

CHROMOSOMAL, ELECTROPHORETIC, AND BREEDING STUDIES OF  
SELECTED POPULATIONS OF DEER MICE (*PEROMYSCUS  
MANICULATUS*) AND BLACK-EARED MICE (*P. MELANOTIS*)

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The deer mouse, *Peromyscus maniculatus*, has the widest geographic distribution of the native species of rodents in North America. This is correlated with a high degree of genetic diversity as reflected by (1) the amount of morphological divergence and the large number of subspecies (Hall and Kelson, 1959; King, 1968), (2) the unusual amount of geographic chromosomal polymorphism (Arakaki and Sparkes, 1967; Duffey, 1972; Kreizinger and Shaw, 1970; Ohno et al., 1966; Singh and McMillan, 1966; Sparkes and Arakaki, 1966; Bradshaw and George, 1969) and (3) the degree of biochemical variation (Rasmussen, 1964, 1968, and 1970; Rasmussen and Koehn, 1966; Rasmussen et al., 1968; Brown and Welser, 1968; and Jensen and Rasmussen, 1971). The complexity of this species is further compounded because there are several peripheral populations, subspecies and closely related "species" which are distinguishable from "typical" *P. maniculatus* by varying degrees of morphological divergence (Blair, 1950).

Although this situation poses a nightmare to the taxonomist, an analysis of genetic relationship of such populations provides a valuable approach to the study of mammalian evolution. Rasmussen (1970) has already reported on one such study involving the degree of genetic diversity as reflected by electrophoretic patterns. He chose certain populations of deer mice

from the higher elevations in southern Arizona because of their degree of monomorphism and their divergence from other mountain populations of *P. maniculatus*. Rasmussen assumed that this divergence and monomorphism became established as a result of drift after these populations became isolated on the respective mountain tops which now function as terrestrial islands. Divergence of these mountain populations from those of more typical *P. maniculatus* from southern Arizona has been pointed out on the basis of karyotype (Kreizinger and Shaw, 1970). Our data show that some of these populations are not *P. maniculatus*, but members of another species, *P. melanotis*, and that this monomorphism and divergence was characteristic of *P. melanotis* before the isolation of these populations on the mountain tops. There are no published karyotypic data for *P. melanotis*, and the electrophoretic data for this species consist of results from a single specimen (Brown and Welser, 1968).

#### METHODS AND MATERIALS

Only live-trapped mice (see specimens examined) or their F<sub>1</sub> offspring were used for karyotypic and electrophoretic studies. Our karyotypic techniques using bone marrow are described by Baker (1970). At least 10 spreads were counted per specimen. Voucher specimens are deposited in the collection of mammals, The Museum, Texas Tech University. Representative spreads were photographed and idiograms prepared. We follow the chromosomal nomenclature of Patton (1967), although in most cases we refer only to the number of acrocentric versus biarmed elements

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TABLE 1. *Chromosomal characteristics of P. maniculatus and P. melanotis.*

Subspecies	Number of Specimens		Number of Acrocentric Chromosomes	Fundamental Number	Authority
	♂	♀			
<i>P. maniculatus austerus</i>	1	0	18	74	Hsu and Arrighi
<i>P. maniculatus bairdii</i>	9	8	18	74	Singh and McMillan
<i>P. maniculatus bairdii</i>	4	4	8, 9, 10, 11	81, 82, 83, 84	Ohno et al.
<i>P. maniculatus blandus</i>	17	3	6, 8, 10	82, 84, 86	This paper
<i>P. maniculatus fulvus</i>	1	2	8	84	This paper
<i>P. maniculatus gambelii</i>	1	0	17	75	Kreizinger and Shaw
<i>P. maniculatus gracilis</i>	6	9	15	77	Singh and McMillan
<i>P. maniculatus hollesteri</i>	3	0	18	74	Arakaki and Sparkes
<i>P. maniculatus hollesteri</i>	3	5	12, 14, 18, 19	73, 74, 78, 80	Ohno et al.
<i>P. maniculatus luteus</i>	27	34	8, 10, 11, 12	80, 81, 82, 84	This paper
<i>P. maniculatus nubiterrae</i>			9	83	Bradshaw and George
<i>P. maniculatus oreas</i>	1	0	9	83	Kreizinger and Shaw
<i>P. maniculatus ozarkiarum</i>	1	1	10	82	This paper
<i>P. maniculatus rufinus</i> <sup>1</sup>	1	0	11	81	Kreizinger and Shaw
<i>P. maniculatus rufinus</i> <sup>1</sup>	1	0	10	82	Hsu and Arrighi
<i>P. maniculatus rufinus</i> <sup>1</sup>	37	10	7, 8, 9, 10 11, 12, 13	79, 80, 81, 82 83, 84, 85, 86	This paper
<i>P. maniculatus sonoriensis</i>	1	0	12	80	Kreizinger and Shaw
<i>P. melanotis</i> <sup>2</sup>	2	2	30	62	Kreizinger and Shaw
<i>P. melanotis</i> <sup>2</sup>	1	0	30	62	Hsu and Arrighi
<i>P. melanotis</i> <sup>2</sup>	8	1	30	62	This paper
<i>P. melanotis</i>	24	7	30	62	This paper

