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MICE OF THE GENUS PEROMYSCUS IN GUADALUPE MOUNTAINS NATIONAL PARK, TEXAS

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Mice of the genus *Peromyscus* are found in virtually every habitat type in Guadalupe Mountains National Park in West Texas. Because of their abundance and wide distribution, they comprise an important component of the park's ecosystem. The first known specimens of *Peromyscus* from the area now included in the park were collected by Vernon Bailey in 1901 (Bailey, 1905). He collected specimens of *Peromyscus boylii* in Dog and McKittrick canyons. Davis (1940) collected *P.leucopus* at Frijole in 1938 and *P. boylii* in The Bowl in 1938 and 1939. Davis and Robertson (1944) reported collecting *P. pectoralis* from along Bell Creek in 1938. A previously unreported specimen of *P. difficilis* collected in 1901 by Vernon Bailey in McKittrick Canyon was recently reported by Diersing and Hoffmeister (1974).

During a survey of mammals of Guadalupe Mountains National Park conducted from June 1973 to August 1975, specimens of seven species of *Peromyscus* were obtained. In addition to the four previously reported species, specimens of *P. eremicus, P. maniculatus,* and *P. truei* were collected. We are not aware of any other place where seven species of *Peromyscus* occur in such a small area.

Genoways *et al.* (1979) presented general distributional, ecological, and faunal information for all mammals occurring in Guadalupe Mountains National Park. In the present report the use of morphometrics and karyology as methods of identification of deer mice in the park are discussed, and the distribution and ecology of deer mice are described in greater detail than they were in Genoways *et al.* (1979).

Methods and Materials

From 1973 through 1975, selected sites were visited throughout the Park. Mice were collected during all seasons using folding aluminum Sherman live traps and Museum Special kill traps. All individuals collected were prepared as standard museum specimens and deposited, along with field notes, in The Museum, Texas Tech University (TTU). Additional specimens deposited in the Texas Cooperative Wildlife Collection (TCWC) at Texas A&M University and the National Museum of Natural History (USNM) in Washington, D.C., were examined.

Five external measurements (total length, tail length, body length, hind foot length, and ear length) were recorded from skin labels. Eight cranial measurements as detailed below were taken to the nearest 0.10 millimeter with dial calipers:

Skull length.—The greatest length of the skull as measured between two vertical planes, one just touching the tips of the nasals, the other marking the posterior limits of the skull.

Length of rostrum.—The distance in a straight line from the shallow notch that lies lateral to the lacrimal bone (on the superior orbital border of the zygomatic arch), anteromedially to the tip of the nasal on the same side of the skull.

Interorbital breadth.—The least diameter of the frontal bones between the orbital fossae.

Mastoid breadth.—The greatest width of the skull across the mastoid processes.

Skull depth.—The distance from the dorsal limits of the braincase to a horizontal plane passing through the incisor tips and the ventral borders of the auditory bullae (taken using a glass microscope slide as described by Hooper, 1957).

Length of bony palate.—The least length of the hard palate between the mesopterygoid fossa and the incisive foramina.

Length of incisive foramen.—The greatest length of one (the right if possible) of the incisive foramina.

Length of molar toothrow.—The greatest length of the alveolar space of the upper molar row.

Mice were assigned to one of six age categories on the basis of the degree of molar wear and pelage development as follows: *Group I*, third upper molar (M3) not completely erupted (does not reach the height of first and second upper molars), juvenile pelage; *Group II,* M3 at full height in toothrow, little or no wear on any check teeth, juvenile pelage; *Group III,* M1 and M3 partially worn, skin in juvenile pelage or molting into subadult pelage; *Group IV,* all major cusps worn smooth, but the cusp pattern still identifiable, adult pelage; *Group V,* heavy wear on all upper molars, many cusps obliterated by wear, adult pelage; *Group VI,* extreme wear on all upper molars, all cusps obliterated, adult pelage.

Mice of age groups I and VI were not represented in the sample. The following standard statistics were calculated for each species and age group for all external and cranial measurements: mean, standard deviation, standard error of the mean, range, and coefficient of variation. A two-way analysis of variance was used to test for differences between sexes, among age groups, and the interaction between age and sex for each species except *P. truei* (the sample size of which was too small for statistical evaluation). Results from this analysis indicated the following for each species: there were no significant differences between the sexes, although males tended to be slightly larger than females; there were distinct age differences; and there existed a significant ($P<0.05$) interaction between age and sex. In order to investigate the source of this interaction, a one-way analysis of variance was performed to determine the differences across age groups within each sex for each species. As expected, both sexes of each species demonstrated a high level of significance across ages. Duncan's Multiple Range Test, used to determine which of the age groups gave rise to these differences, indicated that in both males and females of each species there was a general tendency in most characters for the younger age groups (II, III) to separate from the older age groups (IV, V). Thereafter, for purposes of statistical comparisons among species, age groups II and III were lumped together to form a subadult age category, and age groups IV and V were lumped to form an adult category. Additionally, inasmuch as males and females were not found to be significantly different, they were lumped together in each of the above categories for each species.

Structural details of four teeth, the opposing upper and lower first and second molars on the right side, were observed and coded for each species according to the scheme proposed by Hooper (1957). Primary attention was given to the lophs (lophids) and styles (stylids) that are situated in enamel valleys between the principal cusps. According to Hooper (1957), these are the structures most responsible for the complexities in dental topography in *Peromyscus*. When these structures are present and fully developed, the tooth is "complex" and elaborate in pattern; when they are lacking, the dental pattern is "simple."

The penis was removed from selected standard museum specimens of each species, cleared, stained, and preserved, following the technique outlined by Lidicker (1968).

Each species was compared with respect to several qualitative features of the pelage, skull, and phallus. These characters and their character states are discussed and illustrated beyond.

Karyotypes of selected individuals were examined by means of a bone marrow technique (Baker, 1970; Patton, 1967). A minimum of 10 metaphase cells was counted to determine the diploid number of each individual. The number of arms of the autosomal complement (FN) was determined for each specimen. Chromosomes were described according to the system proposed by Patton (1967).

Description of Guadalupe Mountains National Park

Guadalupe Mountains National Park is one of the newest National Parks in the United States. It was proposed as early as 1932 (Wright *et al.*, 1933) that Carlsbad Caverns National Park be extended southward to include part of the southern Guadalupe Mountains that extend into Texas. It was not until 1966, however, that Guadalupe Mountains National Park was authorized by Congress; on 30 September 1972, the park was established.

The park includes 30,946 hectares in Culberson and Hudspeth counties of the Trans-Pecos, Texas. The rugged Guadalupe Mountains extend from southeastern New Mexico southward approximately 13.7 kilometers into Texas, terminating abruptly in the spectacular cliff faces of 2462-meter El Capitan. North of El Capitan, several peaks rise to elevations above 2438 meters including Guadalupe Peak, the highest point in Texas at 2667 meters. The 1219-meter section of uplifted Permian marine limestone known as the Capitan Reef is the major geological feature of the park and the largest known fossil reef (Matthews, 1973).

Elevations within the park range from 1112 to 2438 meters. The lower elevations are characterized by floral and faunal elements of the Chihuahuan Desert, whereas the higher elevations contain montane elements. A complex suite of interacting factors, including the wide variation of elevation, a variety of soil types, and the rugged dissected topography, has resulted in a unique and diverse community of plants and animals. This community is a mixture

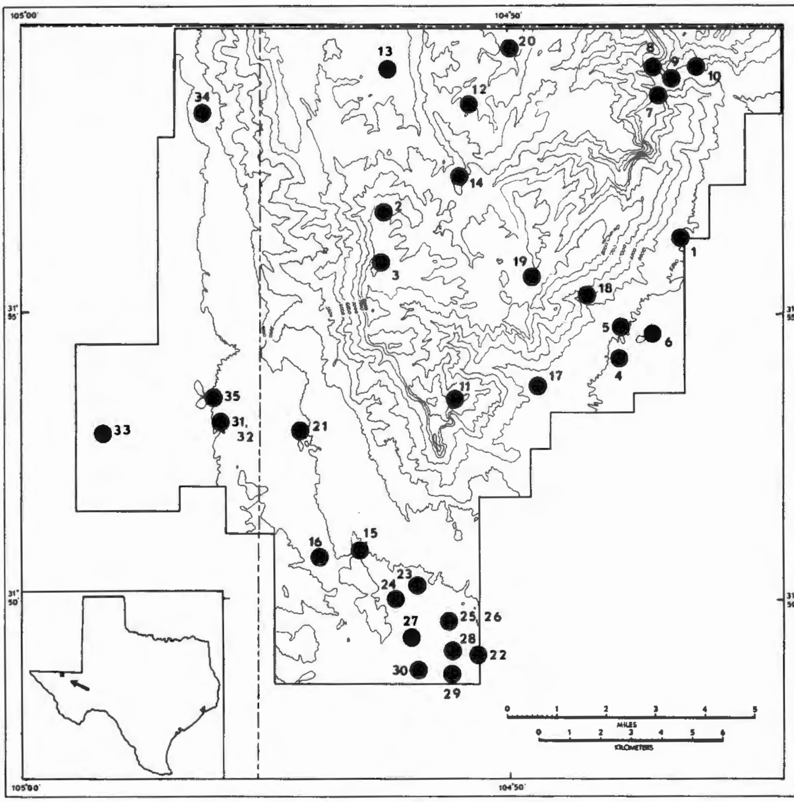

FIG. 1.—Map depicting localities where specimens of *Peromyscus* were captured. See text for key to numbers.

of desert, grassland, riparian woodland, montane, and widespread species.

Listed below are localities from which specimens of *Peromyscus* were collected in Guadalupe Mountains National Park. Localities are numbered to correspond to those shown in Fig. 1. Following each locality is a brief description of the habitat; localities with very similar vegetation and topography are described together. Fig. 2 illustrates the four major habitat types found in the park.

Culberson County

1) *Bell Creek, 7 mi. N Pine Springs* (1615 m.).—The vegetation along Bell Creek is riparian woodland, with succulent desert vegetation on the slopes and mixed-grassland on the rolling hills nearby.

2) *Blue Ridge Campsite* (2438 m.).—Blue Ridge Campsite is situated at the confluence of two trails at the north end of Blue Ridge, which extends due north of

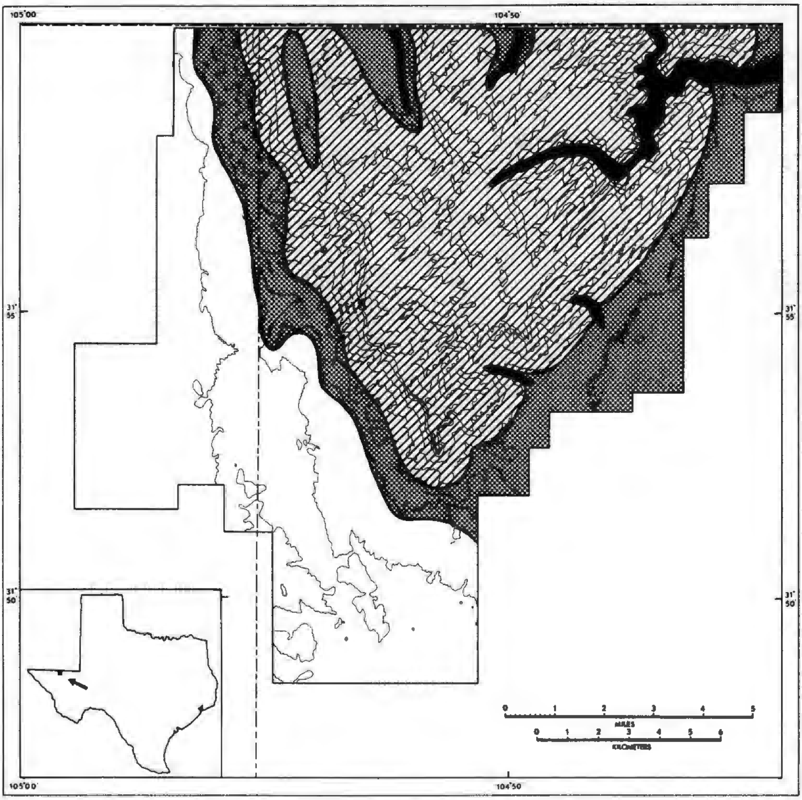

FIG. 2.—Map depicting the four major habitat types found in Guadalupe Mountains National Park: open area, desert; stippled, grassland; lined, montane; solid, riparian woodland.

