2-1983

Coccidia from Kangaroo Rats (*Dipodomys* spp.) in the Western United States, Baja California, and Northern Mexico with Descriptions of *Eimeria merriami* sp. n. and *Isospora* sp.

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J. Parasitol., 69(1), 1983, pp. 209–214

COCCIDIA FROM KANGAROO RATS (*DIPODOMYS* SPP.) IN THE WESTERN UNITED STATES, BAJA CALIFORNIA, AND NORTHERN MEXICO WITH DESCRIPTIONS OF *EIMERIA MERRIAMI* SP. N. AND *ISOSPORA* SP.

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ABSTRACT: Since January 1975, 104 of 361 (29%) kangaroo rats (*Dipodomys* spp.) examined for Coccidia had oocysts in their feces. These included 32 of 71 (45%) *D. agilis* from California (3 of 8, 38%) and Baja California Norte (29 of 63, 46%); none of 18 *D. deserti* from Sonora, Mexico; one of one *D. gravipes* from Baja Norte; 43 of 124 (35%) *D. merriami* from California (1 of 4, 25%), New Mexico (16 of 49, 33%), Baja Norte (12 of 23, 52%), Baja Sur (6 of 20, 30%), and Sonora, Mexico (8 of 28, 29%); 17 of 103 (17%) *D. ordii* from Oregon (0 of 9), Texas (3 of 9, 33%), and New Mexico (14 of 85, 17%); three of 14 (21%) *D. panamintinus* from California; and eight of 30 (27%) *D. spectabilis* from New Mexico. The following coccidians were identified from infected rats: *Eimeria balphae, E. chobotari, E. scholtysecki, Eimeria* sp., *E. utahensis,* and *Isospora* sp. from *D. agilis*; *E. scholtysecki* from *D. gravipes*; *E. balphae, E. chobotari, E. chihuahuaensis, E. dipodomysis, Eimeria merriami* sp. n., *Eimeria* sp., and *E. utahensis* from *D. merriami*; *E. balphae, E. chobotari,* and *E. dipodomysis* from *D. ordii*; *E. scholtysecki* and *Eimeria* sp. from *D. panamintinus*; and *E. balphae* and *E. scholtysecki* from *D. spectabilis.* Sporulated oocysts of *Eimeria merriami* sp. n. from *D. merriami* were subspherical, 24.3 × 22.7 (21–27 × 20–26) μm with ovoid sporocysts 10.6 × 7.6 (9–12 × 7–9) μm. No micropyle or polar body were present, but oocyst and sporocyst residua, Stieda and substieda bodies were present. The oocyst wall has two layers. Sporulated oocysts of *Isospora* sp. from *D. agilis* were nearly spherical, 25.5 × 25 (21–28 × 20–28) μm with broadly ovoid sporocysts 14.5 × 10.0 (12–19 × 9–13) μm. No micropyle, oocyst residuum and substieda body were present, but a polar granule, sporocyst residuum and Stieda body were present. The oocyst wall had two layers. There are no other isosporans described from heteromyid rodents. Greater than 91% (195 of 213) of all *Dipodomys* found to be naturally infected with Coccidia in this study, and in all other published surveys, harbored only a single parasite species at any one time.

We examined eight species of *Dipodomys* from California, New Mexico, Oregon, Baja California (Norte and Sur), and Sonora, Mexico, and found them to be infected with seven eimerians and one isosporan. One of the eimerians, found in two specimens of *D. merriami,* is described here as new. Oocysts of an isosporan were also found in one specimen of *D. agilis,* but because only a few oocysts were available for study we decline to name it at this time.

MATERIALS AND METHODS

All hosts were killed in the field a few hr after being live trapped. The abdominal cavity was opened, the intestinal tract removed, and the cecum and colon were slit lengthwise and preserved, with their contents, in vials containing 2.5% aqueous (w/v) $K_2Cr_2O_7$.