<sup>1</sup> Specimens from: Colorado: Larimer and Weld counties; New Mexico: Lincoln, Otero, Taos and Torrance counties; Arizona: Coconino County.

<sup>2</sup> Specimens from: Arizona: Cochise, Graham and Pima counties (currently considered *P. maniculatus rufinus*).

(metacentric, submetacentric and subtelocentric of Patton). Fundamental number is the number of arms of the autosomal complement. Morphology of the sex elements cannot be determined accurately with our techniques (Kreizinger and Shaw, 1970), and we considered the X and Y to be biarmed. Processing of mice and subsequent electrophoretic techniques were the same as those by Selander et al. (1971) utilizing hemolysate and plasma samples. Identification numbers of specimens used for electrophoretic analysis refer to accession numbers in catalogs of the laboratory of R. K. Selander.

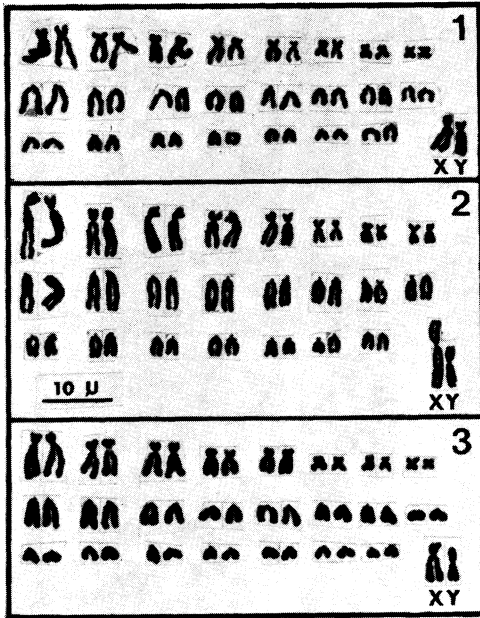
Crosses were made in cages 38 cm × 30 cm × 20 cm under 14 hours of light and 10 hours of darkness. At least 6 weeks were allowed before an attempted cross was considered negative.

#### RESULTS AND DISCUSSION

The diploid number of all 133 specimens of *P. maniculatus* was 48 with individual

variation in the number of acrocentric ranging from 6–19 (Figs. 4–6). Several workers have referred to the unique amount of morphological chromosomal variation within *P. maniculatus* (Ohno et al., 1966; Singh and McMillan, 1966; Hsu and Arrighi, 1968; Arakaki et al., 1970). A compilation of our results and literature reports reveal individuals of *P. maniculatus* with 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18 and 19 acrocentrics respectively (Fig. 7). Forty specimens, including those from the Chiricahua, Pinaleno, and Santa Catalina mountains currently considered *P. maniculatus* had a diploid number of 48 with 30 acrocentrics, resulting in a fundamental number of 62 (Table 1 and Figs. 1–3). The geographic distribution of the number of acrocentrics found in the karyotypes of *P. maniculatus* and *P. melanotis* is shown in Fig. 7.

The degree of electrophoretic pattern variation in *P. maniculatus* is also striking (Birdsall et al., 1970; Canham et al., 1970;



FIGS. 1-3. Representative karyotypes of male *P. melanotis*. 1) Number 13684 collected from 4 mi. E. Perote, Veracruz, Mexico, 2) Number 13677 collected from 29.1 mi. W. El Salto, Durango, Mexico, and 3) Number 13661 collected from the Santa Catalina Mountains, Pima County, Arizona.