Bush Mountain. The vegetation is open woodland including *Pinus ponderosa, Quercus gambelii, Pseudotsuga menziesii, Juniperus deppeana, Bouteloua gracilis, Muhlenbergia pauciflora,* and *M. dubia.*

3) *Bush Mountain* (2530 m.).—Bush Mountain, one of the tallest peaks in the park, forms part of the western ridge of the Guadalupe Mountains. Trapping was conducted in a pine-oak grassland association immediately southeast of the summit. Plants included *Pinus ponderosa, Quercus gambelii, Pseudotsuga menziesii, Juniperus deppeana, Ceanothus greggii, Cercocarpus montanus, Bouteloua gracilis, Muhlenbergia pauciflora, M. dubia,* and *Hymenoxys richardsonii.*

4) *Frijole Ranger Station* (1692 m.); 5) *Manzanita Spring* (1676 m.); 6) *Nipple Hill* (1646 m.).—Frijole, Manzanita Spring, and Nipple Hill are on the bajada east of the Guadalupe Escarpment. The vegetation at these places is open juniper woodland and grassland including *Juniperus pinchotii, Muhlenbergia setifolia, Bouteloua gracilis, B. warnockii,* and *Parthenium incanum.* Manzanita Spring is a permanent pool of water spring fed from below. Nipple Hill is a cone-shaped rock formation arising from the bajada.

7) *½ mi. NNE Grisham-Hunter Lodge* (1615 m.); **8)** *North McKittrick Canyon at Devil's Den Canyon* (1585 m.); **9)** *Pratt Lodge* (1585 m.); **10)** *0.3 mi. N, 0.5 mi. E Pratt Lodge* (1570 m.).—An intermittent stream in McKittrick Canyon is the only permanent stream in Guadalupe Mountains National Park. The vegetation of the canyon walls is succulent desert, whereas the canyon floor is riparian woodland. Plants include *Acer grandidentatum, Quercus muhlenbergii, Arbutus xalapensis, Pinus ponderosa, Stipa tenuissima, Muhlenbergia emersleyi, Quercus undulata, Juniperus deppeana,* and *Dasylirion leiophyllum.*

11) *Guadalupe Peak Campsite* (2439 m.).—Guadalupe Peak Campsite is situated on top of the eastern edge of the Guadalupe Escarpment due east of Guadalupe Peak. The vegetation is open coniferous woodland dominated by *Pinus ponderosa* and *Muhlenbergia pauciflora.*

12) *Lost Peak Mine* (2164 m.).—Lost Peak Mine is an abandoned copper mine between Dog Canyon Ranger Station and Lost Peak. The vegetation is chaparral and succulent desert including *Ceanothus greggii, Cercocarpus montanus, Nolina micrantha, Dasylirion leiophyllum,* and *Quercus undulata.*

13) *Marcus Cabin, West Dog Canyon, 6⅜ mi. N, ¾ mi. W Guadalupe Peak* (1905 m.).—West Dog Canyon is a relatively large canyon that extends southward into the park from New Mexico. A steep wall marks the east side of the canyon, while the west side is formed by a more gradual slope. Deep soil on the canyon floor is cut by a system of dry washes. The vegetation is mixed grassland with riparian shrubs along the washes. Plants include *Muhlenbergia repens, Bouteloua gracilis, B. warnockii, Aristida glauca, Berberis haematocarpa, Fallugia paradoxa, Opuntia imbricata, Xanthocephalum sarothrae, Xanthium spinosum, Verbesina encelioides,* and *Pinus edulis.*

14) *Mescalero Campsite, 4½ mi. N, ¾ mi. E Guadalupe Peak* (2286 m.).—Mescalero Campsite is situated on top of a ridge separating West Dog Canyon watersheds from South McKittrick Canyon watersheds. The campsite is on the trail between Dog Canyon Ranger Station and The Bowl. The woodland vegetation includes *Pinus edulis, P. ponderosa, Quercus undulata, Juniperus deppeana, Nolina micrantha, Ceanothus greggii, Rosa stellata,* and *Muhlenbergia dubia.*

15) *Patterson Hills Notch, 3 1/16 mi. S, 1⅜ mi. W Guadalupe Peak* (1356 m.); **16)** *3¼ mi. S, 2⅜ mi. W Guadalupe Peak* (1341 m.).—A notch has been cut through the eastern ridge of the Patterson Hills near Williams Ranch Road by water erosion. The vegetation on the Patterson Hills is succulent desert, the dry wash in the notch supports riparian vegetation, and the vegetation on the surrounding bajada is desert scrub. Species include *Larrea tridentata, Chilopsis linearis, Fallugia paradoxa, Prosopis glandulosa, Acacia neovernicosa, Brickellia laciniata, Yucca torreyi, Agave lecheguilla, Parthenium incanum,* and *Viguiera stenoloba.*

17) *Pine Springs Canyon* (1768 m.).—Pine Springs Canyon cuts deeply into the eastern side of the Guadalupe Mountains. Canyon floor vegetation is open riparian woodland with succulent desert plants on the slopes. Plant species include *Arbutus xalapensis, Juniperus deppeana, Quercus grisea, Bouteloua curtipendula, B. gracilis,* and *Dasylirion leiophyllum.*

18) *Smith Canyon* (1829 m.).—Approximately one-third of the way up Smith Canyon lies Smith Spring. The vegetation is riparian woodland becoming more open toward the canyon mouth. Plants include *Juniperus deppeana, Quercus grisea, Bothriochloa* sp., *Bouteloua gracilis, Lycurus phleoides,* and *Panicum obtusum.*

19) *The Bowl* (2377 m.).—The Bowl is relict coniferous forest interspersed with hardwoods. In many areas young trees are growing in very dense stands. A manmade earthen tank intermittently contains water. Plants include *Pinus ponderosa, P. strobiformis, Pseudotsuga menziesii, Quercus gambelii, Muhlenbergia emersleyi, M. pauciflora,* and *Agropyron smithii.*

20) *Dog Canyon Ranger Station* (1920 m.).—The ranger station is located on the floor of Upper Dog Canyon just north of a point where the canyon narrows considerably. The deep soil of the canyon floor supports open woodland and mixed grass meadows. The vegetation of the dry washes in the canyon is riparian woodland, whereas open slopes support chaparral and succulent desert vegetation. Riparian woodland includes *Quercus muhlenbergii, Acer grandidentatum, Arbutus xalapensis, Cercocarpus montanus, Quercus undulata, Ceanothus greggii,* and *Dasylirion leiophyllum.* Open slopes include *Quercus grisea, Cercocarpus montanus, Nolina micrantha, Agave neomexicana, Ceanothus greggii, Dasylirion leiophyllum,* and *Juniperus deppeana.* Grasses on the canyon floor include *Stipa tenuissima, Muhlenbergia repens, Panicum obtusum,* and *Bouteloua gracilis.*

21) *$\frac{1}{2}$ mi. S, 2 $\frac{5}{8}$ mi. W Guadalupe Peak* (1356 m.).—This location is between Williams Ranch and the Patterson Hills near the road that extends due west from the ranch house. The bajada vegetation is desert scrub whereas the slopes are characterized by succulent desert vegetation. Desert scrub includes *Larrea tridentata, Prosopis glandulosa, Opuntia lindheimeri, Sporobolus contractus, Setaria leucopila, Muhlenbergia porteri, Bouteloua gracilis,* and *B. eriopoda.* Succulent desert forms include *Agave lecheguilla, Dasylirion leiophyllum, Parthenium incanum,* and *Bouteloua eriopoda.*

22) *Williams Ranch Road Entrance, $4\frac{3}{4}$ mi. S, $\frac{7}{8}$ mi. E Guadalupe Peak* (1311 m.); **23)** *4 mi. S, $\frac{1}{2}$ mi. W Guadalupe Peak* (1341 m.); **24)** *$4\frac{1}{4}$ mi. S, 1 mi. W Guadalupe Peak* (1387 m.); **25)** *4.3 mi. S Guadalupe Peak* (1349 m.); **26)** *$4\frac{5}{16}$ mi. S Guadalupe Peak* (1349 m.); **27)** *$4\frac{3}{8}$ mi. S, $\frac{1}{2}$ mi. W Guadalupe Peak* (1356 m.); **28)** *$4\frac{7}{8}$ mi. S, $\frac{1}{8}$ mi. E Guadalupe Peak* (1326 m.); **29)** *$5\frac{1}{8}$ mi. S Guadalupe Peak* (1311 m.); **30)** *$5\frac{3}{8}$ mi. S, $\frac{1}{2}$ mi. W Guadalupe Peak* (1288 m.).—Williams Ranch Road enters the park near the southeastern corner. This area is bajada with patches of sand and rock outcrops. The vegetation is desert scrub including *Larrea tridentata, Prosopis glandulosa, Xanthocephalum sarothrae, Sporobolus contractus,* and *Bouteloua eriopoda.*

Hudspeth County

31) *Crossroads, $\frac{9}{16}$ mi. S, $4\frac{5}{16}$ mi. W Guadalupe Peak* (1219 m.); **32)** *$\frac{3}{8}$ mi. S, $4\frac{11}{16}$ mi. W Guadalupe Peak* (1234 m.).—The Crossroads is the area surrounding the junction of primitive roads due west of Williams Ranch House and immediately north of the central ridge of the Patterson Hills. This area is bajada cut by dry washes. The bajada vegetation is desert scrub with succulents and riparian vegetation in the washes. Plants include *Larrea tridentata, Prosopis glandulosa, Fallugia paradoxa, Atriplex canescens, Opuntia lindheimeri, O. leptocaulis, O. imbricata,* and *Chilopsis linearis.*

33) *Lewis Well, $\frac{11}{16}$ mi. S, $6\frac{5}{8}$ mi. W Guadalupe Peak* (1128 m.).—Lewis Well is a dry water well marked by a windmill tower on the bajada near the western boundary of the park. West of the well is a large white gypsum sand dune, patches of crusted gypsum soil, and an area of lacustrine clay. Each of these areas supports distinct plant communities. The bajada near the well is dominated by *Larrea tridentata* and *Prosopis glandulosa.* Lacustrine clay is dominated by *Atriplex canes-*

cens; crusted gypsum soil by *Coldenia hispidissima.* The most common plant on the gypsum sand dune is *Bouteloua breviseta.*

34) *Northwest Corner, 4 mi. N, 5½ mi. W Guadalupe Peak* (1158 m.).—The bajada in the Northwest Corner of the park has been subjected to far less grazing pressure than any other area of the park to the west and south of the mountains. This area may be an example of the potential natural vegetation of the creosote dominated bajada areas of the park. The vegetation is mixed grassland and succulents including *Bouteloua eriopoda, Sporobolus cryptandrus, Tridens muticus, Aristida pansa, Krameria glandulosa, Erioneuron pulchellum, Dyssodia pentachaeta, Viguiera stenoloba, Yucca torreyi, Prosopis glandulosa, Larrea tridentata, Opuntia lindheimeri, O. phaeacantha, O. imbricata, O. schottii, O. violacea, O. leptocaulis,* and *Fouquieria splendens.*

35) *Stage Coach Hills, 9/16 mi. S, 4 15/16 mi. W Guadalupe Peak* (1219 m.).—The Stage Coach Hills are a pair of small hills north and slightly east of the central ridge of the Patterson Hills. The vegetation of the slopes of the hills is succulent desert, whereas that of the surrounding bajada is desert scrub. Plants include *Coldenia hispidissima, C. greggii, Larrea tridentata, Agave lecheguilla, Jatropha dioica, Opuntia lindheimeri, O. phaeacantha, Viguiera stenoloba, Sporobolus cryptandrus, Bouteloua eriopoda, Muhlenbergia porteri, Hybiscus denudatus, Fouquieria splendens,* and *Selaginella wrightii.*

Identification

The identification of the species of *Peromyscus* is sufficiently difficult that misidentification is more often the rule than the exception, especially among amateurs or "untrained" professionals. Only two keys (Osgood, 1909; Hall and Kelson, 1959) are available that include all species in the genus. The degree of geographic variation within many species is such that the characters used in these keys are not useful for species recognition in all geographic areas. Furthermore, in many instances, single characters used in dichotomous keys are not sufficient for identifying species; instead, reliable identifications are normally achieved by using a combination of several morphological features including quantitative and qualitative characters. The best way to ensure proper identification is to preserve voucher specimens that include, if possible, the following items: skin with external measurements, skull with teeth, penis, and karyotype. Most species are sufficiently distinct in certain of these features that accurate identification is possible.