Upon return to the laboratory, vials were refrigerated (4 C) until they could be processed and examined. Processing for oocysts consisted of separating fecal contents from cecal/colon tissue, filtering, incubating and examining by coverslip flotation as described elsewhere (Duszynski et al., 1982). Oocysts were measured with an ocular micrometer and photographed with either Panatomic-X or Ilford Pan F 35 mm film within a Zeiss Universal Photomicroscope equipped with both brightfield (Neofluar) and Nomarski-interference 100× objectives. All measurements are in μm with the ranges in parentheses following the means.

Received 11 January 1982; revised 9 June 1982; accepted 15 June 1982.

RESULTS

The hosts, the coccidians with which they were infected, and collection localities are presented in Table I.

Coccidians

Eimeria balphae Ernst, Chobotar, and Anderson, 1967. This species was found in 10 of 32 (31%) infected *D. agilis,* three of 43 (7%) infected *D. merriami,* 11 of 17 (65%) infected *D. ordii,* and seven of eight (88%) infected *D. spectabilis.*

Eimeria chobotari Ernst, Oaks, and Sampson, 1970. This species was found in two of 32 (6%) infected *D. agilis,* 25 of 43 (58%) infected *D. merriami,* and in five of 17 (29%) infected *D. ordii.*

Eimeria chihuahuaensis Short, Mayberry, and Bristol, 1980. This species was found in 10 of 43 (23%) infected *D. merriami.*

Eimeria dipodomysis Levine, Ivens, and Kruidenier, 1957. This species was found in one of

TABLE I. *Eimeria spp. recovered from seven Dipodomys spp. collected from the western United States, Baja California, and northern Mexico including new host (*) and/or locality (state or country) records (†).*

Dipodomys spp.	Country: County and/or state	No. hosts infected/ examined (%)	*Eimeria* spp. identified from hosts: This study	*Eimeria* spp. identified from hosts: All previous studies
agilis	Mexico			none
	Baja Norte	29/63 (46)	*balphae**†, *chobotari**†, *scholtysecki**†, *utahensis**†, sp.‡	
	USA			
	San Bernardino Co., CA	1/3 (33)	*balphae*†, sp.‡	
	Riverside Co., CA	2/5 (40)	*chobotari*†, sp.‡	
deserti	Mexico			none
	Sonora	0/18	–	
gravipes	Mexico			none
	Baja Norte	1/1	*scholtysecki**†	
merriami	Mexico			*balphae*
	Baja Norte	12/23 (52)	*chobotari*†, *merriami**†, *utahensis**†	*chobotari*
	Baja Sur	6/20 (30)	*chobotari*†, *chihuahuaensis*†, sp.‡	*chihuahuaensis*
	Sonora	8/28 (29)	*balphae*†, *chobotari*†, *chihuahuaensis*†	
	USA			
	Kern Co., CA	1/4 (25)	*chobotari*	
	Chavez Co., NM	10/30 (30)	*dipodomysis**†	
	Hidalgo Co., NM	1/3 (33)	*chobotari*†	
	Socorro Co., NM	4/12 (33)	*balphae*†, *chobotari*, *chihuahuaensis*†	
	Valencia Co., NM	1/4 (25)	*balphae*	
ordii	USA			*balphae*
	Chavez Co., NM	6/9 (67)	*chobotari*, *dipodomysis*	*chobotari*
	Hidalgo Co., NM	1/4 (25)	*balphae*	*dipodomysis*
	Torrence Co., NM	3/14 (21)	*balphae*	*scholtysecki*
	Valencia Co., NM	4/58 (7)	*balphae*	*utahensis*
	Harney Co., OR	0/9	–	
	Motley Co., TX	3/9 (33)	*balphae*	
panamintinus	USA			*mohavensis*
	Kern Co., CA	3/14 (21)	*scholtysecki**†, sp.‡	
spectabilis	USA			none
	Chavez Co., NM	1/20 (5)	*scholtysecki**†	
	Hidalgo Co., NM	3/5 (60)	*balphae**†	
	Socorro Co., NM	4/5 (80)	*balphae*	
Totals 7		104/361 (29)	7	7

‡ Unsporulated oocysts, unable to identify.