FIGS. 4-6. Representative karyotypes of male *P. maniculatus*. 4) *P. m. fulvus*, Number 10343 from 7 mi. S.S.E. of Perote, Veracruz, 5) *P. m. rufinus*, Number 13622 from Coconino County, Arizona, and 6) *P. m. blandus*, Number 13577 from 2.2 mi. S.E. Portal Cochise County, Arizona.

Rasmussen, 1970; Savage and Cameron, 1971; Jensen and Rasmussen, 1971). The mountain top populations that have 30 acrocentric chromosomes differed from the other populations studied (Rasmussen, 1970; Jensen and Rasmussen, 1971) by having different gene frequencies and by being monomorphic for several loci where *P. maniculatus* is usually polymorphic. Our electrophoretic data are from a limited number of specimens (Table 2); however, most (80-90%) of the genetic variation in a species of *Peromyscus* can be detected in mice from a single population (Selander et al., 1971). On the assumption that the alleles in the Chiricahua populations were identical in both studies, our data are consistent with those of Rasmussen (1970) with one exception (Table 2). We did not detect the rare hemoglobin variant in the Chiricahua Mountain population. Albumin and transferrin are monomorphic and

hemoglobin essentially monomorphic in the populations from the Chiricahua, Pinaleno (sometimes referred to as the Graham Mountains) and Santa Catalina mountains, Arizona, and El Salto, Perote, and Distrito Federal, Mexico. The various populations of *P. melanotis* (the samples from Mexico) are identical to those of supposed *P. maniculatus* from southern Arizona in their albumin, transferrin and hemoglobin banding patterns.

We also processed two individuals of *P. maniculatus* from near Portal, Arizona and three from the mountains near Flagstaff, Arizona. Exact allele designation in accordance with Rasmussen's designation is impossible for each allele without running comparison gels using his specimens. However, it is probable that Trf-B, Trf-C and Alb-B and Alb-C were present at both locations as at least one mouse from each site was heterozygous for each system, and

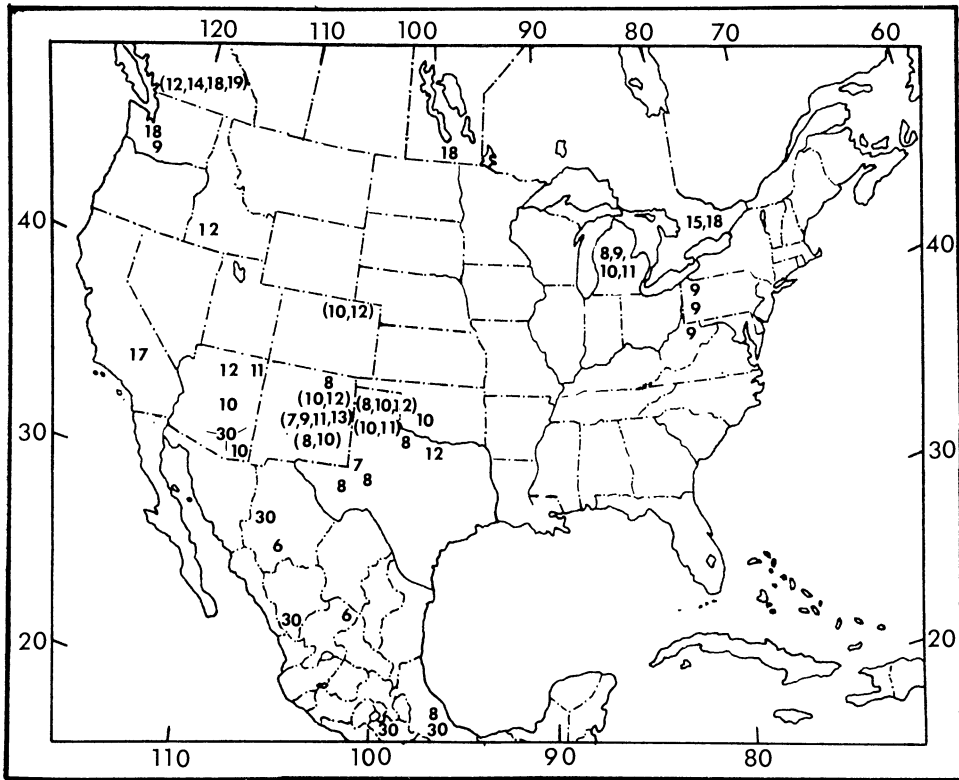


FIG. 7. Variation in the number of acrocentric chromosomes of *P. maniculatus* and *P. melanotis*. Values enclosed in parentheses represent polymorphism in a single population. Data are from this study and available literature.

