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REVIEW OF THE DESERT POCKET GOPHER, *GEOMYS ARENARIUS* (MAMMALIA: RODENTIA)

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ABSTRACT

The desert pocket gopher (*Geomys arenarius*), which occupies a restricted geograpic range in Texas, New Mexico, and Chihuahua, was examined for morphological variation. Univariate and multivariate analyses were used to determine age, sexual, individual, and geographic variation. Significant differences were found among different age classes and between sexes. Males displayed higher individual variation than females and external measurements were more variable than cranial measurements. Two subspecies—*G. a. arenarius* and *G. a brevirostris*—were recognized after analyses of geographic variation.

INTRODUCTION

The desert pocket gopher, *Geomys arenarius,* occupies a restricted geographic range in Texas, New Mexico, and Chihuahua, Mexico. *G. arenarius* is a member of the *bursarius*-species group as defined by Russell (1968). Alvarez (1963) seemed to suggest that *G. arenarius* was derived from *Geomys personatus* of this group, probably by invading along the Rio Grande Valley. Russell (1968) on the other hand, derived both *personatus* and *arenarius* directly from *Geomys bursarius*. Chromosomal (Davis et al., 1971), genic (Selander et al., 1975), and ectoparasite data (Price and Emerson, 1971) support the specific distinct-

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ness of *G. arenarius*. However, they do not give any conclusive answer to the relationship of *arenarius* except that it definitely belongs to the *bursarius* group.

The species was originally described by Merriam (1895) based upon specimens from El Paso, El Paso Co., Texas. The hypodigm consisted of specimens from Deming and Las Cruces, New Mexico, and Juarez, Chihuahua, as well as material from the type locality. *G. arenarius arenarius* is basically restricted to the valley of the Rio Grande, where it reaches high population levels in some areas and is considered an agricultural pest. Hall (1932) described the other currently-recognized subspecies, *G. a. brevirostris,* based upon material from the White Sands area of New Mexico.

Davis (1940) was the last person to review this species. However, with considerably more material now available, we have conducted both univariate and multivariate analyses of *Geomys arenarius*. The results of our analyses are given below.

METHODS

From all specimens, three external and 13 cranial measurements were recorded. The external measurements were as recorded by the collector; cranial measurements, as described by Williams and Genoways (1977), were taken by means of dial calipers. All measurements are given in millimeters. Specimens were assigned to one of three age groups as described by Williams and Genoways (1977).

For the analysis of geographic variation, adult specimens were grouped into nine samples as follows (Fig. 1): *sample 1*—Tularosa Basin, Otero Co., New Mexico; *sample 2*—Doña Ana Co., New Mexico, using Doña Ana, Las Cruces (except 15 mi W Las Cruces), Mesilla, Mesilla Dam, and Mesilla Park as reference points; *sample 3*—Doña Ana Co., New Mexico, specimens from 15 mi W Las Cruces and localities using Afton and Kenzin as reference points; *sample 4*—Doña Ana Co., New Mexico, and El Paso Co., Texas, using Anthony, Chamberino, and Strauss as reference points; *sample 5*—Luna Co., New Mexico, using Columbus as a reference point; *sample 6*—Chihuahua, Doña Ana Co., New Mexico, and El Paso Co., Texas, using El Paso, Fabens-Carlsbad Road, Juarez, Porvenir, and Ysleta as reference points; *sample 7*—El Paso Co., Texas, using Fabens as a reference point; *sample 8*—Chihuahua using Samalayuca as a reference point; *sample 9*—Hudspeth Co., Texas, using Fort Hancock and McNary as reference points.

Statistical procedures were performed on the IBM 370 computer at Texas Tech University. Univariate analyses were performed using the program UNIVAR. This program yields standard statistics (mean, range, standard deviations, standard error of the mean, variances, and coefficient of variation), and employs a single-classification analysis of variance (F-test, significance level 0.05) to test for significant differences between or among means (Sokal and Rohlf, 1969). When means were found to be significantly different, the Sum of Squares Simultaneous Test Procedure (SS-STP) developed by Gabriel (1964) was used to determine maximally nonsignificant subsets.

Cluster and principal components analyses were performed using the NT-SYS program. Matrices of Q-mode correlation (among OTUs) and phenetic distance coefficients were computed. Cluster analyses were conducted using UPGMA (unweighted pair-group method using arithmetic averages) on the correlation and distance matrices and a phenogram was generated for each. Phenograms were compared with their respective ma-

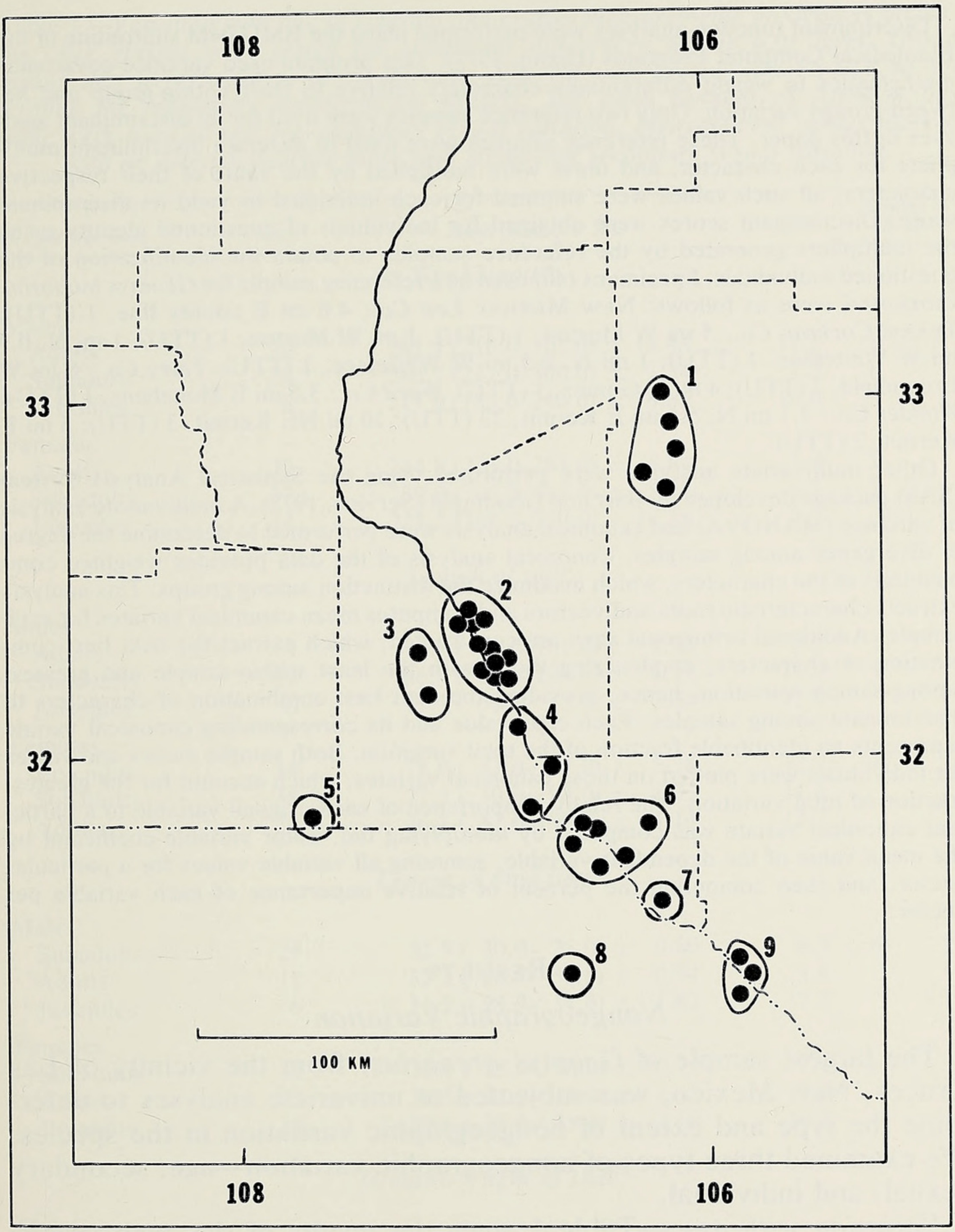

Fig. 1.—Approximate geographic areas included in the nine samples of *Geomys arenarius*. See text for localities included in each sample.

trices, and a coefficient of cophenetic correlation was computed. A matrix of Pearson's product-moment correlation among characters was computed, and the first three principal components extracted. Projections of the OTUs onto the first three principal components were made.

Discriminant function analyses were performed using the BMD-04M subroutine of the Biomedical Computer Programs (Dixon, 1971). This program used variance-covariance mathematics to weight differentially characters relative to their within-group and between-groups variation. Only two reference samples were used for all discriminant analyses in this paper. These reference samples were used to generate discriminant multipliers for each character, and these were multiplied by the value of their respective characters; all such values were summed for each individual to yield its discriminant score. Discriminant scores were obtained for individuals of questioned identity using the multipliers generated by the reference samples to obtain the identification of the questioned individuals. Specimens (40) used as a reference sample for *Geomys bursarius knoxjonesi* were as follows: NEW MEXICO: *Lea Co.:* 4.6 mi E county line, 1 (TTU). TEXAS: *Cockran Co.:* 5 mi W Morton, 1 (TTU); 1 mi W Morton, 1 (TTU); 1 mi N, 0.9 mi W Whiteface, 1 (TTU); 1 mi N, 0.5 mi W Whiteface, 1 (TTU). *Terry Co.:* 6 mi W Brownfield, 2 (TTU); 4 mi N Gomez, 5 (TTU). *Ward Co.:* 3.5 mi E Monahans, 1 (TTU). *Winkler Co.:* 4.1 mi N, 5.1 mi E Kermit, 22 (TTU); 10 mi NE Kermit, 3 (TTU); 5 mi E Kermit, 2 (TTU).

Other multivariate analyses were performed using the Statistical Analysis System (SAS) package developed by Barr and Goodnight (Service, 1972). A multivariate analysis of variance (MANOVA) and canonical analysis were performed to determine the degree of divergence among samples. Canonical analysis of the data provides weighted combinations of the characters, which maximize the distinction among groups. This analysis extracts characteristic roots and vectors and computes mean canonical variates for each sample. Additional orthogonal axes are constructed, which extract the next best combination of characters, emphasizing those with the least within-sample and greatest among-sample variation, hence, providing the next best combination of characters to discriminate among samples. Each eigenvalue and its corresponding canonical variate represents an identifiable fraction of the total variation. Both sample means and values for individuals were plotted on those canonical variates, which account for the greatest fraction of total variation. The relative importance of each original variable to a particular canonical variate was computed by multiplying the vector variable coefficient by the mean value of the dependent variable, summing all variable values for a particular vector, and then computing the percent of relative importance of each variable per vector.

RESULTS

Nongeographic Variation

The largest sample of *Geomys arenarius,* from the vicinity of Las Cruces, New Mexico, was subjected to univariate analyses to determine the type and extent of nongeographic vartiation in the species. We examined three types of nongeographic variation—age, secondary sexual, and individual.