17 (6%) infected *D. ordii* and in 10 of 43 (23%) infected *D. merriami.*

Eimeria scholtysecki Ernst, Frydendall, and Hammond, 1967. This species (Figs. 1, 2) was found in eight of 32 (25%) infected *D. agilis,* one of one infected *D. gravipes,* two of three (67%) infected *D. panamintinus,* and one of eight (13%) infected *D. spectabilis.* Photomicrographs of this species have not been previously published thus are included here (Figs. 1, 2).

Eimeria sp. Some hosts had oocysts which either never sporulated or were too deteriorated to identify at the time they were examined. These included 18 of 32 (56%) infected *D. agilis,* one of 43 (2%) infected *D. merriami* and one of three (33%) infected *D. panamintinus.*

Eimeria utahensis Ernst, Hammond, and Chobotar, 1968. This species was found in four of 32 (13%) infected *D. agilis* and one of 43 (2%) infected *D. merriami.*

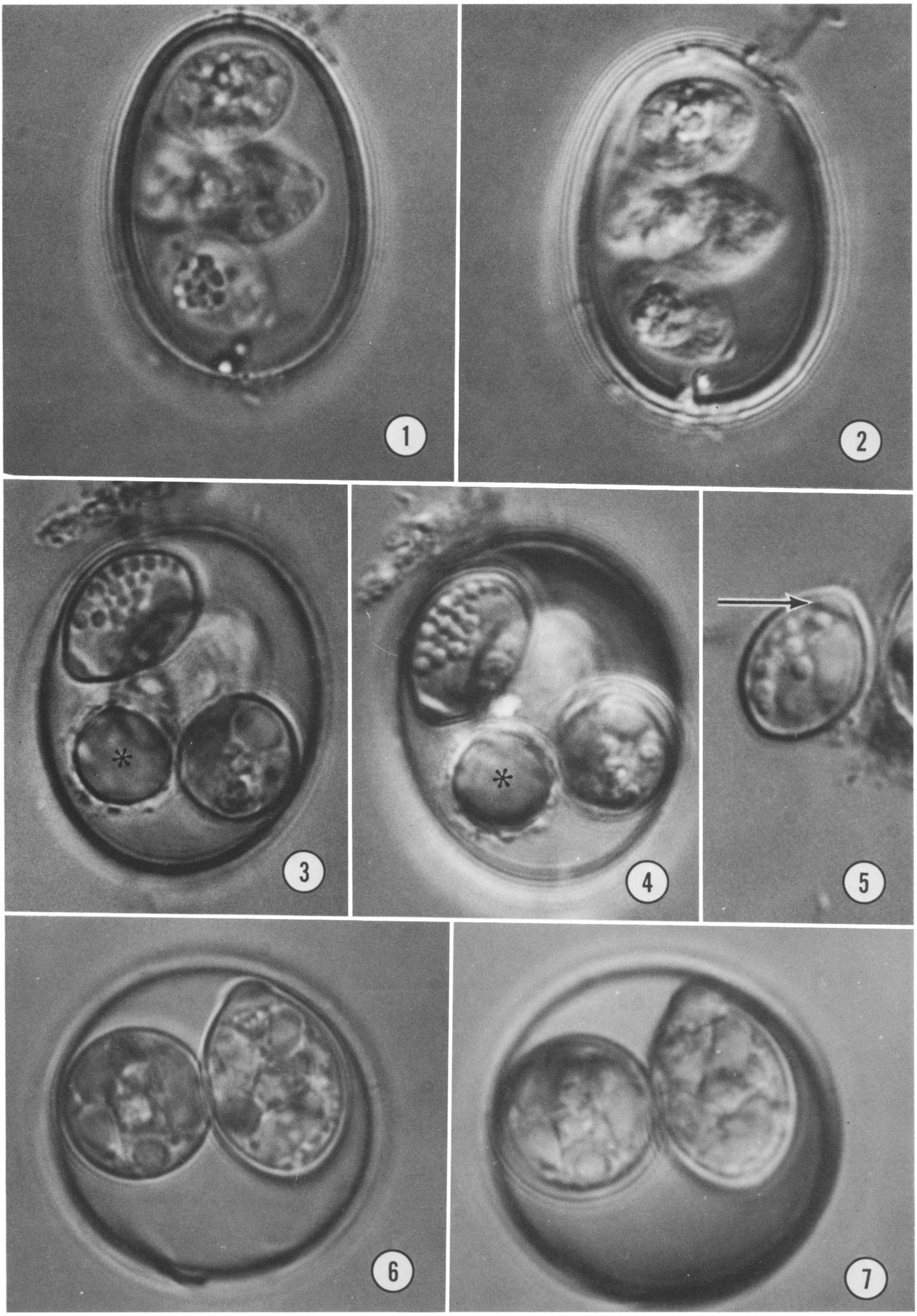
***Eimeria merriami* sp. n.**
(Figs. 3–5, 8)

