolling foothill plateau which backs the coast plain gradually approaches the shore from the north and

TABLE 1.—Secondary sexual dimorphism in size of 19 external and cranial characters

Character	Character-state means[1] ♂♂ (N = 56)	♀♀ (N = 54)	Analysis of variance[2] df	*F*-ratio[3]
External				
Total length	306.8	300.0	1,100	8.048**
Body length	130.6	127.1	1,108	9.045**
Tail length	176.1	173.2	1,100	2.116
Hind foot length	44.8	44.1	1,108	11.420**
Ear length	13.3	13.5	1,105	0.110
Cranium				
Basal length	23.0	22.9	1,102	0.693
Greatest length	41.6	40.6	1,96	5.501*
Maxillary arch spread	23.6	23.4	1,100	1.352
Interorbital width	10.9	10.8	1,104	0.148
Nasal length	14.8	14.6	1,107	6.300*
Intermaxillary width	7.9	8.0	1,105	0.378
Alveolar length	5.3	5.3	1,104	0.000
Lacrimal length	4.5	4.5	1,107	0.682
Maxillary arch width	6.1	6.1	1,108	0.656
Basioccipital length	6.2	6.1	1,98	5.669*
Greatest depth	13.7	13.6	1,100	2.738
Greatest width	26.0	25.7	1,100	3.813
Zygomatic width	21.2	20.9	1,103	3.386
Nasal width	4.0	3.9	1,104	4.857*

[1]Dimensions in mm; N = number of specimens
[2]Single-classification analysis of variance, sexes compared pairwise for each character
[3]Minimally significantly sexual dimorphism assumed where $P \leq 0.05$ (one asterisk); two asterisks indicate $P \leq 0.01$

TABLE 2. — Variation in means of the 19 external and cranial characters exhibiting significant interlocality variation. Statistically homogeneous subsets derived from SS-STP analyses are shown by lines below the sample number and ranked means

Character	Males			Females		
	Results of SS-STP			Results of SS-STP		
External						
Total length	3	2	1	3	1	2
	312.3	306.9	299.4	310.3	297.0	295.8
Body length	3	1	2	3	1	2
	132.3	131.4	128.8	129.9	126.0	125.7
Tail length	3	2	1	3	1	2
	180.0	177.9	168.0	180.4	171.0	170.4
Hind foot length	3	2	1	3	1	2
	45.3	44.7	44.2	44.7	43.8	43.7
Ear length	3	2	1	3	2	1
	15.8	12.7	11.1	16.1	13.1	11.3
Cranium						
Basal length	3	1	2	3	1	2
	23.3	23.0	22.7	23.1	22.9	22.6
Greatest length	3	1	2	3	1	2
	42.5	41.6	41.0	41.8	40.8	39.4
Maxillary arch spread	3	1	2	3	2	1
	24.2	23.3	23.2	23.9	23.1	23.1
Interorbital width	3	2	1	3	2	1
	11.0	10.8	10.8	11.1	10.8	10.6
Nasal length	3	1	2	3	1	2
	15.2	14.8	14.6	14.9	14.6	14.4
Intermaxillary width	3	1	2	3	2	1
	8.0	7.9	7.9	8.0	8.0	7.9
Alveolar length	3	1	2	3	2	1
	5.4	5.3	5.3	5.4	5.3	5.3
Lacrimal length	3	1	2	3	1	2
	4.6	4.5	4.5	4.7	4.5	4.3
Maxillary arch width	3	1	2	3	2	1
	6.4	6.1	5.9	6.3	6.0	5.9
Basioccipital length	3	1	2	3	2	1
	6.4	6.2	6.1	6.2	6.1	6.1
Greatest depth	3	2	1	3	2	1
	14.0	13.6	13.6	14.0	13.5	13.4
Greatest width	3	2	1	3	2	1
	26.6	25.7	25.6	26.1	25.6	25.4
Zygomatic width	3	2	1	3	2	1
	21.6	21.0	20.8	21.3	20.9	20.6
Nasal width	1	3	2	3	1	2
	4.0	4.0	4.0	3.9	3.9	3.9

reduces the plain to a narrow point, ending a little south of Socorro." Approximately halfway between El Socorro and El Rosario the mesas approach the Pacific Ocean (near El Consuelo), but there remains the possibility of contact between the northern and El Rosario populations along the coast. Today the beaches here are comprised of boulders backed by steep sandy cliffs, but more suitable habitat may have previously extended southward to the Arroyo del Rosario. In 1971 I collected two specimens of *Dipodomys gravipes* 12 miles N of El Rosario (just N of El Consuelo); these were not included in the present analyses, but were karyotyped by Stock (1974).