Variation with age.—Table 1 gives the results of the analyses for variation with age in males and females. Fourteen of the 16 measurements studied were found to vary significantly with age in both males (length of hind foot and interorbital breadth not significant) and females (length of tail and length of hind foot not significant).

In most of the measurements tested, all three age classes recognized formed separate groups. Exceptions to these were found for total length and breadth across maxillaries for both sexes, length of tail,

Table 1.—*Variation with age in external and cranial measurements of* Geomys arenarius. *Age classes were tested for significant differences at the 0.05 level. Group means that were found to be significantly different were tested with SS-STP to determine the maximally nonsignificant subsets. The adult samples as listed in this table were used to test for secondary sexual variation. Measurement names marked with an asterisk indicate those with significant secondary sexual variation.*

Sex and age class	N	Mean (Range) ± 2SE	CV	Results of SS-STP		
		*Total length**				
Males						
Adults	10	261.1 (210.0–302.0) ± 18.44	11.2	I		
Subadults	28	260.3 (227.0–300.0) ± 7.34	7.5	I		
Juveniles	6	217.0 (183.0–240.0) ± 18.83	10.6		I	
Females						
Adults	22	244.8 (223.0–283.0) ± 5.64	5.4	I		
Subadults	37	239.9 (205.0–265.0) ± 5.28	6.7	I		
Juveniles	14	223.2 (166.0–250.0) ± 10.36	8.7		I	
		*Length of tail**				
Males						
Adults	9	90.7 (78.0–101.0) ± 4.98	8.2	I		
Subadults	29	86.4 (60.0–109.0) ± 4.17	13.0	I		
Juveniles	6	72.5 (58.0– 85.0) ± 7.64	12.9		I	
Females						
Juveniles	14	78.0 (47.0– 87.0) ± 5.28	12.7	ns		
Subadults	38	77.5 (50.0– 93.0) ± 2.93	11.6			
Adults	22	76.8 (52.0– 95.0) ± 4.14	12.7			
		*Length of hind foot**				
Males						
Subadults	29	32.9 (30.0– 35.0) ± 0.80	6.5	ns		
Adults	11	32.3 (28.0– 37.0) ± 0.94	4.8			
Juveniles	6	31.2 (28.0– 34.0) ± 1.82	7.2			
Females						
Subadults	38	31.1 (25.0– 36.0) ± 0.71	7.1	ns		
Adults	22	30.5 (22.0– 34.0) ± 1.15	8.8			
Juveniles	14	29.6 (23.0– 35.0) ± 1.60	10.1			
		*Greatest length of skull**				
Males						
Adults	11	46.0 (42.0– 49.4) ± 1.47	5.3	I		
Subadults	26	44.6 (39.1– 48.2) ± 0.96	5.5	I		
Juveniles	6	37.3 (32.8– 39.6) ± 2.09	6.9		I	
Females						
Adults	23	42.9 (41.1– 45.9) ± 0.47	2.6	I		
Subadults	32	41.5 (37.9– 44.5) ± 0.62	4.2		I	
Juveniles	13	38.0 (36.1– 42.0) ± 0.93	4.4			I

Table 1.—(*Continued*)

Sex and age class	N	Mean (Range) ± 2SE	CV	Results of SS-STP		
		*Condylobasal length**				
Males						
Adults	13	45.1 (40.8– 48.8) ± 1.30	5.2	I		
Subadults	31	42.8 (37.7– 46.7) ± 0.99	6.4		I	
Juveniles	6	36.2 (31.8– 38.8) ± 2.04	6.9			I
Females						
Adults	22	41.7 (39.3– 44.3) ± 0.50	2.8	I		
Subadults	38	40.4 (36.9– 44.1) ± 0.57	4.3		I	
Juveniles	14	36.3 (29.2– 40.5) ± 1.36	7.0			I
		*Basal length**				
Males						
Adults	13	42.6 (38.2– 46.4) ± 1.33	5.6	I		
Subadults	31	40.0 (35.0– 43.9) ± 0.94	6.5		I	
Juveniles	6	33.2 (29.0– 35.7) ± 2.01	7.4			I
Females						
Adults	22	39.2 (36.8– 41.8) ± 0.50	3.0	I		
Subadults	38	37.7 (34.4– 40.6) ± 0.55	4.5		I	
Juveniles	14	33.7 (26.6– 38.1) ± 1.37	7.6			I
		*Palatal length**				
Males						
Adults	13	29.3 (25.9– 33.2) ± 1.10	6.8	I		
Subadults	31	27.4 (23.6– 30.3) ± 0.74	7.5		I	
Juveniles	6	22.2 (19.1– 24.3) ± 1.52	8.4			I
Females						
Adults	23	26.9 (25.1– 28.7) ± 0.37	3.3	I		
Subadults	38	25.6 (22.9– 28.2) ± 0.42	5.0		I	
Juveniles	14	22.6 (17.4– 25.8) ± 1.02	8.4			I
		*Palatofrontal depth**				
Males						
Adults	13	16.6 (14.7– 18.1) ± 0.54	5.8	I		
Subadults	31	15.9 (13.9– 17.5) ± 0.36	6.3	I		
Juveniles	6	13.4 (12.0– 14.7) ± 0.74	6.8		I	
Females						
Adults	24	15.8 (14.6– 17.1) ± 0.22	3.5	I		
Subadults	39	15.1 (13.5– 16.7) ± 0.23	4.8		I	
Juveniles	14	13.5 (11.5– 15.1) ± 0.45	6.3			I
		*Length of nasals**				
Males						
Adults	11	16.7 (14.4– 18.9) ± 0.86	8.5	I		
Subadults	26	15.8 (13.2– 18.7) ± 0.55	8.9	I		
Juveniles	6	12.8 (11.3– 13.9) ± 0.78	7.4		I	

Table 1.—(*Continued*)

Sex and age class	N	Mean (Range) ± 2SE	CV	Results of SS-STP		
Females						
Adults	23	15.1 (12.9– 16.9) ± 0.34	5.3	I		
Subadults	32	14.4 (12.4– 15.9) ± 0.36	7.0		I	
Juveniles	13	12.9 (11.8– 15.2) ± 0.50	7.0			I
		*Diastema**				
Males						
Adults	13	15.7 (12.8– 18.7) ± 0.80	9.1	I		
Subadults	32	14.3 (11.6– 16.1) ± 0.47	9.4		I	
Juveniles	6	10.8 (8.8– 12.1) ± 0.92	10.5			I
Females						
Adults	24	14.0 (12.5– 14.9) ± 0.26	4.5	I		
Subadults	39	13.1 (11.5– 15.1) ± 0.27	6.3		I	
Juveniles	14	11.1 (7.8– 13.2) ± 0.65	10.9			I
		*Zygomatic breadth**				
Males						
Adults	13	28.7 (25.1– 31.6) ± 1.00	6.2	I		
Subadults	31	26.3 (22.8– 30.3) ± 0.74	7.8		I	
Juveniles	6	20.7 (17.5– 21.9) ± 1.36	8.1			I
Females						
Adults	23	25.9 (23.5– 28.6) ± 0.53	4.9	I		
Subadults	37	24.5 (21.0– 26.8) ± 0.45	5.6		I	
Juveniles	14	21.1 (17.1– 24.4) ± 0.85	7.5			I
		*Mastoid breadth**				
Males						
Adults	13	25.8 (23.7– 28.6) ± 0.80	5.6	I		
Subadults	31	24.4 (21.6– 27.0) ± 0.50	5.8		I	
Juveniles	6	20.6 (17.9– 21.8) ± 1.18	7.0			I
Females						
Adults	24	24.1 (22.4– 25.7) ± 0.31	3.2	I		
Subadults	39	22.9 (20.5– 24.5) ± 0.31	4.2		I	
Juveniles	14	20.9 (17.3– 23.5) ± 0.78	7.0			I
		*Squamosal breadth**				
Males						
Adults	13	18.9 (18.1– 20.3) ± 0.40	3.8	I		
Subadults	31	18.8 (16.5– 19.9) ± 0.78	5.6	I		
Juveniles	6	16.7 (14.7– 17.5) ± 0.85	6.2		I	
Females						
Adults	24	18.4 (17.2– 19.5) ± 0.28	3.7	I		
Subadults	39	17.8 (16.1– 19.4) ± 0.20	3.5		I	
Juveniles	14	17.0 (15.6– 17.6) ± 0.29	3.2			I

Table 1.—(*Continued*)

Sex and age class	N	Mean (Range) ± 2SE	CV	Results of SS-STP		
		*Rostral breadth**				
Males						
Adults	13	10.6 (9.7– 11.6) ± 0.36	6.1	I		
Subadults	32	10.0 (9.1– 11.4) ± 0.21	6.0		I	
Juveniles	6	8.6 (7.9– 9.3) ± 0.43	6.1			I
Females						
Adults	24	9.9 (9.0– 10.6) ± 0.19	4.8	I		
Subadults	39	9.4 (8.5– 10.4) ± 0.15	5.1		I	
Juveniles	14	8.5 (7.2– 9.5) ± 0.30	6.7			I
		Interorbital constriction				
Males						
Adults	13	6.5 (5.9– 7.1) ± 0.19	5.3	ns		
Subadults	32	6.4 (5.7– 7.0) ± 0.11	5.0			
Juveniles	6	6.3 (6.0– 6.8) ± 0.28	5.4			
Females						
Adults	24	6.3 (5.4– 7.0) ± 0.14	5.3	I		
Subadults	39	6.3 (5.6– 7.8) ± 0.13	6.2	I		
Juveniles	14	6.0 (5.6– 6.6) ± 0.16	5.1		I	
		Breadth across maxillaries				
Males						
Adults	13	7.9 (7.2– 8.6) ± 0.25	5.6	I		
Subadults	32	7.8 (7.0– 8.3) ± 0.11	4.1	I		
Juveniles	6	7.4 (6.7– 7.7) ± 0.34	5.6		I	
Females						
Adults	24	7.7 (7.3– 8.3) ± 0.09	2.9	I		
Subadults	39	7.5 (6.7– 8.4) ± 0.10	4.0	I		
Juveniles	14	7.2 (6.7– 7.9) ± 0.15	4.0		I	

greatest length of skull, palatofrontal depth, length of nasals, and squamosal breadth for males and interorbital breadth for females. In all of these characters, the adults and subadults formed a group differing significantly from the juveniles. Adults averaged the largest in all measurements except length of tail for females in which the juveniles were the largest, and length of hind foot for both sexes in which the subadults were largest.

Clearly, the three ages that we recognized are morphologically distinct. In the following analyses, we have used only adults.

Secondary sexual variation.—The same adult male and female samples used in the variation with age analyses were used to test for secondary sexual variation (Table 1). Males averaged significantly larger than females in all measurements except in interorbital constriction and breadth across maxillaries. Even in these two measurements, in which there were no significant differences, the males averaged larger than the females. In all analyses of geographic variation, males and females were treated separately.