It is important to note how valuable the karyotype was in identifying mice of this taxonomically complex genus. Based on standard karyotypes all species could be discriminated by the number of arms in the autosomal complement with the exception of *P. pectoralis* and *P. difficilis.* G-bands reveal, however, that even these two species are karyotypically distinct (Robbins and

Baker, 1981). The G-bands of a total of 18 species were examined by these authors and all were karyotypically unique. Clearly in cases where it is important to identify a few individuals of *Peromyscus* as a reference series, the karyotype holds the greatest promise for providing accurate specific identification.

To identify properly the species of *Peromyscus* inhabiting Guadalupe Mountains National Park, we found it necessary to study a large series of specimens collected in the park itself as well as series of specimens of known identity from adjacent geographic regions. The purpose of this section is to establish a set of morphological criteria whereby all species of *Peromyscus* occurring in Guadalupe Mountains National Park can be identified. Such a document should be of considerable value to scientists conducting future ecological and systematic studies of *Peromyscus* in the park in which proper identification is essential to the accuracy of the work.

One of us (Schmidly) examined each specimen of *Peromyscus* collected in Guadalupe Mountains National Park during this study and determined that seven species of *Peromyscus* occur in the park. He then assigned each specimen to one of those seven species. Schmidly's identifications were based on his familiarity with the genus *Peromyscus*, particularly in west Texas. Most adult specimens could be identified to species without difficulty by using the dichotomous key provided below. However, for a few individual specimens, assignments using the key were considered tentative. In order to clarify the identity of those specimens, as well as to verify the identity of all other individuals, a series of qualitative features and quantitative measurements of the external pelage, skull, teeth, and phallus were recorded for each specimen. Additionally, individuals of each species were karyotyped. The seven species of *Peromyscus* occurring within Guadalupe Mountains National Park were then compared with respect to all features. In using quantitative measurements of the skin and skull, it is important to stress the value of precise age control. In comparing species, only specimens of a similar age class should be compared. Many errors of identification result when adults of one species are compared to subadults of another.

KEY TO THE SPECIES OF *PEROMYSCUS* IN GUADALUPE MOUNTAINS NATIONAL PARK

1. Nasals decidedly exceeded by premaxillae; two principal outer angles of first and second upper molars simple, without (or at most with rudimentary) acces-

sory cusps or enamel lophs; soles of hind foot naked to end of calcaneum (occasionally naked in narrow area or covered medially by ends of lateral rooted hairs on tarsus between ends of metatarsals and end of calcaneum); no pectoral mammae; inguinal mammae, 2-2; no acrocentric chromosomes . . . . *Peromyscus eremicus*

Nasal slightly or not at all exceeded by premaxillae; two principal outer angles of first and second upper molars with well-developed accessory tubercles or enamel lophs; sole of hind foot hairy on proximal fourth to calcaneum; pectoral mammae, 1-1; inguinal mammae, 2-2; acrocentric chromosomes present 2

2. Tail much shorter than head and body; tail terete, that is, with no conspicuously elongate terminal hairs; number of acrocentric chromosomes less than 20 3

   Tail as long as or longer than head and body; tail tufted, with terminal hairs that are conspicuously longer than others; number of acrocentric chromosomes more than 30 4

3. Total length of adults usually more than 170 mm.; length of tail usually more than 75 mm.; greatest length of skull usually more than 26 mm.; tail not sharply bicolored; number of acrocentric autosomes greater than 14 . . . . *Peromyscus leucopus*

   Total length of adults usually less than 170 mm.; length of tail usually less than 75 mm.; greatest length of skull usually less than 26 mm.; tail sharply and evenly bicolored; number of acrocentric autosomes less than 14 . . . . *Peromyscus maniculatus*

4. Ear longer than hind foot; tail about as long as head and body; bullae unusually inflated; six pairs of small biarmed elements present in karyotype . . . . *Peromyscus truei*

   Ear equal to or shorter than hind foot; tail usually longer than head and body; bullae moderately or less inflated; only four pairs of small biarmed elements present 5

5. Flanks of adults predominantly grayish in color; total length of adults usually greater than 210 mm.; greatest length of skull (in adults) usually greater than 28 mm.; mastoid breadth usually greater than 12 mm.; bullae moderately inflated . . . . *Peromyscus difficilis.*

   Flanks of adults predominantly bright yellowish brown; total length of adults usually less than 210 mm.; greatest length of skull (in adults) usually less than 28 mm.; mastoid breadth usually less than 12 mm.; bullae slightly inflated 6

6. Tarsal joints of ankles white like upper side of hind foot; posterior ends of the nasal bones truncate; baculum with long cartilaginous spine at its terminal end; 8 large biarmed autosomes . . . . *Peromyscus pectoralis*

   Dusky color of hind leg extending to and more or less over tarsal joint; posterior ends of the nasal bones tapered in a V-shaped pattern; baculum with a short cartilaginous spine at its terminal end; 2 large biarmed autosomes . . . . *Peromyscus boylii*

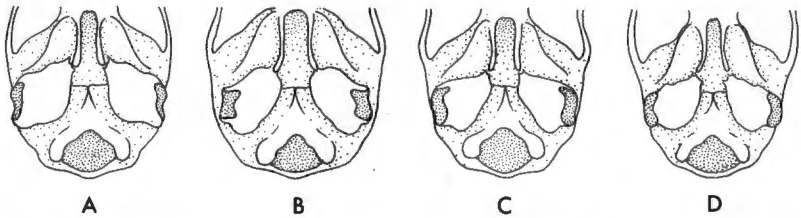

FIG. 3.—Posteroventral view of skull showing degree of inflation of auditory bulla in *Peromyscus* from Guadalupe Mountains National Park. A, greatly inflated as in *P. truei*; B, moderately inflated as in *P. difficilis*; C, slightly inflated as in *P. boylii* and *P. pectoralis* (figured); D, less inflated as in *P. maniculatus* (figured), *P. leucpus*, and *P. eremicus*.

COMPARISONS

The species of *Peromyscus* from Guadalupe Mountains National Park can conveniently be broken into two groups on the basis of the length of the tail in relation to the length of the body. In one group (hereafter referred to as the short-tailed group including *P. leucopus*, *P. maniculatus*, and *P. truei*) the tail is either equal to or shorter than the length of the body. In the other group (hereafter referred to as the long-tailed group including *P. eremicus*, *P. pectoralis*, *P. boylii*, and *P. difficilis*) the tail is always longer than the length of the body. Of the short-tailed species, *truei* can be easily distinguished from *maniculatus* and *leucopus* by size of the auditory bullae and length of the ear. In *truei*, the auditory bullae are actually and relatively larger than the bullae in *leucopus* and *maniculatus* (Fig. 3). The length of the ear in *truei* is nearly always greater than 23 millimeters, whereas this measurement is always less than 22 in *leucopus* and *maniculatus*. The latter two species are more difficult to identify and features which distinguish them will be discussed in detail below.

Species of the long-tailed group, with the exception of *P. eremicus*, are more difficult to distinguish from one another than are the members of the short-tailed group. *P. eremicus* is easily distinguished from *pectoralis*, *boylii*, and *difficilis* by using features of the skull, dentition, and penis (Fig. 4). The posterior exten-

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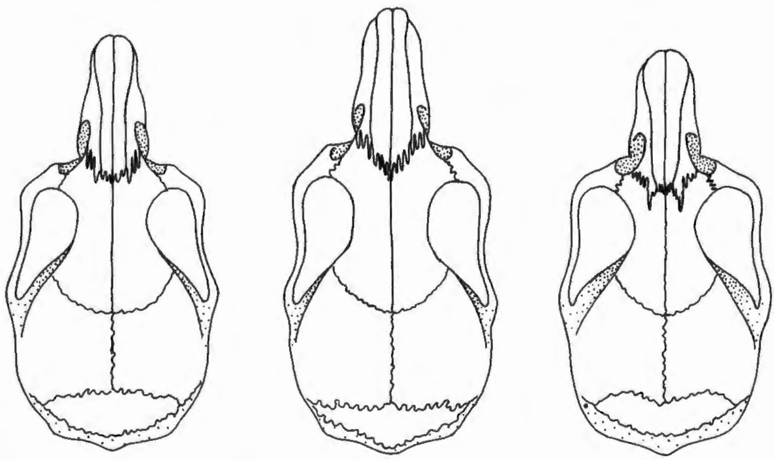
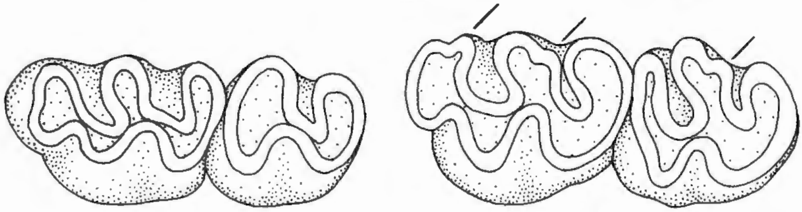
FIG. 4.—Qualitative differences in skull, teeth, and penis among *P. eremicus* and other long-tailed species of *Peromyscus*. **Top.** Position of nasals: A, *pectoralis*; B, *boylii*; C, *eremicus*. **Middle.** Lateral view of teeth (M1 and M2) illustrating molar complexity: A, *eremicus*; B, *difficilis*. **Bottom.** Lateral and dorsal view of the penis showing degree of development of protrusible tip on glans: A, *difficilis*; B, *eremicus*. See text for discussion of character states of each feature.