Nelson (1922: 118) included most of the Arroyo del Rosario in the San Diegan Faunal District together with the northern range of *Dipodomys gravipes*. In the vicinity of El Rosario two other "Districts" meet the San Diegan. Nelson's life zone map (1922: Plate 32) places the El Rosario *D. gravipes* localities into the Lower Sonoran, and the northern *D. gravipes* localities into the Upper Sonoran Life Zone. Brown and Lowe (1980) have similarly separated the range of *D. gravipes:* the El Rosario and El Socorro localities are in the Vizcaino Subdivision of their Desertscrub Formation, while the northernmost localities are in the California Coastalscrub of their Scrub Formation. Thus, the El Rosario population seems to be at least partially geographically isolated from the northern populations, and there are biotic differences between the two areas. Both factors may have contributed significantly to the development of the morphologic differences described herein.

Although this study significantly increases the known geographic range of *Dipodomys gravipes,* the species has been virtually eliminated from most of its native range during the past decade due to extensive cultivation. The broad open areas 8.5 miles N of San Quintin that were dotted with *D. gravipes* burrows in 1972 are now cropland. Over 1000 trap nights there in July 1980 yielded only two specimens (neither from the cropland). The area 6 miles E of El Rosario, where I collected 35 *D. gravipes* in June 1972, was covered by a paved highway and cropland in 1980.

Acknowledgments. — This study was partially supported by grants from the Society of the Sigma Xi and the National Science Foundation (GB-33062, GB-30814). Personnel at the San Diego Natural History Museum, the Museum of Vertebrate Zoology at the University of California, Berkeley, the Los Angeles County Museum, and the University of Michigan Museum of Zoology generously made specimens available. H. A. Smith helped collect and record the data, W. R. Barber assisted in data analyses, and T. L. Yates provided the computer time. D. J. Hafner and J. H. Bandoli critically reviewed the manuscript.

LITERATURE CITED

BEST, T. L. 1978. Variation in kangaroo rats (genus *Dipodomys*) of the *heermanni* group in Baja California, Mexico. *J. Mammal.*, **69**:160-175.

———. 1981. Bacular variation in kangaroo rats (genus *Dipodomys*) of the *heermanni* group in Baja California, Mexico. *Southwest. Nat.*, **25**:529-534.

———. 1982. Relationships between ecogeographic and morphologic variation of the agile kangaroo rat (*Dipodomys agilis*) in Baja California, Mexico. *Bull. South. Calif. Acad. Sci.* (for 1981), **80**:60-69.

——— AND G. D. SCHNELL. 1974. Bacular variation in kangaroo rats (genus *Dipodomys*). *Am. Midl. Nat.*, **91**: 257-270.

BROWN, D. E. AND C. H. LOWE. 1980. Biotic communities of the southwest. *U.S. For. Serv. Gen. Tech. Rep. RM-78.*

GABRIEL, K. R. AND R. R. SOKAL. 1969. A new statistical approach to geographic variation analysis. *Syst. Zool.*, **18**: 259-278.

HUEY, L. M. 1925. Two new kangaroo rats of the genus *Dipodomys* from Lower California. *Proc. Biol. Soc. Wash.*, **38**: 83-85.

NELSON, E. W. 1922. Lower California and its natural resources. Natl. Acad. Sci. 26. (Repr. 1966 by Manessier Pub. Co., Riverside, Calif.). xvi + 194 p.

ROHLF, F. J., J. KISHPAUGH AND D. KIRK. 1972. Numerical taxonomy system of multivariate statistical programs (NT-SYS). Version of October, 1972; State Univ. New York, Stony Brook.

SCHNELL, G. D., T. L. BEST AND M. L. KENNEDY. 1978. Interspecific morphologic variation in kangaroo rats (*Dipodomys*): Degree of concordance with genic variation. *Syst. Zool.*, **27**: 34-48.

SNEATH, P. H. A. AND R. R. SOKAL. 1973. Numerical taxonomy. W. H. Freeman Co., San Francisco. 573 p.

STOCK, A. D. 1974. Chromosome evolution in the genus *Dipodomys* and its taxonomic and phylogenetic implications. *J. Mammal.*, **55**: 505-526.

TROY L. BEST, Department of Biology and Museum of Southwestern Biology, The University of New Mexico, Albuquerque 87131. *Submitted 29 March 1982; accepted 10 August 1982.*