Individual variation.—Coefficients of variation for adult males ranged from 3.8 to 11.2 and for adult females from 2.6 to 12.7 for the 16 external and cranial measurements tested (Table 1). The coefficients of variation for the external measurements are generally higher than for cranial measurements with length of hind foot for males being the exception. Squamosal breadth had the lowest value (3.8) and diastema had the highest value (9.1) for cranial measurements for males; for females, greatest length of skull had the lowest value (2.6) and length of nasals and interorbital constriction had the highest values (5.4 and 5.3, respectively). The mean coefficient of variation for the 16 measurements was 6.4 for males and 4.8 for females. Males had larger coefficients of variation than females for all measurements except interorbital constriction in which both sexes had a value of 5.3.

Geographic Variation

Univariate analyses.—Five samples of both males and females had a sufficient number of specimens to allow their use in the univariate analyses. For males, the samples were as follows: sample 1, vicinity of Whites Sands National Monument, New Mexico; sample 2, vicinity of Las Cruces, New Mexico; sample 3, vicinity of Kenzin, New Mexico; sample 6, vicinity of El Paso, Texas; sample 7, vicinity of Fabens, Texas. For females, sample 3 was replaced by sample 9 from the vicinity of Ft. Hancock, Texas. Results of the analyses of variance and SS-STP for these samples are given in Table 2.

All measurements except squamosal breadth for males and interorbital constriction for females exhibited significant geographic variation. In males, samples 1 and 3 averaged the smallest in size for all measurements except interorbital constriction, in which samples 1 and 7 averaged the smallest in size. Samples 6 and 7 averaged the largest in size for males in all measurements except rostral breadth, interorbital constriction, length of nasals, and zygomatic breadth. In the last three of these measurements, specimens from sample 6 averaged the largest in size.

The SS-STP analyses separate the samples of males into two basic groups—1 and 3, and 2, 6, and 7. Samples 1 and 3 are significantly different from the other three samples in greatest length of skull and condylobasal length. In six other measurements (basal length, palatal length, palatofrontal depth, diastema, zygomatic breadth, and mastoid breadth), two or three overlapping subsets of samples are formed, but

Table 2.—*Geographic variation in external and cranial measurements of* Geomys arenarius. *Samples are defined in text. Samples were tested for significant differences at the 0.05 level. Sample means that were found to be significantly different were tested with SS-STP to determine the maximally nonsignificant subsets.*

Sex and locality number	N	Mean (Range) ± 2SE	CV	Results of SS-STP	
		Total length			
Males					
7	4	284.2 (277.0–291.0) ± 7.86	2.8	I	
6	6	280.5 (271.0–289.0) ± 6.61	2.9	I	I
2	11	261.4 (210.0–302.0) ± 16.69	10.6	I	I
1	9	253.4 (236.0–275.0) ± 8.12	4.8		I
3	3	251.0 (237.0–260.0) ± 14.19	4.9		I
Females					
7	15	251.7 (236.0–267.0) ± 4.39	3.4	I	
6	24	245.8 (218.0–273.0) ± 5.03	5.0	I	
2	27	243.3 (222.0–283.0) ± 5.27	5.6	I	I
9	6	234.7 (225.0–245.0) ± 6.38	3.3	I	I
1	13	233.3 (220.0–256.0) ± 6.31	4.9		I
		Length of tail			
Males					
7	4	97.4 (91.0–106.0) ± 6.61	6.8	I	
6	6	91.7 (82.0– 95.0) ± 4.06	5.4	I	I
2	10	90.1 (78.0–101.0) ± 4.59	10.9	I	I
1	9	83.9 (75.0– 97.0) ± 5.42	9.7	I	I
3	3	82.3 (73.0– 91.0) ± 10.41	10.9		I
Females					
7	15	81.1 (67.0– 98.0) ± 3.88	9.3	I	
9	6	78.2 (73.0– 82.0) ± 3.32	5.2	I	I
2	27	76.7 (52.0– 95.0) ± 3.45	11.7	I	I
6	24	76.7 (61.0– 90.0) ± 2.88	9.2	I	I
1	13	71.8 (60.0– 80.0) ± 3.85	9.7		I
		Length of hind foot			
Males					
6	6	33.5 (31.0– 35.0) ± 1.13	4.1	I	
7	4	33.5 (32.0– 35.0) ± 1.29	3.9	I	
2	12	32.4 (30.0– 35.0) ± 0.90	4.8	I	I
1	9	31.0 (30.0– 33.0) ± 0.71	3.4		I
3	3	30.3 (29.0– 31.0) ± 1.33	3.8		I
Females					
6	24	31.6 (27.0– 35.0) ± 0.71	5.5	I	
9	6	31.4 (30.0– 32.0) ± 0.75	2.9	I	
7	15	30.6 (28.0– 32.0) ± 0.55	3.4	I	I
2	27	30.5 (22.0– 34.0) ± 0.95	8.1	I	I
1	13	28.8 (27.0– 31.0) ± 0.69	4.3		I

Table 2.—(*Continued*)

Sex and locality number	N	Mean (Range) ± 2SE	CV	Results of SS-STP		
		Greatest length of skull				
Males						
6	7	47.2 (45.1– 48.9) ± 0.93	2.6	I		
7	4	46.7 (45.6– 48.6) ± 1.37	2.9	I		
2	12	45.9 (42.0– 43.2) ± 1.34	5.1	I		
1	10	42.8 (40.5– 45.7) ± 1.05	3.9		I	
3	3	42.3 (41.0– 43.2) ± 1.33	2.7		I	
Females						
7	14	43.9 (41.7– 46.1) ± 0.68	2.9	I		
6	20	43.4 (40.7– 49.9) ± 0.85	4.4	I		
2	27	42.6 (39.9– 45.9) ± 0.54	3.3	I		
9	3	42.0 (41.4– 42.6) ± 0.70	1.4	I	I	
1	10	38.8 (37.1– 42.8) ± 1.15	4.7		I	
		Condylobasal length				
Males						
6	7	45.9 (44.2– 47.5) ± 0.87	2.5	I		
7	4	45.6 (43.8– 47.6) ± 1.58	3.5	I		
2	14	45.0 (40.8– 48.8) ± 1.15	5.0	I		
1	10	41.6 (39.3– 44.5) ± 1.04	4.0		I	
3	3	41.2 (40.2– 42.2) ± 1.15	2.4		I	
Females						
7	15	43.1 (41.5– 45.6) ± 0.64	2.9	I		
6	24	41.6 (39.5– 43.8) ± 0.52	3.0		I	
2	27	41.3 (38.7– 44.3) ± 0.57	3.6		I	
9	6	40.7 (40.1– 41.6) ± 0.45	1.4		I	
1	13	38.1 (35.9– 41.5) ± 0.98	4.6			I
		Basal length				
Males						
6	7	43.6 (42.3– 45.3) ± 0.85	2.6	I		
7	4	42.9 (41.1– 44.5) ± 1.40	3.3	I	I	
2	14	42.5 (38.2– 46.4) ± 1.24	5.5	I	I	
3	3	39.0 (38.0– 40.0) ± 1.16	2.6		I	I
1	10	38.9 (35.9– 41.4) ± 1.15	4.7			I
Females						
7	15	40.9 (39.1– 42.9) ± 0.59	2.8	I		
6	24	39.0 (37.1– 41.3) ± 0.48	3.0		I	
2	27	38.8 (36.0– 41.8) ± 0.57	3.8		I	
9	6	38.1 (37.4– 38.7) ± 0.38	1.2		I	
1	13	35.5 (33.5– 38.8) ± 0.95	4.8			I

Table 2.—(*Continued*)

Sex and locality number	N	Mean (Range) ± 2SE	CV	Results of SS-STP		
		Palatal length				
Males						
6	7	30.0 (28.7–31.7) ± 0.90	4.0	I		
7	4	29.4 (28.0–30.3) ± 1.00	3.4	I	I	
2	14	29.2 (25.9–33.2) ± 1.05	6.7	I	I	
3	3	26.5 (26.0–27.5) ± 0.97	3.2		I	I
1	10	26.1 (23.8–28.0) ± 0.88	5.3			I
Females						
7	15	27.9 (26.1–29.7) ± 0.50	3.5	I		
2	28	26.6 (23.9–28.7) ± 0.43	4.3		I	
6	24	26.6 (25.0–28.1) ± 0.39	3.6		I	
9	6	26.1 (25.8–26.6) ± 0.23	1.1		I	
1	13	23.5 (21.8–26.0) ± 0.72	5.5			I
		Palatofrontal depth				
Males						
6	7	17.1 (16.1–17.7) ± 0.50	3.9	I		
7	4	16.7 (15.3–17.7) ± 1.08	6.5	I		
2	14	16.6 (14.7–18.1) ± 0.50	5.7	I		
3	3	15.6 (15.0–16.1) ± 0.66	3.6	I	I	
1	10	15.5 (14.9–16.1) ± 0.25	2.6		I	
Females						
7	15	16.1 (15.3–16.9) ± 0.28	3.4	I		
2	29	15.7 (14.6–17.1) ± 0.23	3.9	I	I	
6	25	15.5 (14.5–16.5) ± 0.23	3.7		I	
9	6	15.2 (14.7–15.7) ± 0.28	2.3		I	I
1	13	14.7 (14.2–16.0) ± 0.34	4.1			I
		Length of nasals				
Males						
6	7	17.5 (16.7–18.4) ± 0.49	3.7	I		
2	12	16.8 (14.4–18.9) ± 0.80	8.2	I	I	
7	4	16.6 (15.2–17.9) ± 1.14	6.9	I	I	I
3	3	14.7 (14.4–15.1) ± 0.44	2.6		I	I
1	10	14.6 (13.3–15.6) ± 0.50	5.4			I
Females						
7	14	15.7 (14.6–16.9) ± 0.39	4.7	I		
6	20	15.3 (14.0–16.6) ± 0.34	4.9	I		
2	27	15.1 (12.9–16.9) ± 0.33	5.7	I		
9	3	14.8 (14.4–15.5) ± 0.68	4.0	I		
1	10	13.0 (11.6–14.9) ± 0.67	8.2		I	

Table 2.—(*Continued*)