A B C



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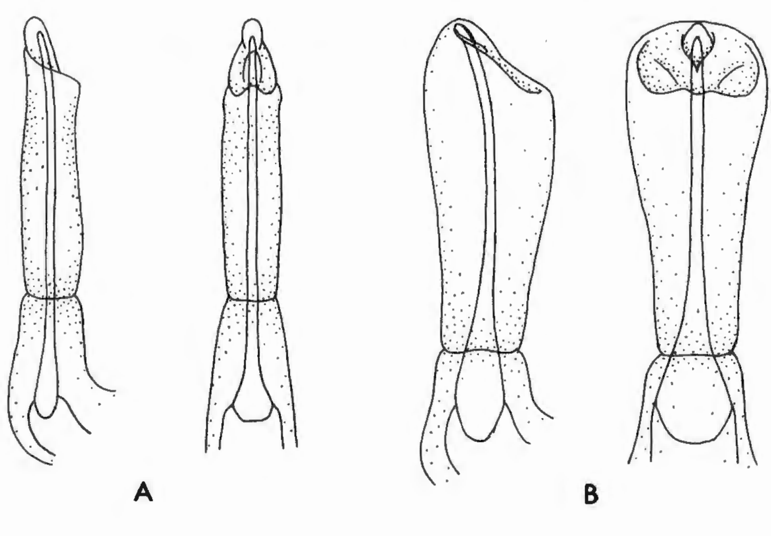

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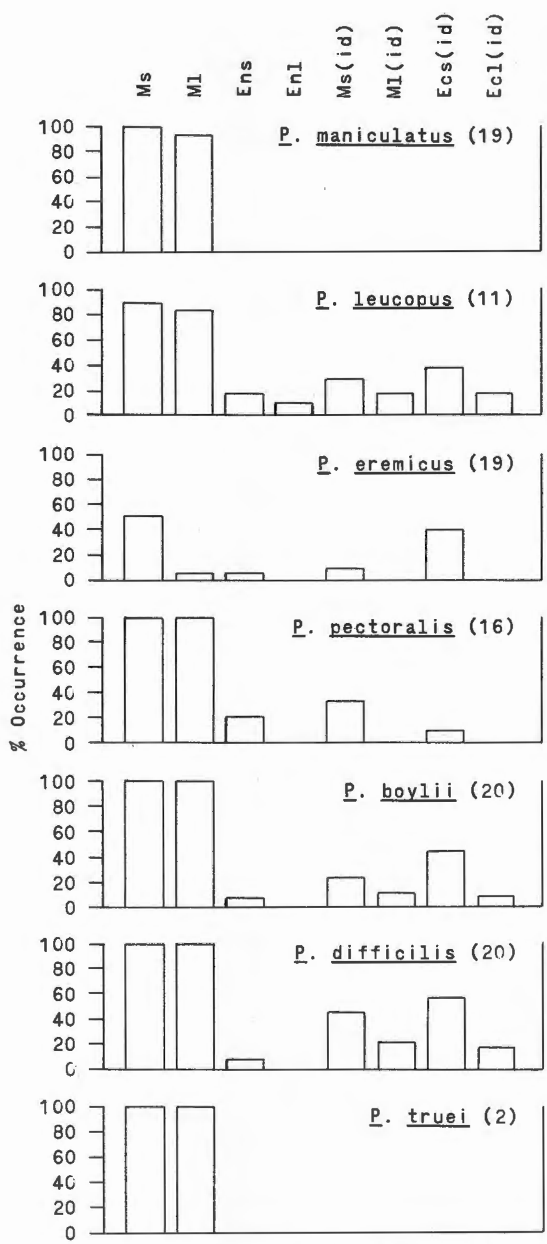

FIG. 5.—Frequencies of styles (stylids) and lophs (lophids) among seven species of *Peromyscus* from Guadalupe Mountains National Park (sample sizes are in parentheses): Ms, mesostyle; Ml, mesoloph; Ens, entostyle; Enl, entoloph; Ms(id), mesostylid; Ml(id), mesolophid; Ecs(id), ectostylid; Ecl (ectolophid).

TABLE 1.—*Numbers and morphology of chromosomes of* Peromyscus *from Guadalupe Mountains National Park based on specimens from the park and the literature (Hsu and Arrighi, 1968).*

Species	Specimens examined	2n	Autosomes Biarmed	Autosomes Acrocentric	X[a]	Y	FN[b]	Figure
P. eremicus	2	48	46	0	M	ST	92	6A
P. maniculatus	3	48	38	8	SM	M	84	6B
P. leucopus	4	48	22	24	SM	SM	68	6C
P. boylii	5	48	6	40	ST	M	52	7A
P. pectoralis	3	48	12	34	ST	M	58	7B
P. truei	1	48	16	30	ST	A	62	7C
P. difficilis	5	48	12	34	ST	SM	58	8

[a]M = metacentric; SM = submetacentric; ST = subtelocentric; A = acrocentric.
[b]FN = total number of autosomal arms.

sions of the premaxillae extend far beyond the posterior ends of the nasal bones in *eremicus,* whereas in the other species they are either truncate with or only barely exceed the nasals. The dentition of *eremicus* is simple and the two principal outer angles of M1 and M2 lack (or at most have rudimentary) accessory cusps or enamel loops; other species of the long-tailed group have complex dentition with more or less well-developed accessory tubercles or enamel loops on the two principal outer angles of M1 and M2 (Fig. 5). Pectoral mammae are absent in *eremicus* but present in the other species. The structure of the male phallus is also markedly different between *eremicus* and the other species. In *eremicus,* the glans is vase-shaped, broad with respect to length, and strongly flared distally; in the other species, the glans is an elongate rod-shaped structure, which is topographically split into two parts: 1) a main body of comparatively dense tissues and 2) a tapered, protractile tip. The karyotype of *eremicus* is distinct in that all of the autosomes (46) are biarmed (Fig. 6A), whereas the other long-tailed species possess 16 or fewer biarmed autosomes (Table 1).

Although P. *eremicus* and *P. truei* can be distinguished easily from the other five species of *Peromyscus* in Guadalupe Mountains National Park, there are three combinations of species that are particularly difficult to separate; these are discussed below in detail.

leucopus compared with *maniculatus*

Although slight color differences are apparent between adults of these two short-tailed species, proper identification requires care-

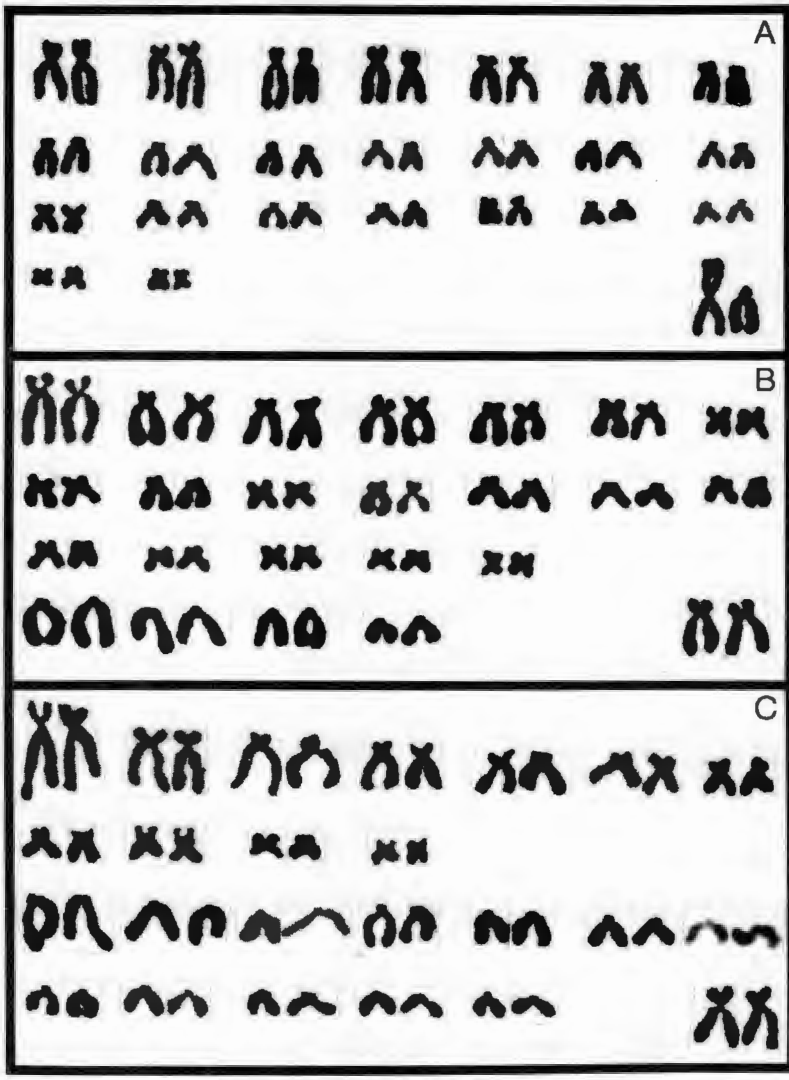

FIG. 6.—Representative karyotypes of: A, male *Peromyscus eremicus*; B, female *P. maniculatus*; C, female *P. leucopus*.

ful examination of external and cranial measurements. *P. maniculatus* is much more richly colored (brownish or tawny), whereas *P. leucopus* is usually more pinkish-buff or grayish with scattered dark hairs. Some of the conspicuous external and cranial differences between the two are described below.

Among subadults (Table 2), *leucopus* has significantly greater total length and tail length, longer skull, longer rostrum, wider interorbital constriction, wider mastoid breadth, deeper skull, longer bony palate, and longer toothrow.

In adult mice (Table 3), *leucopus* has significantly greater total length and tail length, greater length of skull, wider mastoid breadth, and deeper skull. The zygomata of *maniculatus* tend to be parallel to each other, whereas those of *leucopus* are more laterally bowed; the sides of the rostrum differ in the same way.

Some dental differences are apparent between these two species but these are not diagnostic in and of themselves (Fig. 5). In *P. maniculatus*, the upper teeth almost always have a mesostyle and mesoloph, but they never have an entostyle or entoloph; the lower molars are usually simple and lack accessory cusps or enamel loops. In *P. leucopus*, the lower molars are more complex and the incidence of structures such as the mesostylid, mesolophid, and ectolophid is greater than in *maniculatus*. The upper molars of *leucopus* are complex and similar in structure to those of *maniculatus*, except that the frequency of specimens with an entostyle and entoloph is greater.

Based on karyotypic differences, *P. maniculatus* (with 14 or fewer acrocentric elements, Fig. 6B) from Guadalupe Mountains National Park are easily distinguished from *P. leucopus* (24 acrocentric or near acrocentric pairs, Fig. 6C). It should be noted that *maniculatus* has a highly variable karyotype with up to 19 acrocentric elements (Bowers *et al.*, 1973) in some parts of its geographic range, but *maniculatus* never has 24 acrocentrics as found in *leucopus*.

boylii compared with *difficilis*

These are the two species of *Peromyscus* most difficult to distinguish from one another in Guadalupe Mountains National Park. Adult specimens of the two are probably best distinguished by subtle color differences along the flanks. The flanks of adult *boylii* are bright yellow brown, whereas in adult *difficilis* they are predominantly grayish. These color differences, however, are not as reliable in distinguishing subadult and juvenile specimens. Generally, *boylii* is smaller in external and cranial measurements than is *difficilis*. Some of the most conspicuous external and cranial differences are described below.

Subadults (Table 2) of *P. boylii* differ from those of *P. difficilis* externally in having consistently shorter hind feet; cranially, in

TABLE 2.—*Means (first row), 95 per cent confidence limits (second row), and extremes (third row) for external and cranial measurements of subadult specimens of seven species of* Peromyscus.