Description

Oocyst ellipsoid (Figs. 3, 4); wall ≅ 1.6 consisting of two layers: outer layer smooth, light yellow, ≅ ⅔ of

⟶

FIGURES 1–7. Sporulated oocysts of coccidians recovered from feces of *Dipodomys* spp. ×1,866. **1, 2.** *Eimeria scholtysecki* from *D. agilis.* **3-5.** *Eimeria merriami* sp. n. from *D. merriami*; note oocyst residuum (*) and substieda body (arrow). **6, 7.** *Isospora* sp. from *D. agilis.*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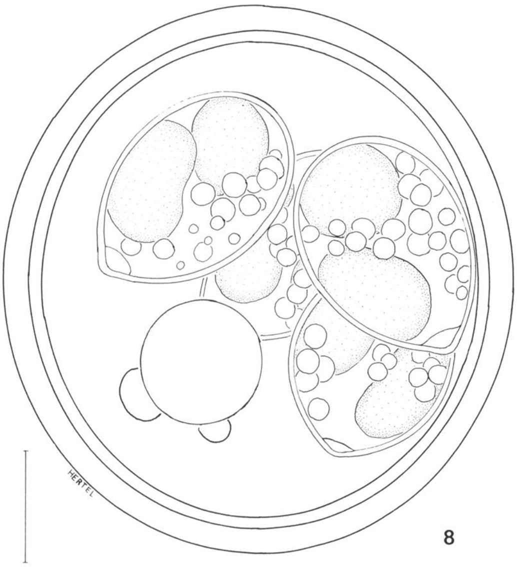

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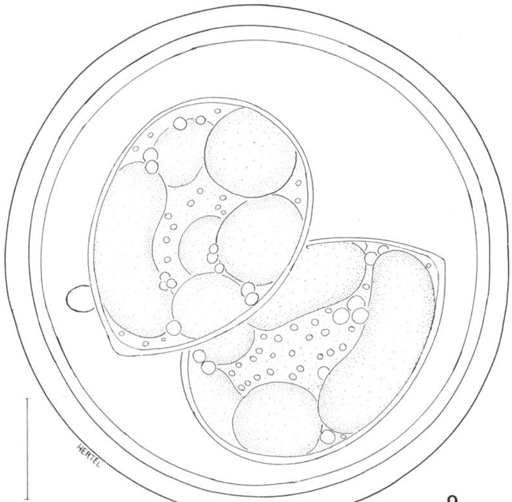

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FIGURES 8, 9. Schematic line drawings of sporulated oocysts of *Eimeria merriami* (Fig. 8) and *Isospora* sp. (Fig. 9). Bar = 5 μm.

total wall thickness, inner layer brown, ≅ ⅓ of total thickness; micropyle and polar body absent; oocyst residuum always consisting of several globules of varying size (Fig. 8); sporulated oocysts (n = 101) 24.3 × 22.7 (21–27 × 20–26) with L:W ratio 1.07 (1.00–1.17); sporocysts ovoid, 10.6 × 7.6 (9–12 × 7–9) with L:W ratio 1.40 (1.19–1.56); Stieda (Figs. 3, 4) and substieda (Fig. 5) bodies present; sporocyst residuum of several dispersed granules; sporozoites generally obscured by residual granules. Oocysts were 180 days old when measured.

Taxonomic summary

Diagnosis: This species most closely resembles *E. chihuahuaensis* but differs from it in being consistently smaller (22 × 24 vs. 26 × 33), in having an oocyst residuum composed of two, three, or more globules, and in having sporocysts with substieda bodies.