Sex and locality number	N	Mean (Range) ± 2SE	CV	Results of SS-STP		
		Diastema				
Males						
7	4	16.1 (15.1– 16.7) ± 0.79	4.9	I		
6	7	15.9 (14.3– 17.1) ± 0.73	6.1	I		
2	14	15.6 (12.8– 18.7) ± 0.75	8.9	I	I	
1	10	14.2 (12.9– 15.3) ± 0.57	6.4		I	I
3	3	13.9 (13.1– 14.6) ± 0.87	5.4			I
Females						
7	15	15.1 (14.0– 16.0) ± 0.32	4.2	I		
6	25	13.9 (12.7– 15.0) ± 0.26	4.6		I	
2	29	13.8 (12.4– 14.9) ± 0.28	5.5		I	
9	6	13.8 (13.3– 14.2) ± 0.30	2.7		I	
1	13	12.4 (11.3– 14.2) ± 0.56	8.1			I
		Zygomatic breadth				
Males						
6	7	29.1 (27.1– 31.6) ± 1.09	5.0	I		
2	14	28.6 (25.1– 31.6) ± 0.94	6.1	I		
7	4	28.5 (27.6– 29.5) ± 0.79	2.8	I		
3	3	26.8 (25.9– 27.3) ± 0.87	2.8	I	I	
1	10	25.6 (23.3– 27.8) ± 0.94	5.8		I	
Females						
7	15	27.0 (24.9– 28.5) ± 0.51	3.6	I		
2	28	25.6 (23.0– 28.6) ± 0.52	5.4		I	
6	25	25.3 (22.7– 29.0) ± 0.48	4.8		I	
9	6	24.6 (23.1– 25.4) ± 0.69	3.4		I	I
1	13	22.8 (20.7– 26.1) ± 0.82	6.5			I
		Mastoid breadth				
Males						
6	7	26.3 (24.5– 28.2) ± 1.04	5.2	I		
7	4	25.8 (24.2– 27.3) ± 1.28	5.0	I		
2	14	25.7 (23.7– 28.6) ± 0.75	5.5	I		
3	3	24.5 (23.9– 25.2) ± 0.75	2.7	I	I	
1	10	24.0 (22.9– 25.6) ± 0.57	3.8		I	
Females						
7	14	24.6 (22.3– 26.1) ± 0.47	3.6	I		
2	29	23.8 (21.2– 25.7) ± 0.36	4.0	I	I	
6	25	23.6 (21.6– 26.5) ± 0.42	4.5	I	I	
9	6	23.2 (22.6– 23.7) ± 0.34	1.8		I	I
1	13	22.2 (20.7– 24.0) ± 0.59	4.8			I

Table 2.—(*Continued*)

Sex and locality number	N	Mean (Range) ± 2SE	CV	Results of SS-STP
		Squamosal breadth		
Males				
6	7	19.2 (17.5– 20.3) ± 0.75	5.2	ns
7	4	19.1 (17.4– 20.1) ± 1.20	6.3	
2	14	18.8 (17.8– 20.3) ± 0.41	4.0	
3	3	18.5 (17.9– 18.9) ± 0.59	2.8	
1	10	18.4 (17.2– 19.6) ± 0.43	3.7	
Females				
7	15	18.8 (17.4– 19.6) ± 0.28	2.9	I
2	29	18.3 (16.8– 19.5) ± 0.27	4.0	I I
6	25	18.0 (16.8– 19.7) ± 0.27	3.7	I I
1	13	17.5 (16.3– 18.5) ± 0.40	4.1	I
9	6	17.4 (17.0– 18.0) ± 0.29	2.0	I
		Rostral breadth		
Males				
2	14	10.6 (9.7– 11.6) ± 0.33	5.9	I
6	7	10.4 (9.9– 11.3) ± 0.37	4.7	I I
7	4	10.1 (9.7– 10.3) ± 0.26	2.6	I I
3	3	9.8 (9.5– 10.1) ± 0.35	3.1	I I
1	10	9.6 (8.9– 10.3) ± 0.26	4.3	I
Females				
2	29	9.8 (8.7– 10.6) ± 0.19	5.3	I
7	15	9.6 (8.6– 10.3) ± 0.24	4.8	I
6	25	9.5 (8.7– 10.4) ± 0.14	3.7	I
9	6	9.4 (9.6– 9.8) ± 0.39	5.0	I I
1	13	9.0 (8.6– 9.6) ± 0.17	3.5	I
		Interorbital constriction		
Males				
6	7	6.6 (6.1– 7.4) ± 0.32	6.5	I
2	14	6.5 (5.9– 7.1) ± 0.18	5.1	I
3	3	6.4 (6.3– 6.6) ± 0.20	2.7	I I
7	4	6.2 (5.8– 6.6) ± 0.35	5.7	I I
1	10	6.1 (5.4– 6.5) ± 0.19	5.0	I
Females				
2	29	6.3 (5.4– 7.0) ± 0.12	5.2	ns
6	25	6.3 (5.8– 6.9) ± 0.14	5.3	
9	6	6.3 (5.9– 6.9) ± 0.28	5.4	
7	15	6.2 (5.4– 6.8) ± 0.21	6.6	
1	13	6.1 (5.6– 6.4) ± 0.12	3.5	

Table 2.—(*Continued*)

Sex and locality number	N	Mean (Range) ± 2SE	CV	Results of SS-STP	
		Breadth across maxillaries			
Males					
6	7	8.5 (8.1– 9.0) ± 0.24	3.8	I	
7	4	7.9 (7.5– 8.1) ± 0.26	3.3		I
2	14	7.9 (7.2– 8.6) ± 0.23	5.4		I
1	10	7.8 (7.4– 8.3) ± 0.18	3.6		I
3	3	7.3 (7.2– 7.5) ± 0.18	2.1		I
Females					
6	25	7.8 (7.2– 8.2) ± 0.13	4.2	I	
2	29	7.7 (7.3– 8.3) ± 0.09	3.1	I	
9	6	7.6 (7.3– 8.1) ± 0.24	3.9	I	I
7	15	7.5 (7.0– 8.0) ± 0.16	4.0	I	I
1	13	7.4 (7.1– 7.8) ± 0.10	2.6		I

samples 1 and 3 always comprise one of the distinct subsets. Samples form two subsets, which overlap at sample 2, in length of hind foot. Samples 2, 6, and 7 are never completely divided from each other into distinct subsets except for breadth across maxillaries, in which sample 6 is a distinct subset.

For females, sample 1 averaged the smallest in size for all measurements except squamosal breadth. In five measurements (condylobasal length, basal length, palatal length, length of nasals, and diastema), sample 1 is significantly different from all other samples. Individuals from sample 9 generally averaged among the smallest, and these were the smallest in squamosal breadth. Together with sample 1 this sample forms a distinct subset in greatest length of skull, palatofrontal depth, zygomatic breadth, mastoid breadth, and rostral breadth. In all cases, sample 9 fell into two subsets for these measurements. Either sample 6 or sample 7 had on the average the largest females for the species. Individuals in sample 7 were significantly larger than all others in five measurements (condylobasal length, basal length, palatal length, diastema, and zygomatic breadth), but individuals in sample 6 never averaged significantly larger than all others. It appears that samples of female *G. arenarius* fall into two size groups—large size (samples 2, 6, 7, 9) and small size (sample 1). Overlap in size of the groups is mainly exhibited by sample 9.

Multivariate analyses.—All nine samples for females and seven samples for males (no adult males were available from samples 5 and 8) were used in multivariate analyses of geographic variation in *Geomys arenarius*. Distance phenograms for males and females generated with

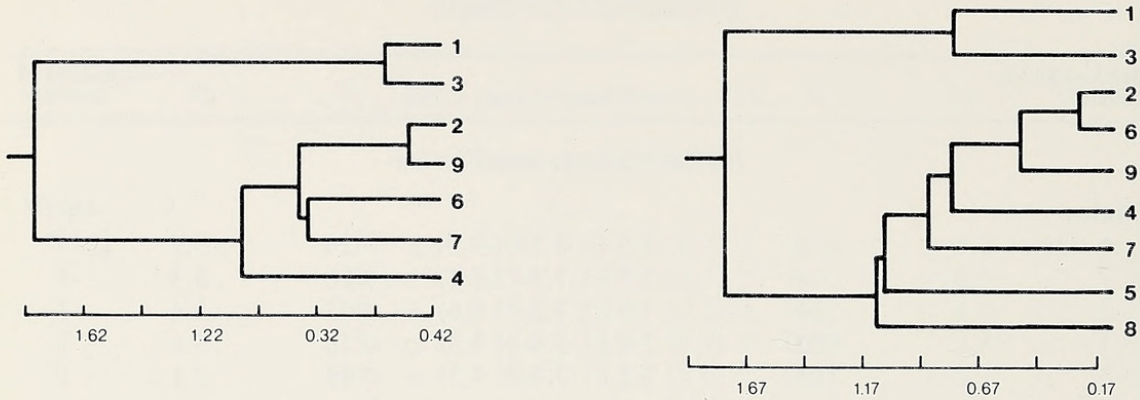

Fig. 2.—Phenograms of numbered samples (see Fig. 1 and text) of *Geomys arenarius* (males left, females right) computed from distance matrices and clustered by unweighted pair-group method using arithmetic averages (UPGMA). The cophenetic correlation coefficient for the phenogram for males is 0.899 and for females is 0.862.

the NT-SYS program package are illustrated in Fig. 2. The distance phenograms for males (cophenetic correlation value, 0.899) and females (cophenetic correlation value, 0.862) show the same basic patterns. Two major clusters are present. The upper cluster in both phenograms is composed of the samples from the vicinities of White Sand National Monument and Kenzin, New Mexico (samples 1 and 3), and the lower contains the remaining samples. Within the lower cluster, samples from the vicinity of Las Cruces, New Mexico (2), and vicinity of Fort Hancock, Texas (9), were the most closely related. The single male from sample 4 was the most distinct within this cluster. In females, the samples from the vicinities of Las Cruces, New Mexico (2), and El Paso, Texas (6) were the most similar within the lower cluster. The remaining samples form a graded series becoming increasingly distinct from samples 2 and 6 (samples 9, 4, 7, 5, and 8, respectively).

The first three principal components extracted from the matrix of correlation among characters are shown for males and females in Fig. 3. The amounts of phenetic variation explained by the first three principal components, for males and females, respectively, were 75.8 and 69.3 for component I, 12.7 and 11.5 for component II, and 6.0 and 10.1 for component III. Results of principal components analyses showing the influence of each character for the first three components are given in Table 3.

Most characters are heavily weighted in the first factor for both sexes. However, rather low values were found for length of tail, interorbital breadth, and breadth across maxillaries for males. In component II, characters with heavy weighting in males were length of tail, squamosal breadth, interorbital breadth, and breadth across maxillaries, and for females were length of tail and interorbital constriction.

Table 3.—*Factor matrix from correlation among 16 characters of* Geomys arenarius *studied.*

Characters	Males			Females		
	Component I	Component II	Component III	Component I	Component II	Component III
Total length	0.898	–0.252	0.241	0.829	–0.399	0.018
Length of tail	0.542	–0.735	0.106	0.330	–0.747	–0.423
Length of hind foot	0.946	0.065	0.243	0.745	–0.379	0.455
Greatest length of skull	0.993	–0.012	0.091	0.950	–0.175	0.216
Condylobasal length	0.993	–0.001	0.093	0.962	–0.164	0.119
Basal length	0.996	0.054	0.049	0.976	–0.045	0.121
Palatal length	0.933	0.086	0.022	0.951	0.041	0.158
Palatofrontal depth	0.971	0.181	0.050	0.971	0.194	–0.003
Length of nasals	0.967	0.091	–0.104	0.917	–0.178	0.189
Diastema	0.929	0.109	0.243	0.942	0.063	0.066
Zygomatic breadth	0.955	0.257	0.004	0.764	0.397	–0.460
Squamosal breadth	0.591	–0.723	–0.290	0.845	0.255	–0.383
Mastoid breadth	0.970	–0.044	–0.177	0.920	0.269	–0.257
Rostral breadth	0.843	0.419	–0.046	0.784	0.400	–0.362
Interorbital constriction	0.494	0.506	–0.673	0.314	–0.559	–0.566
Breadth across maxillaries	0.534	–0.576	–0.408	0.727	0.275	0.467

Interorbital constriction was the only character with high weighting in component III for males and females.