Species and Sample Size	Total length	Tail length	Body length	Hind foot length	Ear length	Skull length	Length of rostrum	Inter-orbital breadth	Mastoid breadth	Skull depth	Length of bony palate	Length of incisive foramen	Length of molar toothrow
	168.82	77.00	91.82	21.09	17.18	26.60	10.29	4.18	11.30	9.57	4.22	5.15	3.90
P. leucopus (11)	163.86-173.78	73.28-80.72	88.45-95.19	20.18-22.00	15.98-18.38	26.19-27.01	10.09-10.49	4.07-4.29	11.13-11.47	9.44-9.70	4.06-4.38	4.99-5.31	3.78-4.02
	155-181	68-90	84-103	18-22	14-20	25.55-27.55	9.65-10.85	3.90-4.45	10.75-11.65	9.30-9.95	3.80-4.70	4.75-5.65	3.55-4.25
	151.49	64.86	86.62	20.11	16.27	24.50	9.61	3.91	10.61	9.09	3.70	5.40	3.67
P. maniculatus (37)	148.03-154.95	62.81-66.91	84.49-88.75	19.79-20.43	15.81-16.73	24.24-24.76	9.45-9.77	3.84-3.98	10.53-10.69	8.99-9.19	3.64-3.76	5.29-5.51	3.62-3.72
	132-171	60-74	83-101	15-22	15-21	23.00-25.70	8.65-10.80	3.45-4.30	10.25-11.15	8.35-9.75	3.25-4.25	4.45-5.90	3.35-4.00
	182.07	92.90	89.17	20.52	17.07	25.31	9.32	4.06	11.09	9.12	3.93	4.81	3.78
P. eremicus (29)	177.64-186.50	90.20-95.60	85.86-92.48	20.24-20.80	16.62-17.52	25.05-25.57	9.17-9.47	4.00-4.12	10.98-11.20	9.01-9.23	3.83-4.03	4.71-4.91	3.72-3.84
	162-203	80-105	67-99	19-22	15-20	23.95-27.55	8.75-10.75	3.75-4.40	10.25-11.75	8.55-9.75	3.60-4.85	4.30-5.25	3.55-4.30
	182.70	96.00	86.70	21.20	18.60	26.99	10.42	4.22	11.34	9.42	4.04	4.94	3.98
P. pectoralis (10)	178.18-187.22	91.42-100.58	82.58-90.82	20.55-21.85	17.70-19.51	26.78-27.20	10.31-10.53	4.15-4.29	11.20-11.48	9.26-9.58	3.90-4.18	4.80-5.08	3.92-4.04
	173.197	89-108	73-94	20-23	16-21	26.40-27.40	10.20-10.70	4.00-4.35	11.00-11.75	9.15-9.95	3.70-4.25	4.60-5.40	3.85-4.15
	184.48	97.29	87.19	21.13	19.55	26.77	10.48	4.30	11.52	9.57	4.13	5.44	4.10
P. boylii (31)	179.62-189.34	94.24-100.34	84.33-90.05	20.76-21.50	19.04-20.06	26.47-27.07	10.32-10.64	4.27-4.33	11.42-11.62	9.47-9.67	4.06-4.20	5.32-5.56	4.07-4.13
	155-201	81-114	70-106	19-23	17-22	24.70-27.95	9.30-11.15	4.15-4.45	10.90-11.95	9.00-10.35	3.75-4.45	4.45-6.15	3.95-4.30
	192.71	102.43	90.28	22.46	20.28	27.75	10.98	4.42	11.96	9.94	4.34	5.51	4.25
P. difficilis (28)	188.38-197.04	99.83-105.03	87.79-92.77	22.04-22.88	19.80-20.76	27.51-27.99	10.83-11.13	4.38-4.46	11.87-12.05	9.81-10.07	4.28-4.40	5.42-5.60	4.20-4.30
	171-212	90-115	76-103	20-24	17-23	26.20-28.70	10.45-11.95	4.15-4.65	11.60-12.60	9.30-11.10	4.00-4.85	4.90-6.05	4.05-4.55
	184.50	87.00	97.50	20.00	24.50	27.45	10.65	4.35	11.82	10.78	4.32	5.22	4.00
P. truei (2)	175.48-193.52	70.96-103.04	90.48-104.52	18.00-20.00	23.49-25.51	26.05-28.85	10.25-11.05	4.25-4.45	10.87-12.77	9.93-11.63	4.16-4.48	5.06-5.38	3.90-4.10
	180-189	79-95	94-101	19-21	24-25	26.75-28.15	10.45-10.85	4.30-4.40	11.35-12.30	10.35-11.20	4.25-4.40	5.15-5.30	3.95-4.05

TABLE 3.—*Means (first row), 95 per cent confidence limits (second row), and extremes (third row) for external and cranial measurements of adult specimens of six species of* Peromyscus.

Species and sample size	Total length	Tail length	Body length	Hind foot length	Ear length	Skull length	Length of rostrum	Inter-orbital breadth	Mastoid breadth	Skull depth	Length of bony palate	Length of incisive foramen	Length of molar toothrow
	176.40	79.80	96.60	21.40	18.00	26.94	10.57	4.13	11.29	9.68	4.04	5.50	3.88
P. leucopus (5)	170.98-181.82	75.60-84.00	92.53-100.67	20.91-21.89	16.91-19.09	26.50-27.38	10.16-10.98	3.77-4.39	11.09-11.49	9.56-9.80	3.69-4.39	5.26-5.74	3.72-4.04
	168-184	76-87	92-104	21-22	17-20	26.35-27.40	10.15-11.15	3.60-4.60	11.05-11.45	9.55-9.85	3.65-4.65	5.20-5.80	3.65-4.10
	159.20	66.67	92.53	19.93	17.67	25.29	10.01	3.92	10.80	9.25	3.68	5.58	3.66
P. maniculatus (15)	154.91-163.49	64.03-69.31	89.70-95.36	19.05-20.81	16.76-18.58	24.41-26.17	9.80-10.22	3.83-4.01	10.70-10.90	9.11-9.39	3.59-3.77	5.39-5.77	3.56-3.74
	144-171	60-74	83-101	15-23	15-21	24.20-26.45	9.30-10.80	3.65-4.20	10.55-11.20	8.85-9.75	3.45-4.10	5.00-6.10	3.45-4.00
	187.45	97.09	89.45	20.09	17.54	25.80	9.36	4.13	11.31	9.24	3.92	4.84	3.76
P. eremicus (11)	180.07-194.83	92.84-101.34	83.72-95.18	19.59-20.59	16.85-18.23	25.51-26.09	9.22-9.50	4.06-4.20	11.14-11.48	9.10-9.38	3.82-4.02	4.65-5.03	3.66-3.86
	173-214	88-112	72-99	19-21	16-18	25.15-26.60	9.10-9.90	3.95-4.35	10.90-11.75	8.75-9.55	3.75-4.25	4.20-5.30	3.50-4.00
	188.71	99.28	89.43	20.57	18.86	27.24	10.59	4.14	11.35	9.34	4.02	5.11	3.88
P. pectoralis (7)	183.31-194.11	95.66-102.90	85.42-93.44	19.61-21.53	17.46-20.27	26.82-27.66	10.34-10.84	3.99-4.29	11.18-11.52	9.14-9.54	3.86-4.18	4.79-5.43	3.78-3.98
	182-199	95-107	84-99	19-22	16-22	26.50-28.10	10.15-11.20	3.95-4.55	11.10-11.75	9.15-9.95	3.70-4.35	4.70-5.95	3.70-4.05
	194.00	100.50	93.50	21.17	19.50	27.62	10.92	4.34	11.69	9.55	4.27	5.58	4.12
P. boylii (6)	187.89-200.11	92.61-108.39	87.97-99.03	20.21-22.13	18.16-20.84	27.36-27.88	10.76-11.08	4.24-4.44	11.54-11.84	9.39-9.71	4.09-4.45	5.37-5.79	4.04-4.20
	183-201	82-108	86-101	19-22	18-22	27.15-28.00	10.80-11.30	4.15-4.45	11.45-11.95	9.35-9.85	3.90-4.50	5.25-5.85	3.95-4.25
	209.11	110.89	98.22	22.33	21.11	28.54	11.45	4.49	12.22	10.01	4.31	5.88	4.22
P. difficilis (9)	203.21-215.01	108.20-113.58	94.25-102.19	21.45-23.21	19.94-22.28	28.34-28.74	11.26-11.64	4.39-4.59	12.03-12.41	9.78-10.24	4.21-4.41	5.75-6.01	4.15-4.29
	196-222	105-116	87-106	20-24	19-24	28.20-29.15	10.95-11.90	4.20-4.75	11.70-12.75	9.55-10.65	4.10-4.60	5.65-6.35	4.10-4.40

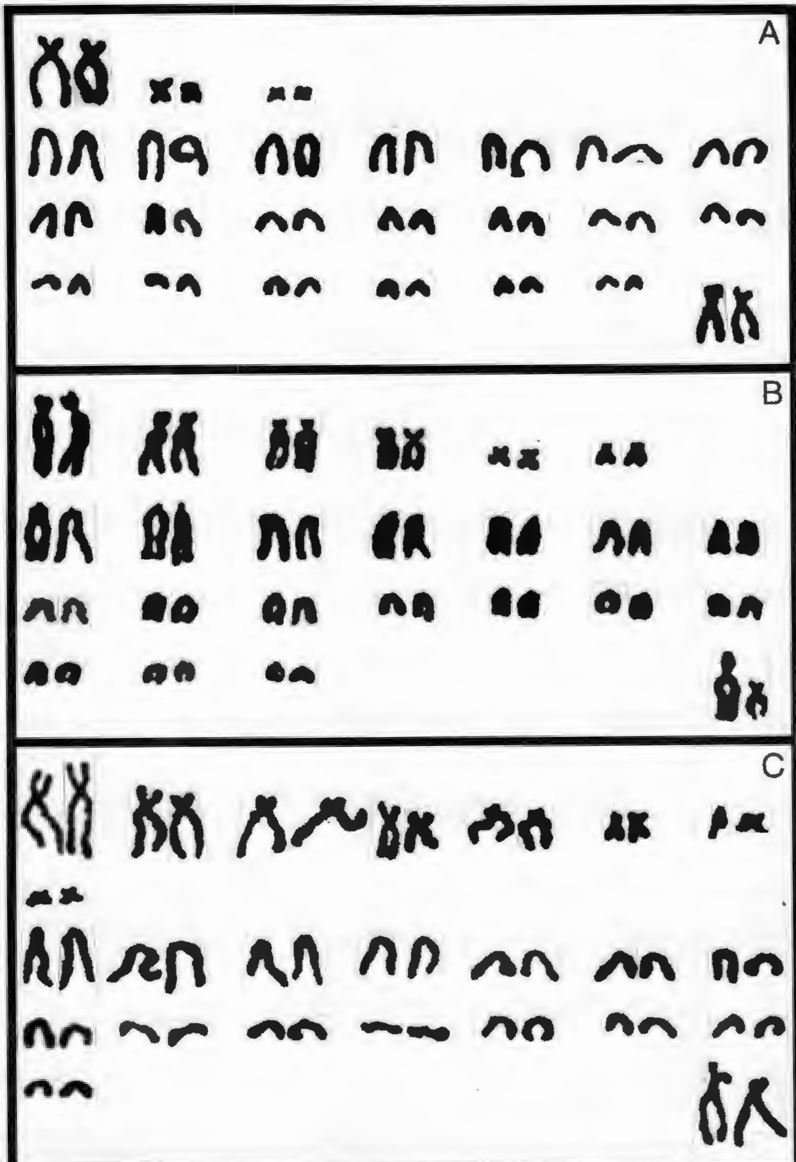

FIG. 7.—Representative karyotypes of: A, female *Peromyscus boylii*; B, male *P. pectoralis*; C, female *P. truei*.