Host: Dipodomys merriami Mearns, Merriam's kangaroo rat, Museum of Southwestern Biology, Division of Mammalogy, MSB 40168 (male), T. L. Yates #523, 24 May 1979 and MSB 40175 (male), D. J. Hafner #1422, 24 May 1979.

Locality: Near San Felipe, Baja California Norte, Mexico.

Prevalence: Found in two of 23 (9%) *D. merriami* collected in Baja California Norte, Mexico.

Site of infection: Unknown. Oocysts recovered from feces.

Etymology: The specific name is derived from the trivial name of the host.

***Isospora* sp.**

(Figs. 6, 7, 9)

Description

Oocyst spherical or nearly so; wall ≅ 1.6 consisting of two layers: outer layer smooth, pale yellow, ≅ ⅔ of total wall thickness, inner layer colorless, ≅ ⅓ of total thickness; micropyle and oocyst residuum absent; single polar granule present; sporulated oocysts (n = 15) 25.5 × 25 (21–28 × 20–28) with L:W ratio 1.02 (1.00–1.09); sporocysts broadly ovoid, 14.5 × 10.0 (12–19 × 9–13) with L:W ratio 1.33 (1.20–1.61); Stieda body present; substieda body absent; sporocyst residuum extensive, composed of dispersed granules of various sizes (Fig. 9). Oocysts were 300 days old when measured.

Taxonomic summary

Diagnosis: No isosporans have been named from *Dipodomys* spp. or any other heteromyid rodents. This species closely resembles *I. lacazei* structurally (a common parasite of birds and often seen in transit through the gut of other hosts), except that sporocysts of *I. lacazei* have a substieda body that is absent in the isosporan reported here. We decline to name this form because: (1) only 15 sporulated oocysts were available for study; (2) oocysts were only found in one host animal; and (3) the oocysts were not transmissible (as measured by oocyst discharge) by oral inoculation to *D. ordii* or *D. merriami* under laboratory conditions.

Host: Dipodomys agilis Mearns, kangaroo rat, Museum of Southwestern Biology, Division of Mammalogy, MSB 42876 (female), T. L. Best #8545, 27 June 1980.

Locality: Misión de San Borja, Baja California Norte, Mexico.

Prevalence: Found in one of 54 (1.8%) *D. agilis* collected in Baja California Norte, Mexico.

Site of infection: Unknown. Oocysts recovered from feces.

Hosts

Dipodomys agilis Gambel, 1848. Twenty-four of the 32 (75%) infected rats were singly-infected with either *E. balphae* (4), *E. chobotari* (2), *E.*

scholtysecki (5), *Eimeria* sp. (12), or *Isospora* sp. (1). Five rats had double infections with *E. utahensis* and *Eimeria* sp. (1), *E. scholtysecki* and *Eimeria* sp. (1), *E. balphae* and *Eimeria* sp. (2), or *E. balphae* and *E. utahensis* (1). Three rats had triple infections with *E. balphae, E. scholtysecki,* and *E. utahensis* (1); *E. balphae, E. scholtysecki,* and *Eimeria* sp. (1); or *E. balphae, E. utahensis,* and *Eimeria* sp. (1).

Dipodomys deserti Stephens, 1887. None of 18 rats collected in Sonora, Mexico had coccidian oocysts in their feces at the time they were examined.

Dipodomys gravipes Huey, 1925. The only rat of this species had oocysts of *E. scholtysecki* at the time we examined it.

Dipodomys merriami Mearns, 1890. Thirty-five of the 43 (81%) infected rats were singly-infected with either *E. balphae* (2), *E. chobotari* (17), *E. chihuahuaensis* (3), *E. dipodomysis* (10), *E. merriami* (2), or *Eimeria* sp. (1). Seven rats had double infections with *E. chobotari* and *E. utahensis* (1) or *E. chobotari* and *E. chihuahuaensis* (6). Only one rat had a triple infection with *E. balphae, E. chobotari,* and *E. chihuahuaensis.*

Dipodomys ordii Woodhouse, 1853. All 17 infected rats were singly-infected with either *E. balphae* (11), *E. chobotari* (5), or *E. dipodomysis* (1).