In both of the three-dimensional projections (Fig. 3), the small-sized samples from the vicinity of White Sands National Monument and Kenzin, New Mexico, are located to the left in the plots. They show a distinct separation from the other samples along component I. In males, samples 2 and 9 are closest to these samples, whereas in females samples 5 and 9 are closest. Sample 4 is located furthest to the right of the plot in males and samples 4 and 7 are furthest to the right in females, indicating that in overall size, individuals in these samples are the largest. We cannot detect any other major breaks in the variation among samples 2, 4–9 along the first component or the second and third components.

In both male and female *G. arenarius*, multivariate analysis of variance showed that there were significant ($P < .0001$) morphological differences among geographic samples in the following tests: Hotelling-Lawley's Trace; Pillai's Trace; Wilks' Criterion; Roy's Maximum Root Criterion.

Two-dimensional plots of the samples onto the first two canonical variates based on a matrix of variance-covariance among 13 cranial

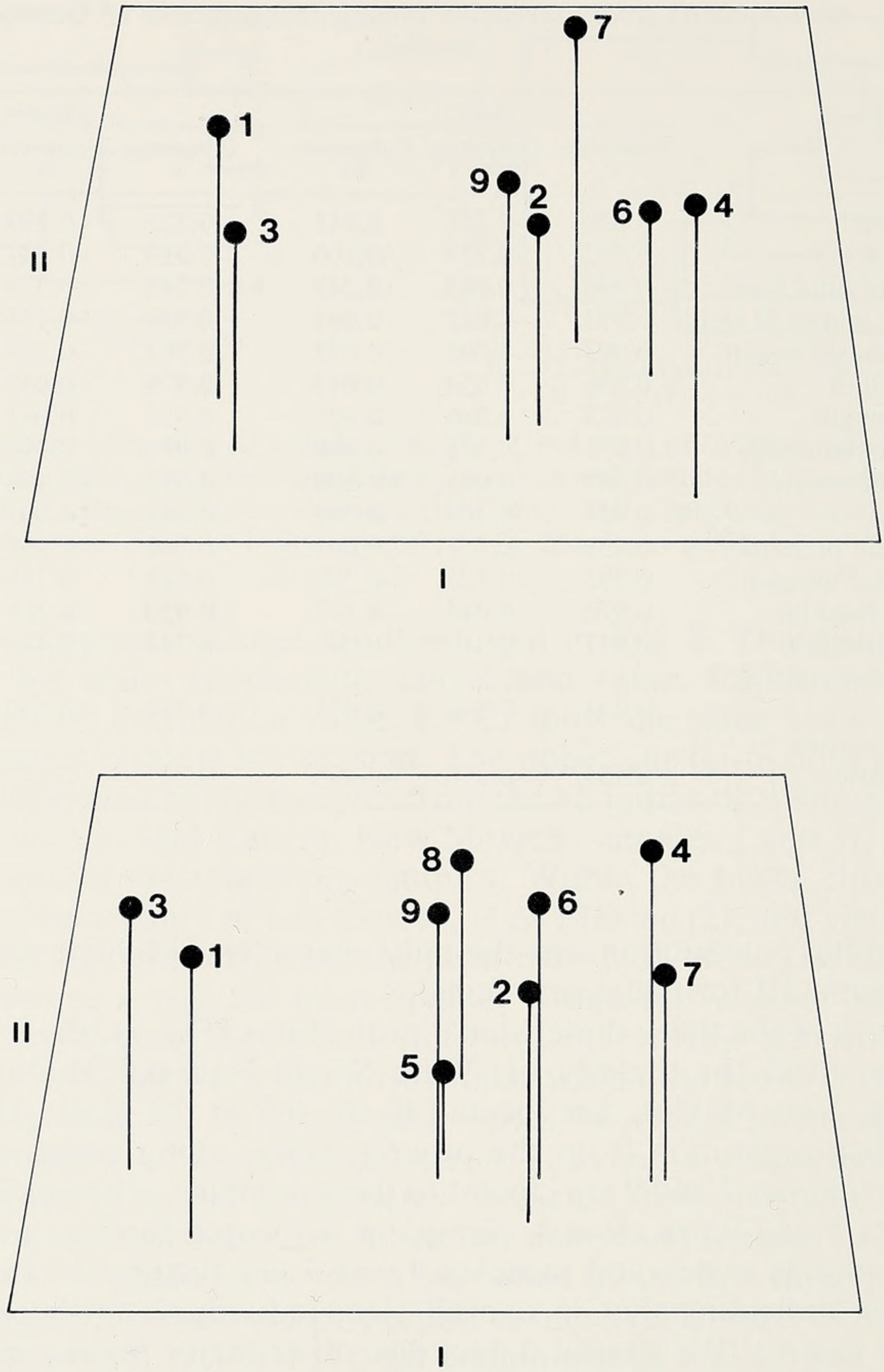

Fig. 3.—Three-dimensional projection of seven samples of male (upper) and nine samples of female (lower) *Geomys arenarius* onto the first three principal components based upon a matrix of correlation among 16 external and cranial measurements. Components I and II are indicated in the plots and component III is represented by height. See Fig. 1 and text for key to samples.

characters are presented for seven male samples in Fig. 4 and for nine female samples in Fig. 5. The percentages of phenetic variation represented in the first three canonical variates, males and females, respectively, were 45.04 and 46.96 for variate I, 27.07 and 23.71 for

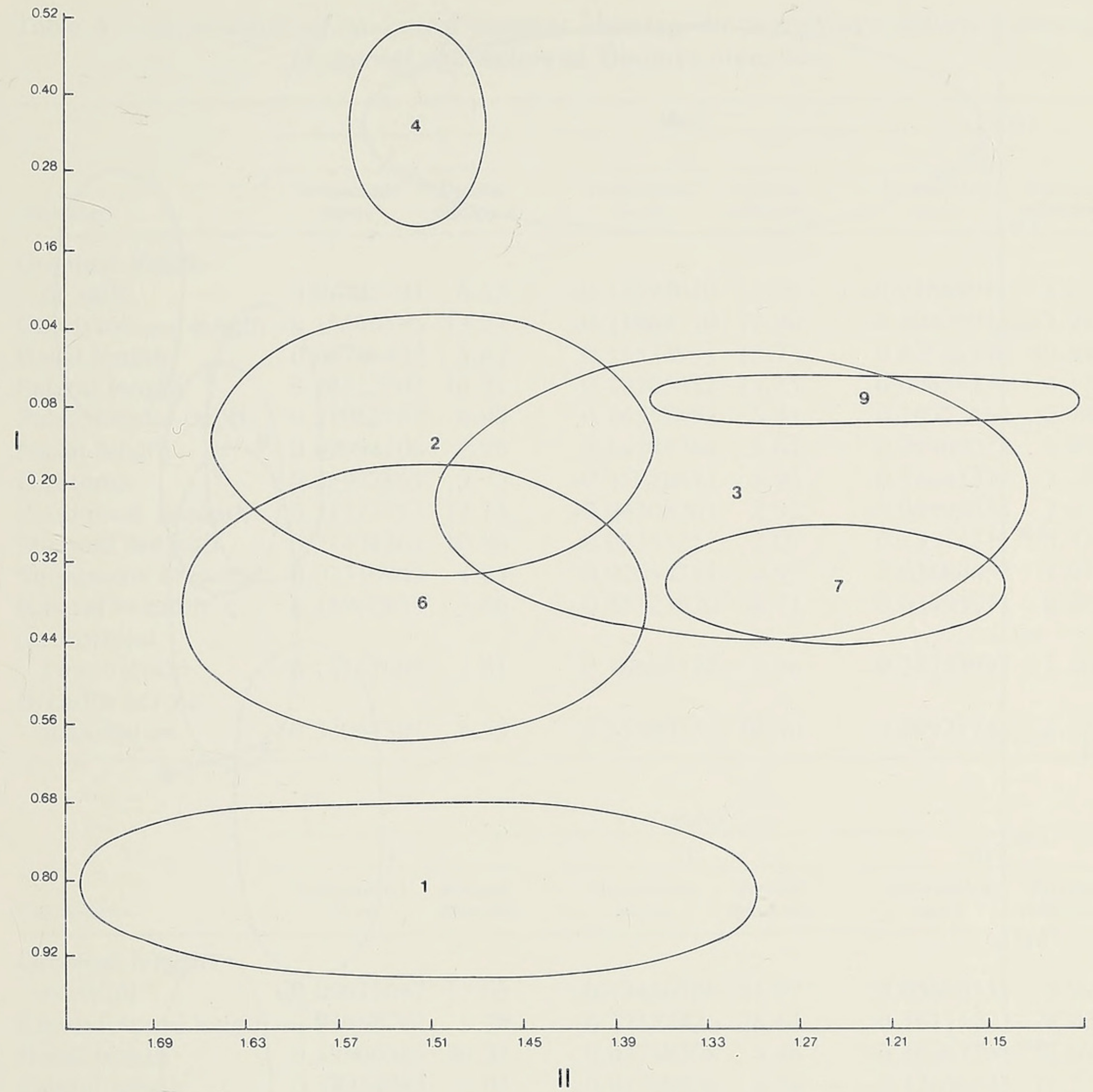

Fig. 4.—Two-dimensional projection of male samples (mean and one standard deviation) of *Geomys arenarius* onto the first two canonical variates based on a matrix of variance-covariance among 13 cranial measurements. See Fig. 1 and text for key to samples.

variate II, and 13.01 and 10.32 for variate III. The relative contribution of each character to the first three canonical variates in males and females are given in Table 4.