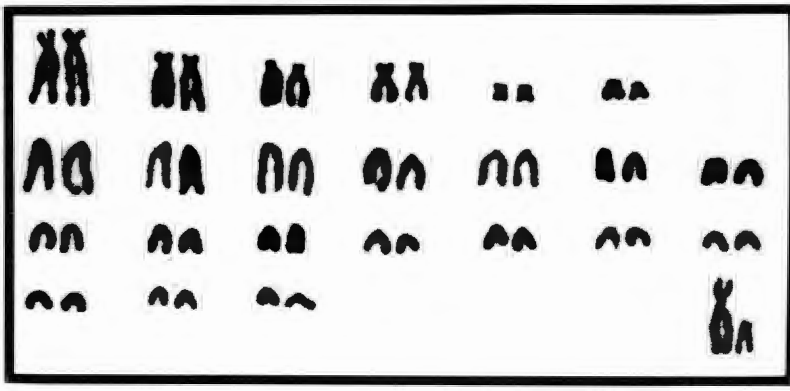

FIG. 8.—Representative karyotype of *Peromyscus difficilis.*

having a shorter skull, shorter rostrum, smaller interorbital constriction, smaller mastoid breadth, smaller depth of skull, shorter bony palate, and shorter maxillary toothrow.

Adults (Table 3) of *P. boylii* differ from those of *P. difficilis* externally in having a shorter total length; cranially, in having a shorter skull, shorter rostrum, smaller mastoid breadth, and smaller depth of skull.

There are no obvious differences in the complexity of the molar teeth between these two species (Fig. 5). However, the karyotypes are sufficiently distinct to be used in species recognition. *P. boylii* has two large biarmed autosomes (Fig. 7A) and an FN of 52; *P. difficilis* has eight large biarmed autosomes and an FN of 58 (Fig. 8; Table 1).

pectoralis compared with *boylii*

P. pectoralis can be confused easily with *P. boylii* but differs in that the dark color of its hind leg does not extend over the tarsal joint, thus leaving its ankles completely white. *P. pectoralis* is grayer in dorsal pelage color than is *boylii*, especially in the cheek region. The tail of *pectoralis* is not as well haired and is paler in dorsal coloration than that of *boylii*. Male specimens of *pectoralis* and *boylii* are easily separated by examining the baculum; that of *pectoralis* has a long cartilaginous spine at its terminal end, whereas in *boylii* the spine is short (Fig. 9).

The skulls of these two species may be easily distinguished by examining two qualitative features (Fig. 10). First, the posterior ends of the nasal bones are truncate or flat in *pectoralis* and not tapered in a V-shaped pattern as they are in *boylii*. Secondly, the

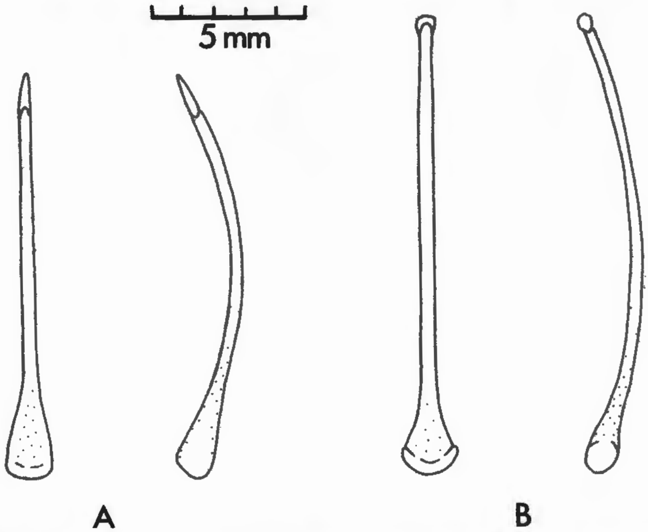

FIG. 9.—Dorsal and lateral views of the baculum of (A) *Peromyscus pectoralis* and (B) *P. boylii* showing degree of development of cartilaginous spines at the terminal end.

anterior margin of the interparietal is slightly curved in *pectoralis* as opposed to being distinctly pointed in *boylii*. In *pectoralis*, the interparietal is triangular in shape; in *boylii*, this bone is more diamond shaped.

There are few significant quantitative differences in external and cranial measurements between *pectoralis* and *boylii*, as reflected by nonoverlapping subsets of 95 per cent confidence limits. Among subadults (Table 2), *boylii* has significantly longer incisive foramina and a longer molar toothrow. In adult mice (Table 3), *boylii* has a significantly wider mastoid breadth and a longer molar toothrow. In all measurements, adults of *pectoralis* average smaller than those of *boylii* (Table 3) and in all but two measurements (hind foot length and greatest length of skull), subadults of *pectoralis* average smaller than those of *boylii* (Table 2).

There were no obvious differences in the complexity of the molar teeth between these two species (Fig. 5). Karyotypically, *pectoralis* differs from *boylii* in having eight large biarmed autosomes and an FN of 58 (Fig. 7B) instead of two large biarmed autosomes and an FN of 52 (Fig. 7A, Table 1).

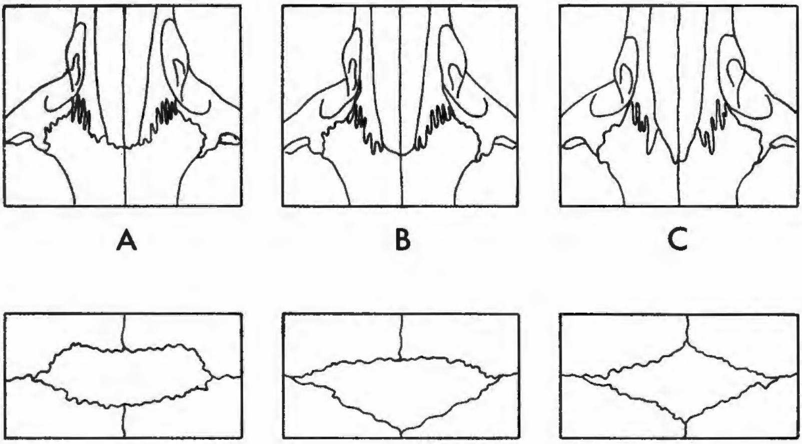

FIG. 10.—Qualitative differences in the skulls of *Peromyscus pectoralis, P. boylii,* and *P. difficilis.* **Top.** Shape of posterior margin of nasals: A and B, *pectoralis;* C, *boylii* (figured) and *difficilis.* **Bottom.** Shape of interparietal: A, *pectoralis;* B, *difficilis;* C, *boylii.*

SPECIES ACCOUNTS

Peromyscus eremicus eremicus (Baird)
Cactus Mouse

Specimens examined (42).—CULBERSON CO.: ½ mi. S, 2⅝ mi. W Guadalupe Peak 6 (TTU); 3$\frac{3}{16}$ mi. S, 1 ⅜ mi. W Guadalupe Peak, 1 (TTU); 3¼ mi. S, 2⅜ mi. W Guadalupe Peak, 1 (TTU); 4 mi. S, ½ mi. W Guadalupe Peak, 2 (TTU); 4¼ mi. S, 1 mi. W Guadalupe Peak, 11 (TTU); 4$\frac{5}{16}$ mi. S Guadalupe Peak, 2 (TTU); 4⅞ mi. S, ⅛ mi. E Guadalupe Peak, 4 (TTU); 5⅛ mi. S Guadalupe Peak, 1 (TTU); Nipple Hill, 2 (TTU); 7 mi. N Pine Springs, 2 (TCWC). HUDSPETH CO.: Crossroads, 6 (TTU); ⅜ mi. S, 4$\frac{1}{16}$ mi. W Guadalupe Peak, 3 (TTU); Northwest Corner, 1 (TTU). Measurements are given in Tables 2 and 3, and the karyotype of this species is shown in Fig. 6A.

Although remains of *Peromyscus eremicus* in Upper Sloth Cave (Logan and Black, 1979) indicate a long history of this species in the Guadalupe Mountains, cactus mice were first reported from the Guadalupe Mountains of Texas by Genoways *et al.* (1979). The first specimens were apparently collected in 1940 by W. B. Davis, but were never reported. With the exception of the specimens taken by Davis and two individuals trapped during this study, all of the cactus mice collected in Guadalupe Mountains National Park were caught on the xeric desert bajadas in the southern and western areas of the park. Cactus mice were often taken in the same trap line with *Peromyscus maniculatus, P. leu-*

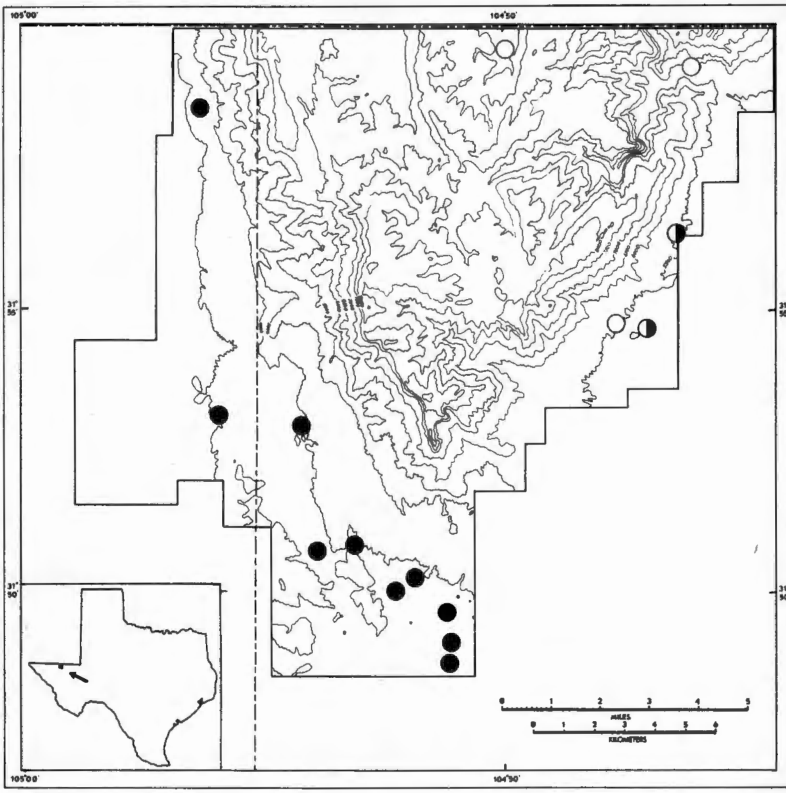

FIG. 11.—Geographic distribution of *Peromyscus eremicus* and *P. pectoralis* in Guadalupe Mountains National Park. Closed circles, *P. eremicus*; open circles, *P. pectoralis*; half-closed circles, places where both species were taken.

copus, Perognathus intermedius, P. penicillatus, and *Dipodomys merriami.* The distributional patterns of *P. eremicus, P. leucopus,* and *P. maniculatus* in the park were strikingly similar (see Figs. 11, 12).

Dice (1930) first conferred the name cactus mouse on this species because of its association with rocky desert situations where cacti are abundant. In Guadalupe Mountains National Park, cactus mice reach their greatest abundance in rocky areas of bajadas dominated by creosote bush and mesquite. On the eastern side of the park and near the northwest corner of the park, *P. eremicus* were obtained in mixed grassland with scattered succulents, but they were uncommon in this habitat. The highest elevation at which cactus mice were captured was 1646 meters.