Dipodomys panamintinus (Merriam, 1894). All three infected rats were singly-infected with either *E. scholtysecki* (2) or *Eimeria* sp. (1).

Dipodomys spectabilis Merriam, 1890. All eight infected rats were singly-infected with either *E. balphae* (7) or *E. scholtysecki* (1).

DISCUSSION

The literature on eimerians from kangaroo rats is mostly descriptive with incidental remarks on laboratory infections and patent periods (e.g., Ernst et al., 1967b) and sympatric species with greatly different infection rates (e.g., Ernst et al., 1968). Only Doran (1953) surveyed more than three *Dipodomys* spp. and tried to use cross-infection experiments, host behavior and climatic and ecological factors to help explain the infection patterns he observed in nature. The results in our study combined with the published literature on coccidians of *Dipodomys* spp. show that only 213 of 1,590 specimens (13.4%) of 11 species of *Dipodomys* from Baja California (present study), California (Doran and Jahn, 1952; Doran, 1953; Ernst et al., 1970), Mexico (Levine et al., 1957; present study), New Mexico (present study), Oregon (present study), Texas (Short et al., 1980; present study), and Utah (Ernst et al., 1967a, b, 1968) had oocysts in their feces at the time they were examined. In any host population sampled the prevalence of infection ranged from 0 to 45% although it rarely exceeded 25%. Possible reasons for this low natural incidence of infection include such factors as solitary behavior of the rats and environmental extremes of the deserts they inhabit (Doran, 1953). Even with such factors considered, there is other evidence that infections are long-lived (Ernst et al., 1968) with weak host immunity evident except during massive infections (Doran, 1953). With little host immunity and long patent periods (extended merogony?) we expected a higher prevalence than we actually found in our rats or in our literature survey of rats sampled by others.

We also noted that more than 91% of infected rats harbor only single species infections. Of the 213 infected rats noted above only 18 (< 9%) were infected with more than one coccidian species at the time they were examined. Experimental work by Doran (1953) and the accumulating evidence from this and previous studies (Ernst et al., 1968, 1970; Short et al., 1980) strongly indicate that eimerians originally described from certain *Dipodomys* spp. show little specificity among congeneric hosts. Nonetheless, of the *Dipodomys* spp. sampled for coccidia in this study and all published reports, > 91% harbored only a single species at the time they were examined. This may suggest there is genetic control of, or some selective advantage for, *Dipodomys* spp. harboring only one eimerian species. For example Doran (1953) collected 327 *D. panamintinus* (4 subspecies) and 197 *D. merriami* from various localities in California, but found only 22 of 251 (9%) *D. p. mohavensis* infected with *E. mohavensis.* None of the other three subspecies of *D. panamintinus* were infected, nor were any of the *D. merriami* (found sympatrically with *D. p. mohavensis*) found to be naturally infected, although all other host species could be infected experimentally. In fact, *D. merriami* was found to be more susceptible to infection under laboratory conditions (as judged by number of oocysts discharged) than was the natural host *D. p. mohavensis.* Perhaps some mechanism operates that allows two sympatric species to divide up the microhabitat such that the more resistant species maintains a natural low-level infection while the more susceptible species never comes in contact with the parasite in its natural environment.

ACKNOWLEDGMENTS

This study was supported by NIH Grant 2 S06 RR-08139-07, and by a grant from the Faculty Research Allocation Committee, College of Arts and Sciences, UNM. We are indebted to the following students and faculty in the Department of Biology, The University of New Mexico, for their help in collecting kangaroo rats: J. H. Bandoli, A. S. Christmas, J. A. Cook, M. Dziadulewicz, S. B. George, D. A. Goebel, J. Haydock, S. Limerick, K. McBee, L. D. McCurley, K. E. Peterson, D. W. Reduker, and Drs. T. L. Best, J. Davis, D. J. Hafner, and T. L. Yates. Ms. L. Hertel did the composite line drawings. Dr. T. L. Yates of our Department and Drs. J. R. Bristol and L. F. Mayberry, Department of Biology, University of Texas at El Paso, and Dr. J. V. Ernst, Agricultural Research Service, Auburn, Alabama, provided useful suggestions on the manuscript.

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