In both males and females, palatal length (males 16.2, females 22.03) contributed the heaviest toward separating the samples on the first variate. Other characters that contributed more than 10% on the first variate include condylobasal length, zygomatic breadth, and mastoid breadth for males and greatest length of skull, basal length, and palatofrontal depth for females. The following characters in males contributed more than 10% on the second variate, greatest length of skull, condylobasal length, basal length, and palatal length, and on the third

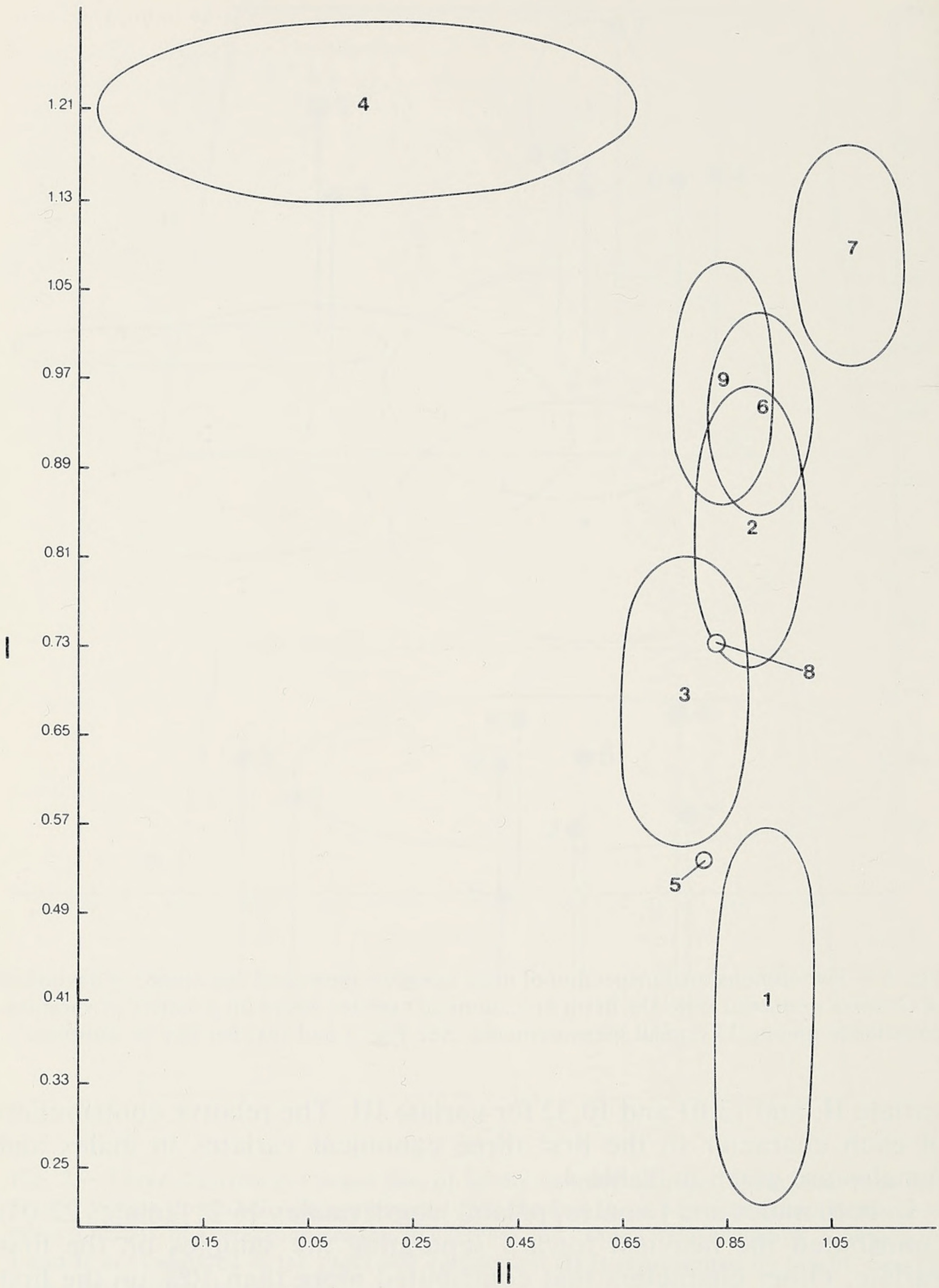

Fig. 5.—Two-dimensional projection of female samples (mean and one standard deviation) of *Geomys arenarius* onto the first two canonical variates based on a matrix of variance-covariance among 13 cranial measurements. See Fig. 1 and text for key to samples.

Table 4.—*Eigenvalues of canonical variates showing the percentage influence among 13 cranial characters of* Geomys arenarius.

	Males					
	I		II		III	
Characters	Normalized score	Percent influence	Normalized score	Percent influence	Normalized score	Percent influence
Greatest length of skull	0.07002704	6.35	−0.13295010	14.70	−0.01864911	1.32
Condylobasal length	−0.15596195	13.77	−0.11989710	12.90	−0.40425914	27.79
Basal length	−0.06744432	5.61	0.13533951	13.73	0.62722390	40.64
Palatal length	0.28522702	16.21	0.19105412	13.23	0.09435236	4.17
Palatofrontal depth	0.21062787	6.90	0.14557893	5.81	−0.10751664	2.74
Nasal length	0.09094108	2.96	0.14144744	5.61	0.26903025	6.82
Diastema	−0.31922869	9.75	−0.15928641	5.93	0.15683399	3.73
Zygomatic breadth	0.21777753	12.13	−0.04308363	2.92	−0.04995854	2.17
Mastoid breadth	−0.21474364	10.86	−0.03353211	2.07	0.13514711	5.32
Squamosal breadth	0.03319949	1.24	0.02034351	0.93	0.03680457	1.07
Rostral breadth	0.18962833	3.86	−0.35123820	8.71	0.03495951	0.55
Interorbital constriction	−0.14167600	1.81	0.18662330	3.06	0.24723997	2.46
Breadth across maxillaries	−0.54068301	8.55	0.53980533	10.40	−0.09921748	1.22

	Females					
	I		II		III	
Characters	Normalized score	Percent influence	Normalized score	Percent influence	Normalized score	Percent influence
Greatest length of skull	−0.09621047	17.05	−0.13456386	21.47	0.05660555	8.99
Condylobasal length	−0.03060782	5.29	0.17127426	26.63	−0.18111032	28.02
Basal length	0.12900585	20.93	0.03738308	5.46	0.10367251	15.07
Palatal length	0.19954883	22.03	−0.01399356	1.39	−0.12656545	12.52
Palatofrontal depth	−0.22064436	14.37	0.01464821	0.86	0.15197624	8.87
Nasal length	0.10353621	6.49	−0.12706368	7.17	−0.02466773	1.38
Diastema	−0.00887428	0.52	0.05728932	3.00	−0.02089690	1.09
Zygomatic breadth	−0.02705509	2.87	0.03618430	3.46	0.07753598	7.37
Mastoid breadth	−0.04863543	4.82	−0.09956718	8.89	0.05476377	4.87
Squamosal breadth	−0.02060481	1.56	0.12561332	8.59	0.05899616	4.01
Rostral breadth	0.05797401	2.32	−0.18096143	6.53	0.08977009	3.22
Interorbital constriction	−0.02595707	0.68	−0.12062981	2.87	−0.12885770	3.04
Breadth across maxillaries	−0.03363756	1.07	0.12973133	3.68	−0.05486456	1.55

variate, condylobasal length and basal length. The following characters in females contributed more than 10% on the second variate, greatest length of skull and condylobasal length, and on the third variate, condylobasal length and palatal length.

Examination of the two-dimensional plots for males and females (Figs. 4, 5) reveals the samples to be divided into three groups. At the bottom of both plots is the sample from White Sands (1). Individuals from this area are clearly the smallest in size for the species. Sample 4 is isolated at the top of each plot; these are the largest individuals of the species. The remaining samples are grouped at the center of each plot. Note that the standard deviation of males from sample 3 broadly overlaps with that of samples 2, 6, 7, and 9. In females, a different pattern is noted. Those samples to the west of the Rio Grande Valley—3, 5, and 8—fall at the lower end of variation for this central group. The one specimen from Samalayuca, Chihuahua (8), falls at the edge of one standard deviation for sample 2. The standard deviation for sample 3 overlaps that of sample 2 but the means for each sample lie outside the standard deviation. The one specimen from Columbus, New Mexico, lies between the standard deviations of samples 1 and 3.

Taxonomic conclusions.—Those individuals occurring along the floodplain of the Rio Grande River in Doña Ana Co., New Mexico, El Paso and Hudspeth cos., Texas, and adjacent Chihuahua, form a unified group characterized by large size. Those from the vicinity of Anthony, Chamberino, and Strauss (4) are among the largest and separate from other samples in some analyses. However, they seem best considered as one extreme in variation in this population. This group includes the holotype of the nominate subspecies from El Paso, El Paso Co., Texas, so the name *Geomys arenarius arenarius* should be applied to it.

The specimens from the vicinity of White Sands, Otero Co., New Mexico (1), are uniformly small in size. These specimens are geographically isolated from those along the Rio Grande River and we recognize them as a distinct subspecies, *Geomys arenarius brevirostris,* with the type locality of 9 mi W Tularosa, Otero Co., New Mexico.

This leaves the status of specimens from samples 3 (vicinity of Kenzin, New Mexico), 5 (near Columbus, New Mexico), and 8 (near Samalayuca, Chihuahua) undetermined. The individuals from sample 3 were as small as those from the White Sands area (1) in a number of characters. In some of the multivariate analyses, sample 3 grouped with sample 1, but in the SAS analyses, where characters were weighted, the specimens from sample 3 grouped closer to those samples from the Rio Grande. The single individuals from samples 5 and 8 grouped with the samples from along the Rio Grande in the cluster and principal component analyses. The position of sample 5 is less clear in the SAS analysis. Because the sample sizes for these areas are quite small and the bulk of the analyses, although inconclusive, seems to ally these samples with those samples from along the Rio Grande. These samples may represent a third subspecies but status is certainly not as distinct as the other two groups and they are assigned to *G. a. arenarius* for the present.

Geomys arenarius arenarius Merriam, 1895

Geomys arenarius Merriam, N. Amer. Fauna, 8:139, 31 January 1895.

Holotype.—Subadult male, skin and skull, USNM 18117/25015, from El Paso, El Paso Co., Texas; obtained on 13 December 1889 by Vernon Bailey, original no. 798.

Measurements of holotype.—Total length, 258; length of tail, 88; length of hind foot, 33; greatest length of skull —; condylobasal length, 42.9; basal length, 40.4; palatal length, 27.4; palatofrontal depth, 15.6; length of nasals, —; diastema, 14.6; zygomatic breadth, 27.0; mastoid breadth, 23.5; squamosal breadth, 18.4; rostral breadth, 9.4; interorbital breadth, 6.8; breadth across maxillaries, 8.1.

Distribution.—Occurring along the Rio Grande River in Hudspeth and El Paso cos., Texas, Doña Ana and Luna cos., New Mexico, and adjacent Chihuahua. The southernmost locality is 1.5 mi NE Porvenir (=Porvenir, Price and Emerson, 1971), Chihuahua (Anderson, 1972), and the northernmost is 7.6 mi N, 3.9 mi W Las Cruces, Doña Ana Co., New Mexico. The western edge of the geographic range is defined by the localities 8 mi S Samalayuca, Chihuahua, 2 mi S, 13 mi E Columbus, and Deming, New Mexico (Fig. 6).

Remarks.—All authors (Merriam, 1895; Bailey, 1895, 1905, 1932; Williams and Baker, 1974; Findley et al., 1975) seem to agree that *G. a. arenarius* prefers loose soil occurring in cultivated areas or along riverbanks. Populations of the species are quite high in the Rio Grande Valley and become agricultural pests in alfalfa fields, orchards, and the banks of irrigation ditches. These areas along the river bottoms are surrounded by hard stony mesas and desert mountains. According to Bailey (1932), specimens from Deming were from "the mellow sand along the Rio Mimbres." The area of distribution of *G. arenarius* is defined as northern Chihuahua Biotic Province by Blair (1950).