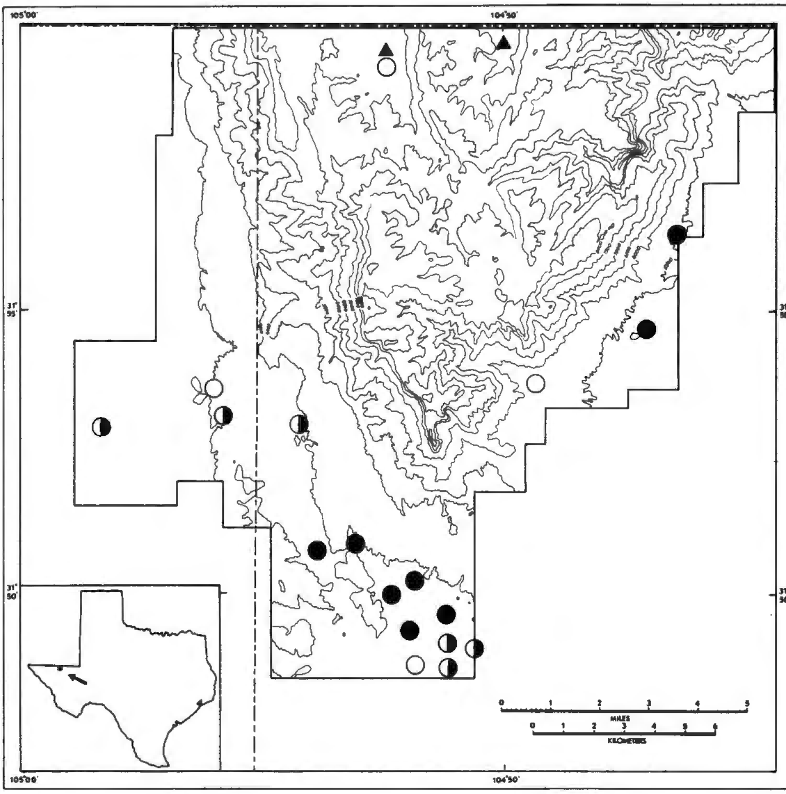

FIG. 12.—Geographic distribution of *Peromyscus maniculatus*, *P. leucopus*, and *P. truei* in Guadalupe Mountains National Park. Closed circles, *P. maniculatus*; open circles, *P. leucopus*; half-closed circles, places where both *P. maniculatus* and *P. leucopus* were taken; closed triangles, *P. truei*.

Three adult females taken on 26 January, 20 May, and 15 August were not pregnant. Three adult males had testes that measured 9, 12, and 11 millimeters on 26 January, 15 August, and 23 August, respectively. August *et al.* (1979) reported a density of 8.6 *P. eremicus* per hectare on a grid near the entrance to Williams Ranch Road. *Peromyscus maniculatus* was present in the same area at a density of 8.1 per hectare.

Peromyscus maniculatus blandus (Osgood)
Deer Mouse

Specimens examined (55).—CULBERSON CO.: ½ mi. S, 2⅝ mi. W Guadalupe Peak, 1 (TTU); 3¼ mi. S, 2⅜ mi. W Guadalupe Peak, 1 (TTU); 4 mi. S, ½ mi. W Guadalupe Peak, 5 (TTU); 4.3 mi. S Guadalupe Peak, 1 (TTU); 4⅜ mi. S, ½ mi.

W Guadalupe Peak, 1 (TTU); Williams Ranch Road, 4½ mi. S, 1 mi. W Guadalupe Peak, 2 (TTU); Williams Ranch Road, 4⅞ mi. S, ⅛ mi. E Guadalupe Peak, 11 (TTU); 5⅛ mi. S Guadalupe Peak, 4 (TTU); Williams Ranch Road, 5⅜ mi. S, ½ mi. W Guadalupe Peak, 5 (TTU); Nipple Hill, 1 (TTU); Patterson Hills Notch, 3 (TTU); 7 mi. N Pine Springs, 1 (TCWC); Williams Ranch Road Entrance, 9 (TTU). HUDSPETH CO.: Crossroads, 9 (TTU); Lewis Well, 1 (TTU). Measurements are given in Tables 2 and 3, and the karyotype of this species is shown in Fig. 6B.

Genoways *et al.* (1979) first reported deer mice from the Guadalupe Mountains of Texas. One specimen of *Peromyscus maniculatus* collected in Bell Canyon by Davis and Robertson (1944) in 1939 was originally reported as *P. leucopus.* All but one of our specimens were obtained on desert bajadas sparsely covered with desert scrub dominated by creosote bush and mesquite (Fig. 12). One deer mouse was taken at Nipple Hill, an area of mixed grassland. *Peromyscus maniculatus* was the most common species of *Peromyscus* obtained in the low desert areas. *P. eremicus* also was relatively abundant in those places but was associated with rocky sites whereas *P. maniculatus* seemed to prefer terrain with few rocks. *Peromyscus leucopus* was much less common than either of the above, and *P. boylii* was uncommon on the desert bajadas. Deer mice were found only below 1615 meters in the park.

August *et al.* (1979) operated a small mammal grid on the desert bajada south of El Capitan, where they estimated a density of 8.1 *P. maniculatus* per hectare in 1975. The density of *Peromyscus eremicus* on the same grid was slightly greater at 8.6 per hectare. *Peromyscus maniculatus* also was present on a grid established by August *et al.* (1979) in desert grassland habitat near Pine Springs, where in 1975 the density of *P. maniculatus* was 7.5 per hectare.

Genoways *et al.* (1979) reported the following testes measurements (in millimeters) for adult males (capture dates in parentheses): 9 (22 March); 10 (19 May); 8 (20 May); 7 (30 June); 10 (12 July); 14 (13 July); 12 (26 July); 12, 13 (10 August); 11 (22 August); 10, 11 (6 October). An adult female captured on 13 July was carrying three embryos that measured 10 millimeters crown to rump. Two subadults were molting from subadult to adult pelage when trapped on 13 July.

Peromyscus leucopus tornillo (Mearns)
White-footed Mouse

Specimens examined (20).—CULBERSON CO.: ½ mi. S, 2⅝ mi. W Guadalupe Peak, 1 (TTU); 5⅛ mi. S Guadalupe Peak, 2 (TTU); 5⅜ mi. S, ½ mi. W Guadalupe Peak, 1 (TTU); Marcus Cabin, West Dog Canyon, 1 (TTU); Pine Springs Campground, 5 (TTU); Williams Ranch Road Entrance, 2 (TTU); Williams

Ranch Road, 4⅞ mi. S, ⅛ mi. E Guadalupe Peak, 5 (TTU). HUDSPETH Co.; Crossroads, 1 (TTU); Lewis Well, 1 (TTU); Stage Coach Hills, 1 (TTU). *Additional record*:—CULBERSON Co.: Frijole, about 5600 ft. (Davis, 1940:80). Measurements are given in Tables 2 and 3, and the karyotype of this species is shown in Fig. 6C.

Davis (1940) collected a white-footed mouse at Frijole near the base of the Guadalupe Mountains on the eastern side of what is now Guadalupe Mountains National Park. Davis and Robertson (1944) reported that *P. leucopus* apparently was restricted to desert areas adjoining the mountains.

One of our specimens was obtained in mixed grassland in West Dog Canyon at an elevation of 1905 meters, and five specimens were taken at the mouth of Pine Springs Canyon, 1768 meters, in open riparian woodland. All of the remaining specimens came from elevations below 1360 meters on desert bajadas dominated by desert scrub vegetation.

White-footed mice were not abundant anywhere in the park. Their distribution is similar to those of *P. maniculatus* and *P. eremicus* (Figs. 11, 12). Specimens of both *P. leucopus* and *P. maniculatus* were taken on the gypsum soils near Lewis Well near the western boundary of the park.

An adult female captured on 24 July contained one embryo that measured 7 millimeters crown to rump. A female taken on 6 October was pregnant, but the number of embryos was not recorded. Nonpregnant adult females were captured on 26 January, 22 March, 20 May, and 7 October. Three adult males collected on 26 January evinced molt in a small area on the head and neck.

Peromyscus boylii rowleyi (J. A. Allen)
Brush Mouse

Specimens examined (82).—CULBERSON Co.: Bush Mountain, 3 (TTU); ½ mi. NNE Grisham-Hunter Lodge, South McKittrick Canyon, 1 (TTU); Guadalupe Mountains, 7800 ft., 1 (USNM); Guadalupe Mountains, Dog Canyon, 6800 ft., 2 (USNM); Guadalupe Mountains, head of McKittrick Canyon, 7800 ft., 1 (USNM); Guadalupe Peak Campground, 1 (TTU); 4⅝ mi. S, ½ mi. W Guadalupe Peak, 1 (TTU); 5⅛ mi. S Guadalupe Peak, 1 (TTU); Lost Peak, 1 (TTU); Marcus Cabin, West Dog Canyon, 1 (TTU); McKittrick Canyon, 8 (TCWC); Nipple Hill, 1 (TTU); Pine Springs Campground, 1 (TTU); Pratt Lodge, McKittrick Canyon, 2 (TTU); Smith Canyon, 4 (TTU); The Bowl, 29 (19 TCWC, 10 TTU); Upper Dog Ranger Station, 23 (TTU); Williams Ranch Road Entrance, 1 (TTU). Measurements are given in Tables 2 and 3, and the karyotype is shown in Fig. 7A.

In 1901, Bailey (1905) collected specimens of *Peromyscus boylii* in Dog and McKittrick canyons. Davis (1940) obtained brush mice in The Bowl and McKittrick Canyon in 1938 and 1939. We found the brush mouse to be the most common and most widespread species of *Peromyscus* in the park. Specimens have been obtained at elevations ranging from about 1295 to over 2430 meters. They are apparently most abundant above 1900 meters because our largest samples were from Upper Dog Ranger Station (1929 m.) and The Bowl (2377 m.).

The brush mouse exhibited wide habitat tolerances within the park but was generally found to be associated with rocky situations. Near Williams Ranch Road Entrance, a brush mouse was obtained in the vicinity of small rocky hills on the bajada dominated by creosote bush and mesquite. In the canyons such as McKittrick, Upper Dog, and West Dog, specimens of *P. boylii* were taken on rocky hillsides dominated by scrub oak, sotol, and agave. Specimens collected by Bailey (1905) were associated with piñons and junipers as well as rocks and cliffs. He reported that brush mice eat juniper seeds, piñon nuts, and acorns, and that they often nest in hollow trees and logs. Individuals obtained by Davis (1940) in McKittrick Canyon apparently preferred rocky areas.

In The Bowl, *P. boylii* was found in a mixed forest dominated by Ponderosa pine, but including Douglas fir and Gambel oak. Davis (1940) reported brush mice to be abundant in this habitat in 1938 and 1939. Most of his specimens were trapped next to fallen logs, although a few were caught in a grassy meadow. Specimens were taken in a log cabin in The Bowl both during his study (Davis, 1940) and by Genoways *et al.* (1979). Although not restricted to rocky situations in The Bowl, brush mice generally were associated with rock outcrops at other montane localities such as Guadalupe Peak Campsite, Bush Mountain, and Lost Peak.

Peromyscus boylii was found in all of the major habitats (desert, grassland, riparian woodland, and montane), and consequently, in one place or another, it occurred sympatrically with each of the other six species known to inhabit the park. *Peromyscus difficilis* also is widespread and was found commonly at localities with *P. boylii* (see Fig. 13).

August *et al.* (1979) reported a density in 1975 of 8.6 mice per hectare for *Peromyscus boylii* on a grassy meadow in Upper Dog Canyon and 6.2 for *P. pectoralis*.