Bailey (1905) reported a specimen from near Monahans, Texas, as a *G. arenarius*. We have examined extensive material from the vicinity of Monahans and Kermit, Texas (Baker and Genoways, 1975), and are convinced that these specimens are best assigned to *Geomys bursarius knoxjonesi* (see also Davis, 1940).

Findley et al. (1975) reported specimens from 5 mi S, 11.8 mi E San Antonio, Socorro Co., New Mexico, at the extreme northern end of the Jornada del Muerto as *G. arenarius*. Our initial examination of these 10 specimens (only three aults) led us to question their specific

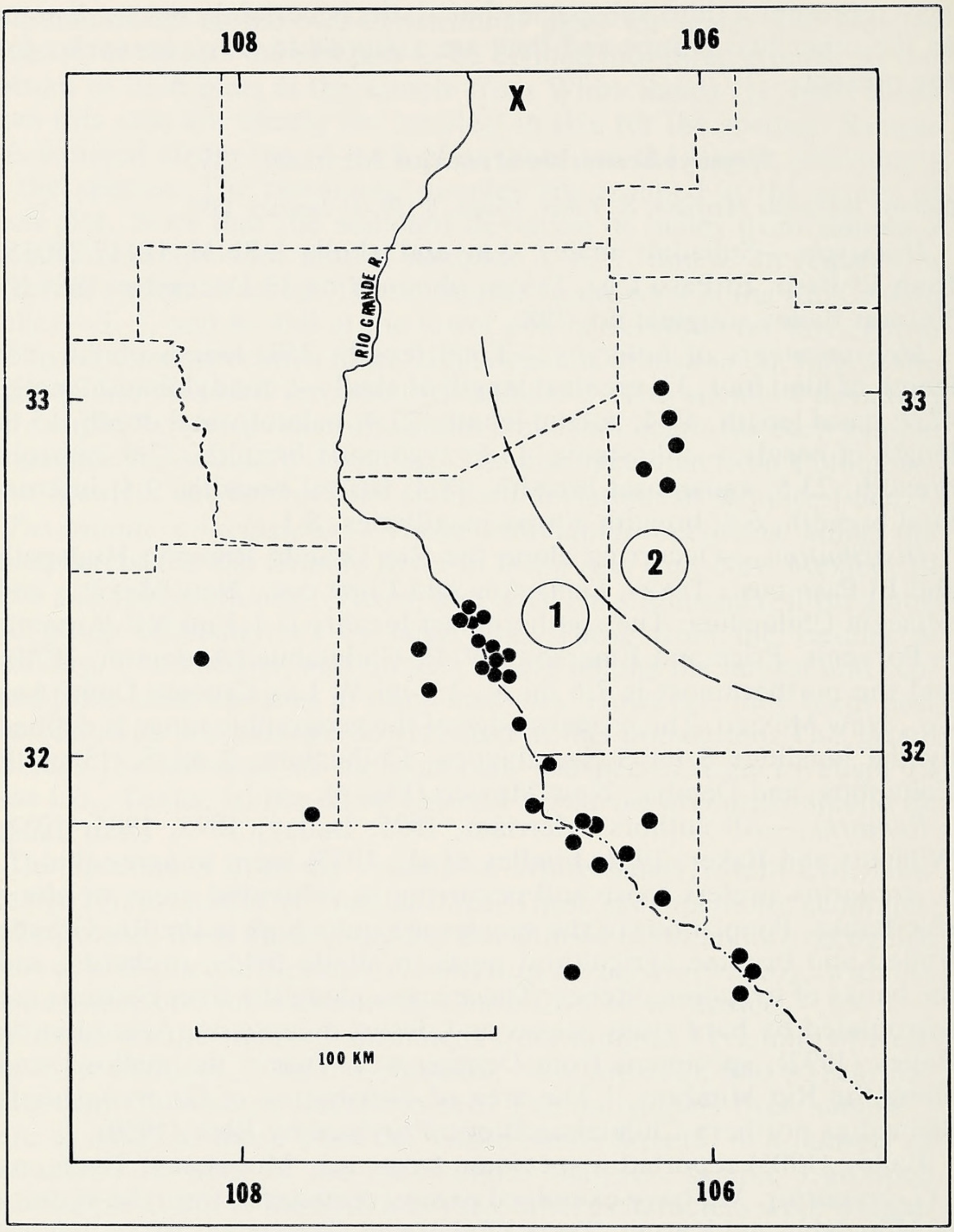

Fig. 6.—Geographic distribution of subspecies of *Geomys arenarius:* 1, *G. a. arenarius;* 2, *G. a. brevirostris.* "X" near top of figure is 5 mi S, 11.8 mi E San Antonio, Socorro Co., New Mexico, which is a locality for *Geomys bursarius knoxjonesi* discussed in text.

Table 5.—*Discriminant function coefficients resulting from a discriminant function analysis comparing reference samples of* Geomys arenarius *and* G. bursarius.

Characters	Discriminant function coefficients	
	Male	Female
Total length	–0.00175	——
Length of tail	0.00462	——
Length of hind foot	0.00387	——
Greatest length of skull	–0.00601	0.04494
Condylobasal length	–0.06442	–0.24073
Basal length	0.03102	0.02990
Palatal length	0.15608	0.33511
Palatofrontal depth	–0.05542	–0.10223
Length of nasals	0.02625	0.12173
Diastema	0.01615	–0.06087
Zygomatic breadth	–0.00102	–0.02849
Mastoid breadth	–0.02766	0.04680
Squamosal breadth	–0.08672	–0.06469
Rostral breadth	–0.18454	–0.12190
Interorbital constriction	0.26064	0.13909
Breadth of maxillaries	–0.07703	–0.06842
Length of basioccipital	——	0.04706

identity and to submit them to a discriminant function analysis to aid in their identification. Table 5 gives the discriminant function coefficients resulting from the comparison of reference samples of male and female *G. arenarius* and *G. bursarius*. The discriminant scores of male *arenarius* ranged from −0.471 to −0.813 and of *bursarius* −0.862 to −1.115. The one adult male from the vicinity of San Antonio (MSB 32641) received a discriminant score of −0.920 thus being classified as a *G. bursarius*. The range of discriminant scores for female *arenarius* was from 0.435 to 0.117 and *bursarius* 0.110 to −0.235. The two adult females from San Antonio (MSB 32600 and 32601) had scores of −0.098 and −0.067; both are identified as *G. bursarius*.

In a key to the pocket gophers of Texas, Davis (1940) used the width of the rostrum as compared to the length of the basioccipital to separate *Geomys arenarius* and *G. bursarius*. The rostral breadth is equal to or less than the basioccipital in *G. arenarius*, whereas in *G. bursarius* the reverse is true. For the three adults cited above and two subadults, the following values were found for these characters (rostral breadth is given first): MSB 32641, 10.2, 9.6; MSB 32600, 9.4, 9.1; MSB 32601, 9.4, 9.2; MSB 3266 (male), 9.6, 9.5; MSB 32834 (male), 9.8, 9.1. Thus all of these specimens, including the subadults, would key to *Geomys bursarius*. We conclude that the specimens from 5 mi S, 11.8 mi E San Antonio, Socorro Co., New Mexico, are best assigned to *Geomys bursarius knoxjonesi*. Based on available specimens and field investigation by us, it appears that the northern limit of the geographic range of *Geomys arenarius* is defined by the point that the Doña Ana Mountains meet the Rio Grande River. At this point, just north of Las Cruces, the river flows through a narrow channel along the western front of a series of low mountains. The narrow, gravelly channel does not provide suitable habitat for *Geomys* as well as several other species that show similar distributional patterns (see Findley et al., 1975; Williams, 1978). Evidently, *Geomys arenarius* has not entered the sandy areas of the Jornada del Muerto to the north and east of its geographic range.

Specimens examined (443).—CHIHUAHUA: Cd. Juarez, 3 (USNM); 7 mi SE Cd. Juarez, 5 (KU); 1½ mi NE Porvenir, 2 (KU); 8 mi S Samalayuca, 1 (KU). NEW MEXICO: *Doña Ana Co.:* 1 mi NE Aden Crater, 1 (MALB); Aden Crater, 2 (MALB); Lava flow, Johnson Ranch (31 mi NW El Paso), 1 (MSB); 5 mi N, 2 mi E Afton, 2 (UIMNH); 3.4 mi N, 3.2 mi W Afton, 4260 ft, T25S, R2W, Sec 24, 2 (NMSU); 3 mi N Afton, 2 (UIMNH); 2.5 mi N, 4.3 mi W Afton, 4240 ft, T25S, R2W, Sec 26, 1 (NMSU); 7⅝ mi W Bishop Cap Peak, 3825 ft, T24S, R2E, Sec 22, 1 (NMSU); 2 mi N, 1½ mi W Chamberino, 1 (UIMNH); 1½ mi N, 1½ mi W Chamberino, 4 (UIMNH); Doña Ana, 1 (KU); Kenzin, 3 (2 UIMNH, 1 UMMZ); 0.8 mi S, 5.5 mi W Kenzin, 4400 ft, T25S, R3W, Sec 36, 1 (NMSU); 3 mi S, 16 mi W La Mesa, 4350 ft, 2 (NMSU); 7.6 mi N, 3.9 mi W Las Cruces, 4000 ft, T22S, R1E, Sec 4, 1 (NMSU); 7.3 mi N, 3.9 mi W Las Cruces, 3935 ft, T22S, R1E, Sec 4, 2 (NMSU); 7.2 mi N, 3.4 mi W Las Cruces, 4000 ft, T22S, R1E, Sec 9, 1 (NMSU); 6.9 mi N, 3.6 mi W Las Cruces, 4000 ft, T22S, R1E, Sec 9, 1 (NMSU); 6.8 mi N, 3.9 mi W Las Cruces, 4000 ft, T22S, R1E, Sec 9, 1 (NMSU); 6.8 mi N, 3.5 mi W Las Cruces, 3935 ft, T22S, R1E, Sec 9, 1 (NMSU); 6.6 mi N, 3.7 mi W Las Cruces, 4000 ft, T22S, R1E, Sec 16, 1 (NMSU); 6.3 mi N, 3.7 mi W Las Cruces, 4000 ft, T22S, R1E, Sec 16, 1 (NMSU); 6.1 mi N, 3.5 mi W Las Cruces, 4000 ft, T22S, R1E, Sec 16, 1 (NMSU); 5.8 mi N, 4.1 mi W Las Cruces, 3930 ft, T22S, R1E, Sec 16, 2 (NMSU); 5.5 mi N, 5.1 mi W Las Cruces, 3940 ft, T22S, R1E, Sec 17, 3 (NMSU); 5.5 mi N, 4.0 mi W Las Cruces, 3930 ft, T22S, R1E, Sec 16, 1 (NMSU); 5.3 mi N, 5.2 mi W Las Cruces, 3940 ft, T22S, R1E, Sec 17, 1 (NMSU); 4.9 mi N, 5.0 mi W Las Cruces, 3935 ft, T22S, R1E, Sec 20, 4 (NMSU); 4.9 mi N, 3.6 mi W Las Cruces, 3920 ft, T22S, R1E, Sec 21, 3 (NMSU); 4.7 mi N, 4.8 mi W Las Cruces, 3920 ft, T22S, R1E, Sec 20, 1 (NMSU); 4.7 mi N, 3.0 mi W Las Cruces, 3920 ft, T22S, R1E, Sec 12, 1 (NMSU); 4.6 mi N, 4.8 mi W Las Cruces, T22S, R1E, Sec 20, 1 (NMSU); 4.4 mi N, 3.3 mi W Las Cruces, 3915 ft, T22S, R1E, Sec 22, 1 (NMSU); 4.0 mi N, 3.7 mi W Las Cruces, 3940 ft, T22S, R1E, Sec 28, 1 (NMSU); 4.0 mi N, 3.1 mi W Las Cruces, 3916 ft, T22S, R1E, Sec 27, 1 (NMSU); 2 mi N, 1 mi W Las Cruces, 2 (TNHC); 1.6 mi N, 3.0 mi W Las Cruces, T23S, R1E, 3 (NMSU); 1.5 mi N, 4 mi W Las Cruces, 3 (NMSU); 1 mi N, ¼ mi W Las Cruces, 2 (NMSU); 1½ mi NW Las Cruces, 3 (NMSU); NE Las Cruces, 3925 ft, T23S, R2E, 1 (NMSU); 15 mi W Las Cruces, 6 (LACM); W Las Cruces (E bank Rio Grande R.), 34 (TTU); 1²/₁₀ mi S US 70-80 Rio Grande Bridge, 2 (MSB); Levee Rd, 3882 ft, T23S, R1E, Sec 27, 2 (NMSU); Las Cruces, 12 (1 MSB, 3 NMSU, 8 USNM); 1.6 mi S, 2.8 mi W Las Cruces, T23S, R1E, Sec 22, 6 (NMSU); 2 mi S, 3 mi E Las Cruces, 3900 ft, 1 (NMSU); 3.1 mi S, 2.8 mi W Las Cruces, 3880 ft, T23S, R1E, Sec 34, 4 (NMSU); NMSU Horticulture Farm, T24S, R2E, 1 (NMSU); 6.2 mi S, 2.4 mi W Las Cruces, 3850 ft, T24S, R1E, 1 (NMSU); 1.6 mi N, 1.5 mi W Mesilla, 3800 ft, T23S, R1E, Sec 22, 1 (NMSU); 1.2 mi N, 1.5 mi W Mesilla, 3800 ft, T23S, R1E, Sec 22, 3 (NMSU); 0.5 mi N, 2 mi W Mesilla, 3990 ft, 1 (NMSU); 0.3 mi S Mesilla, 1 (TNHC); 0.5 mi S, 2.0 mi W Mesilla, 3885 ft, 1 (NMSU); 0.5 mi S, 1.9 mi W Mesilla, 3885 ft, T23S, R1E, Sec 34, 5 (NMSU); 1.4 mi S Mesilla, 3905 ft, T25S, R1E, Sec 15, 2 (NMSU); 3.1 mi S Mesilla, T24S, R1E, Sec 11, 1 (NMSU); 4 mi S Mesilla, 1 (NMSU); 6.0 mi N Mesilla Dam, 1 (TNHC); 2.5 mi N Mesilla Dam, 1 (TNHC); 2.4 mi N Mesilla Dam, 1 (TNHC); 1.3 mi N Mesilla Dam, 1 (TNHC); 1.1 mi N Mesilla Dam, 4 (TNHC); 1.0 mi N Mesilla Dam, 5 (TNHC); 0.9 mi N Mesilla Dam, 4 (TNHC); 0.8 mi N Mesilla Dam, 2 (TNHC); 0.7 mi N Mesilla Dam, 3 (TNHC); 0.5 mi N Mesilla Dam, 1 (TNHC); 0.4 mi N Mesilla Dam, 1 (TNHC); 0.25 mi N, 0.125 mi W Mesilla Dam, 3990 ft, T24S, R1E, Sec 8, 2 (NMSU); ¼ mi N Mesilla Dam, 3905 ft, T25S, R1E, Sec 11, 1 (NMSU); 0.2 mi N Mesilla Dam, 3900 ft, T24S, R2E, Sec 7, 1 (NMSU); 200 yds N Mesilla Dam, T24S, R1E, Sec 12, 3 (NMSU); 12.3 mi W Mesilla Dam, 4260 ft, T24S, R1W, Sec 31, 4 (NMSU); 0.3 mi S Mesilla Dam, 1 (TNHC); 1.4 mi S Mesilla Dam, 3905 ft, T25S, R1E, Sec 15, 2 (NMSU); 1 ¾ mi S, 2¼ mi W Mesilla Dam, 3857 ft, T23S, R2E, Sec 17, 2 (NMSU); 3½ mi S, ¼ mi W Mesilla Park, 6 (MSB); 5 mi E Strauss, 1 (TCWC); ca. ½ mi N Anapra Bridge, Rio Grande floodplain, 1 (MALB); W bank Rio Grande at intersection with Country Club Rd, (NW El Paso), 1 (MALB); ¼ mi S Country Club Rd., 4 (MALB). *Luna Co.:* 2 mi S, 13 mi E Columbus, 1 (MSB); Deming, 3 (USNM); Mexican Boundary Line, Lat. 31°47′, Long. 30°51′, 7 (USNM). TEXAS: *El Paso Co.:* S on W Levee Rd., 1.2 mi from Fm. Rd. 1905 W of Anthony, 3 (MALB); 0.5 mi N, 0.15 mi W Canutillo, 1 (MALB); Canutillo (near river), 1 (MALB); 15 mi above El Paso (bank of Rio Grande), 2 (MVZ); 0.6 mi W Levee Rd. from Borderland Ave., 0.1 mi W Doniphan Dr. (El Paso), 2 (MALB); 1.5 mi W on Country Club Rd. N on Levee Rd. along Rio Grande for 0.3 mi (El Paso), 1 (MALB); down Country Club Rd. to Rio Grande River then N for 0.5 mi, 1 (MALB); Upper Valley, El Paso, 1 (TTU); 428 Lindbergh Ave., Upper Valley, El Paso, 1 (MALB); River Bend Farm, ½ mi S Sunset Dr., 1 (MALB); 2.5 mi S Country Club Rd., El Paso, 1 (MALB); NW El Paso, 1 (MALB); 3 mi N, 3 mi W Rio Grande R. Shore, El Paso, 1 (KU); El Paso, 21 (8 MALB, 1 UMMZ, 12 USNM); El Paso Zoo, 1 (USNM); E El Paso, 20 (USNM); 2 mi E city limits El Paso, 15 (MVZ); 30 mi E El Paso, 2.5 mi N Rio Grande (Fabens), 4 (TTU); 5 mi S, 8 mi E City Hall, El Paso, 3700 ft, 16 (KU); 10 mi SE City Hall, El Paso, 3700 ft, 17 (KU); 6.5 mi NE I-10 on Fabens-Carlsbad cutoff road, 1 (MALB); Fabens, 1 (USNM); 1 mi S Fabens, 50 (TTU); 2 mi S Fabens, 1 (MALB); 3 mi S Fabens, 1 (MALB); Horizon City, 2 (MALB); 1¼ mi N, ¾ mi W Ysleta, 21 (UIMNH); Ysleta, 2 (UIMNH). *Hudspeth Co.:* Ft. Hancock, 14 (2 AMNH, 10 KU, 2 USNM); 2 mi S Ft. Hancock, 7 (KU); 1 mi W McNary, 3 (UIMNH); McNary, 1 (UIMNH).

Geomys arenarius brevirostris Hall, 1932

Geomys arenarius brevirostris Hall, Proc. Biol. Soc. Washington, 45:97, 21 June 1932.

Holotype.—Adult female, skin and skull, MVZ 50460, from E edge of [white] sand [9 mi W Tularosa], Tularosa–Hot Springs Road, Otero Co., New Mexico; obtained on 10 October 1931 by Annie M. Alexander, original no. 1174.

Distribution.—Confined to the White Sands area of Otero Co., New Mexico (Fig. 6).

Remarks.—Benson (1933) found *G. arenarius* to be most abundant about the edges of the ponds in the White Sands area. In many cases the burrows ran close to edge of the water and the earth thrown out in the mounds was saturated. Blair (1941, 1943) believed that *G. arenarius* was the most abundant mammal of White Sands, particularly in the wet and dry valley associations of the interior. They were also found to be abundant in the grama grass–joint fir association of the periphery, but were rare in sumac–yucca association. Recent attempts by field teams from Texas Tech University to locate specimens of this taxon in the vicinity of Alamogordo and White Sands National Monument were unsuccessful. It is difficult to determine the status of this taxon because most of its former range is occupied by the White Sands National Monument and White Sands military installation; however, it clearly is not as abundant as indicated by Blair (1941, 1943). Specimens of *Pappogeomys castanops* were taken at several localities and it is entirely possible that this species is replacing *G. a. brevirostris* in many areas.

In contrast to most mammals living in the White Sands area, *G. a. brevirostris* is darker than other members of the species (Hall, 1932; Benson, 1933; Blair, 1941, 1943). Benson theorized that this dark coloration was the result of *G. a. brevirostris* living in areas of moist soil near ponds. Such soils tend to be darker than the dry sands of White Sands. Blair (1943) disregarded this theory because *brevirostris* is much darker than either the dry or wet gypsum of White Sands, and is darker than *G. a. arenarius*, which live in soils that are darker than the gypsum sand. He theorized that *G. a. brevirostris* was a recent invader of White Sands and that the dark color of this subspecies was fixed before it entered the area. The time since the invasion supposedly was too short to allow adaptation to the local conditions. Blair (1943) believed, and we agree, that the logical route of invasion followed by *brevirostris* was by way of the Escondida red sands, which extend southward from White Sands into Texas.

Our analyses reveal that individuals of the population from White Sands are uniformly small. They are approached in size by some individuals from west of the Rio Grande River but we do not believe there is any current relationship between these samples. Present data seem to indicate that *G. a. brevirostris* is isolated from *G. a. arenarius*. If the Escondida sands were the invasion route for *brevirostris*, then the intervening population no longer exists or else has not been located. However, much of this area is currently occupied by Fort Bliss.

Specimens examined (64).—NEW MEXICO: *Otero Co.:* 19 mi W Alamogordo, 1 (AMNH); 18 mi W Alamogordo, 18 (11 AMNH, 7 MSB); 12 mi W Alamogordo, 1 (MVZ); Alamogordo, 2 (UMMZ); 15 mi SW Alamogordo, 6 (LACM); 27 mi SW Alamogordo, 2 (UMMZ); 10 mi W Tularosa, 3 (UMMZ); White Sands, 10 mi SW Tularosa, 4100 ft, 5 (MVZ); sands SW Tularosa, 2 (MVZ); east edge sands, Tularosa–Hot Springs Rd., 11 (MVZ); 4 mi NW White Sands National Monument Museum, 2 (MVZ); White Sands National Monument, 8 (4 UIMNH, 4 UMMZ); interior White Sands, 3 (1 TNHC, 2 UMMZ).

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