Davis (1940) collected pregnant females on the following dates (number of embryos and crown-rump length in millimeters are stated parenthetically): 20 June (3, no measurement), 22 June (4, 13), 3 August (5, 5), 3 August (5, 10), and 3 August (3, 20). Genoways *et al.* (1979) captured pregnant females on 22 March (3, 4), 6

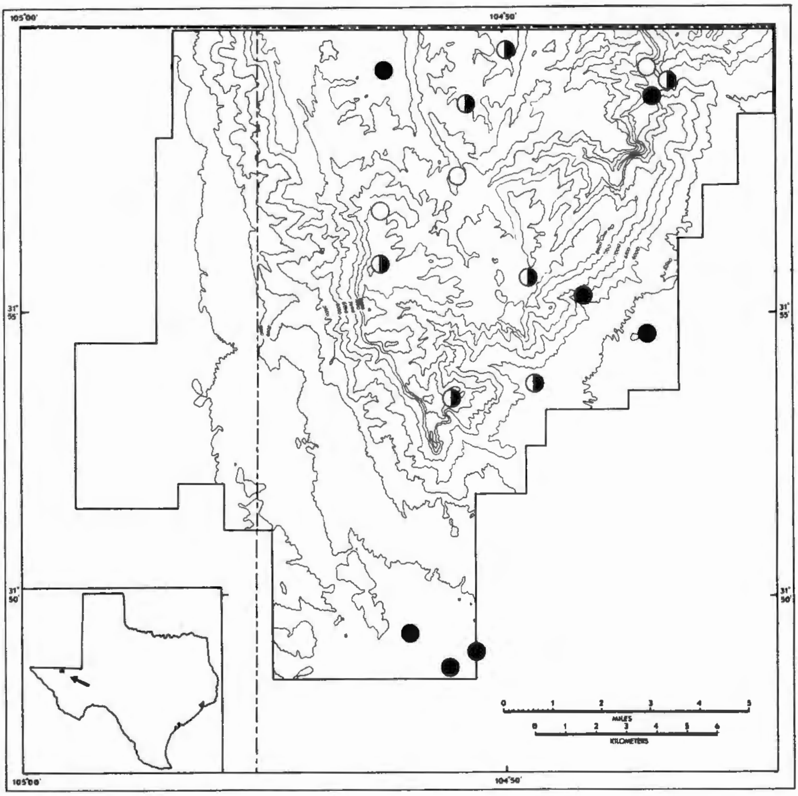

Fig. 13.—Geographic distribution of *Peromyscus boylii* and *P. difficilis* in Guadalupe Mountains National Park. Closed circles, *P. boylii*; open circles, *P. difficilis*; half-closed circles, places where both species were taken.

April (number of embryos not recorded; embryos were minute in size), 23 June (2, 23), and 6 August (4, 4). Nonpregnant females were obtained in May, June, and July. Testes measurements in millimeters for adult males reported by Genoways *et al.* (1979), with dates of capture in parentheses are: 12 (22 March); 4, 12 (31 May); 5 (1 June); 10 (2 June); 13 (3 June); 14 (4 June); 11 (5 June); 10, 12 (9 June); 8 (13 June); 11 (23 June); 14, 15, 15, 15 (6 August). Four adult females evinced molt on various areas of the dorsum when captured on the following dates: 12 June, 23 June, 25 June, 6 August. Our data, and those of Davis (1940), indicate that the breeding season of *P. boylii* extends at least from March through August in Guadalupe Mountains National Park and that two or more litters might be produced in some years.

Peromyscus pectoralis laceianus (Bailey)
White-ankled Mouse

Specimens examined (20).—CULBERSON CO.: 7 mi. N Pine Springs, 15 (TCWC); Manzanita Springs, 1 (TTU); Nipple Hill, 2 (TTU); 0.3 mi. N, 0.5 mi. E Pratt Cabin, McKittrick Canyon, 1 (TTU); Upper Dog Ranger Station, 1 (TTU). Measurements are given in Tables 2 and 3, and the karyotype is shown in Fig. 7B.

In 1938, white-ankled mice apparently were common along Bell Creek north of Pine Springs where Davis and Robertson (1944) collected several specimens. They reported that *P. pectoralis* showed a preference for rocky areas. Most of our specimens came from rocky riparian woodland or open woodland situations, but August *et al.* (1979) reported a density in 1974 of 6.2 *P. pectoralis* per hectare in a meadow near Upper Dog Ranger Station and 15 per hectare in rocky desert grassland near Pine Springs. White-ankled mice appear to have a relatively narrow habitat tolerance and elevation range within the park (Fig. 11). Only *P. truei* was less common in the park. Guadalupe Mountains National Park is near the northern limit of the range of the white-ankled mouse (Hall and Kelson, 1959; Findley *et al.*, 1975).

Adult females taken on 26 January and 15 July were not pregnant. Adult males captured on 3 June, 23 June, and 29 July had testes that measured 11, 11, and 12 millimeters, respectively.

Peromyscus truei truei (Shufeldt)
Piñon Mouse

Specimens examined (4).—CULBERSON CO.: Marcus Cabin, West Dog Canyon, 3 (TTU); Upper Dog Ranger Station, 1 (TTU). External and cranial measurements for one male and one female are given in Table 2, and the karyotype is shown in Fig. 7C.

Our specimens of piñon mice were the first records of this subspecies from Texas (Genoways *et al.*, 1979). These specimens were taken at intermediate elevations (1905 and 1920 m.) in canyons in the extreme northern portion of the park. Both localities are characterized by open riparian woodland with grassy understories.

Throughout its geographic range, the piñon mouse is most common in piñon-juniper woodlands, and, in Guadalupe Mountains National Park, they have not been found outside of that habitat. In West Dog Canyon, *P. truei* was associated with piñon-juniper woodland including piñon pine (*Pinus edulis*) and alligator juniper (*Juniperus deppeana*). In Upper Dog Canyon, alligator juniper was present, but piñon pine was absent. Three other species of *Peromyscus* were taken in Upper Dog Canyon, including *P. pectoralis, P. difficilis,* and *P. boylii* (Figs. 11-13). Other *Peromyscus* in West Dog Canyon included *P. boylii* and *P. leucopus.*

Peromyscus truei, apparently the least common species of deer mouse in the park, exhibits the narrowest elevational range of any *Peromyscus* there and seems to be the most habitat specific. According to Douglas (1969), piñon mice depend on piñon pine and juniper for nesting and hiding places and utilize their seeds for food. The possession of long toes, a long tail, and large hind feet adapt these mice to climbing, adding a third (vertical) dimension to their home ranges (Horner, 1954; Douglas, 1969).

One of our specimens was an adult female that was carrying four embryos (5 mm. in crown-rump length) when captured on 24 July. This specimen was molting on the lower flanks. A male taken on 2 June had testes 11 millimeters in length.

Peromyscus difficilis nasutus (J. A. Allen)
Rock Mouse

Specimens examined (43).—CULBERSON Co.: Blue Ridge, 1 (TTU); Blue Ridge Campground, 3 (TTU); Bush Mountain, 4 (TTU); Guadalupe Peak Campground, 4 (TTU); Guadalupe Mountains, McKittrick Canyon, 7800 ft., 1 (USNM); Junction North McKittrick Canyon and Devil's Den Canyon, 1 (TTU); Lost Peak, 3 (TTU); Mescalero Campground, 2 (TTU); Pine Springs Campground, 1 (TTU); The Bowl, 7 (3 TCWC, 4 TTU); Upper Dog Ranger Station, 16 (TTU). Measurements are given in Tables 2 and 3 and the karyotype is shown in Fig. 8.

The first specimen of *Peromyscus difficilis* from the Guadalupe Mountains of Texas was collected by Vernon Bailey in 1901 at 7800 feet (2377 m.) in McKittrick Canyon (Diersing and Hoffmeister, 1974). We found rock mice to be relatively common at elevations above 1900 meters. Our lowest recorded elevation for *P. difficilis* was 1585 meters at the Junction of North McKittrick Canyon and Devil's Den Canyon. At seven of the 11 localities from which rock mice were collected, they were taken together with *Peromyscus boylii* (Fig. 13). At higher elevations, rock mice appeared to be more abundant than brush mice, whereas brush mice were more abundant at intermediate elevations. Where the two species occurred together, there were no apparent habitat differences. Both generally were taken in rocky situations.

Two females containing embryos were trapped during our work. One taken on 3 June carried four embryos that measured 4 millimeters; one on 1 July contained five that measured 3 millimeters crown to rump. Three males taken on 30 May had testes that averaged 8.3; six males taken on 9 to 11 June averaged 9.8;

and a single male trapped on 26 June had testes 7 millimeters in length. Molting adults were taken on 30 May (2), 3 June, and 10 June.

Discussion

Specimens of *Peromyscus* invariably pose problems in identification. These problems are further complicated when several species of *Peromyscus* occur together in a relatively small area. We know of no other restricted area where as many as seven species of *Peromyscus* occur. The key presented here should be useful in identifying specimens not only from Guadalupe Mountains National Park but also from throughout the northern Chihuahuan Desert region. When collecting specimens of *Peromyscus* it is particularly important to preserve voucher specimens that include the skin with external measurements, skull with teeth, penis, and karyotype. It should again be emphasized that only specimens of a similar age class should be compared.

One or more species of *Peromyscus* occur in every vegetative zone and at every elevation in Guadalupe Mountains National Park. The complexity of vegetation and topography, the variation in elevations (1112 to 2438 m.), and the variety of soil types result in a wide range of habitats, all of which are occupied by *Peromyscus*.

Four species of *Peromyscus* occur in the lower elevations of the park. *Peromyscus maniculatus* was the most common species on the desert bajadas in the southern and eastern areas of the park. *Peromyscus eremicus* was also common in those areas, but was associated with rocky areas whereas *P. maniculatus* was found in the less rocky more open areas. In some areas the density of *P. eremicus* might exceed that of *P. maniculatus* (August *et al.*, 1979). Davis (1940) reported *P. leucopus* to be the common mouse in the desert adjacent to the Guadalupe Mountains, but during our study *P. leucopus* was not as common as *P. maniculatus* or *P. eremicus* in the desert areas. Although these three species are more abundant in the desert, all three occur in grassland areas on the east side of the park. Only *P. leucopus* was obtained above 1650 meters. One specimen of *P. leucopus* was caught in grassland at 1905 meters in West Dog Canyon, and five were taken at 1768 meters in open riparian woodland at the mouth of Pine Springs Canyon.

The range of *Peromyscus boylii* overlaps with that of all of the other species in the park. Specimens have been taken from rock outcrops in the desert bajada at elevations of approximately 1295 meters to the top of the Guadalupe Mountains at elevations above 2438 meters. *Peromyscus boylii* was the most common species of *Peromyscus* in the park, and was most abundant at elevations above 1900 meters. At intermediate and higher elevations, the ranges of *P. boylii* and *P. difficilis* broadly overlap. Both species have an affinity for rocky situations and they are often taken in the same trap line. At higher elevations, *P. difficilis* appears to be more common, whereas *P. boylii* is more common at intermediate elevations. *Peromyscus pectoralis* also has an affinity for rocky areas, but this species was not found above 1920 or below 1550 meters. August *et al.* (1979) reported *P. pectoralis* occurring with *P. maniculatus* near Pine Springs and with *P. boylii* in Upper Dog Canyon.

Peromyscus truei occurred only in piñon and juniper woodland at intermediate elevations. It was the least common *Peromyscus* in the park, where it exhibited the greatest habitat specificity and narrowest range in elevation. Specimens of *P. truei* were taken in West Dog Canyon along with *P. boylii* and *P. leucopus.* One specimen was collected in Upper Dog Canyon where *P. boylii, P. difficilis* and *P. pectoralis* also occur.

Guadalupe Mountains National Park is obviously an excellent place to study mice of the genus *Peromyscus.* A great deal remains to be learned about their ecology, especially interspecific relationships, within the park. Population studies, diet analyses, and light tracking should prove particularly enlightening. We hope the information in this paper will serve to stimulate such investigations.

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