neither band corresponded to Alb-D and Trf-C of *P. melanotis*. All five *P. maniculatus* were homozygous for the common hemoglobin allele in *P. maniculatus*. Neither albumen band corresponded to Alb-C and neither transferrin band corresponded to Trf-C of *P. melanotis*.

The probable explanation of this large amount of karyotypic and electrophoretic variation in presumed *P. maniculatus* is that more than one species is involved. We believe this to be the case concerning the forms from the Chiricahua, Pinaleno and Santa Catalina mountains of southern Arizona. A comparison of the karyotypes of *P. melanotis* from Perote, Veracruz (Fig. 1), and El Salto, Durango (Fig. 2), with that of *P. maniculatus rufinus* (Fig. 3) from Pima County, Arizona, reveals the three

karyotypes to be indistinguishable from each other. All populations of *P. maniculatus* that have thirty acrocentrics are restricted to higher life zones (coniferous forest) of the isolated mountain ranges (Fig. 7). The lowland populations from southern Arizona have 10 acrocentrics. The ecological range of *P. melanotis* is restricted to the high coniferous forest of central and northern Mexico and its associated grasslands.

That the similarity of habitat, karyotype and electrophoretic mobility patterns reflect a true genetic relationship is also supported by the results of breeding studies. Forty-two crosses have been attempted between animals from the southern Arizona mountain populations having 30 acrocentric chromosomes with specimens of *P. melanotis* from Perote, Veracruz, Popo-

TABLE 2. *Estimated allelic frequencies in montane populations of Peromyscus.*

	Protein Alleles										
	Albumins					Transferrins			Hemoglobins		
	N	A	B	C	D	E	A	B	C	A	O
Kaibab Plateau <sup>1</sup>	85	0.01	0.04	0.95	0.01		0.01	0.81	0.18	0.61	0.39
Flagstaff <sup>1</sup>	47	0.01	0.03	0.95	0.01			0.76	0.24	0.62	0.38
Mingus Mtn. I <sup>1</sup>	24	0.02	0.17	0.81				0.83	0.17	0.69	0.31
Mingus Mtn. II <sup>1</sup>	34		0.04	0.96				0.63	0.37	0.54	0.46
White Mtns., 1966 <sup>1</sup>	37	0.03	0.11	0.86				0.85	0.15	0.36	0.64
White Mtns., 1968 <sup>1</sup>	18		0.14	0.83		0.03		0.72	0.28	0.42	0.58
White Mtns., 1969 <sup>1</sup>	18	0.06	0.17	0.78			0.03	0.69	0.28	0.61	0.39
Pinaleno Mtns. <sup>1</sup>	56				1.00				1.00	1.00	
Pinaleno Mtns.	2				1.00				1.00	1.00	
Chiricahua Mtns. <sup>1</sup>	62				1.00				1.00	1.00	0.06
Chiricahua Mtns.	9				1.00				1.00	1.00	
Santa Catalina Mtns. <sup>1</sup>	38				1.00				1.00	1.00	
El Salto, Durango	3				1.00				1.00	1.00	
Districto Federal	3				1.00				1.00	1.00	
Perote	3				1.00				1.00	1.00	

<sup>1</sup> Data from Rasmussen (1970) and Jensen and Rasmussen (1971).

cateptel, Distrito Federal, and El Salto, Durango. Twenty-four of these attempted crosses were successful (57%). Successful crosses between individuals from each of three southern Arizona mountains (Chiricahua, Pinaleno and Santa Catalina) have been made with specimens of *P. melanotis* from each of the above mentioned localities. Attempted crosses of specimens from the southern Arizona mountain top populations with 30 acrocentrics times *P. maniculatus* with 10 acrocentric elements (30 crosses attempted) collected from the lowlands of Arizona southeast of Portal and times individuals from the coniferous forest of the mountains of Arizona and New Mexico (58 crosses attempted) have failed to produce a single litter. Crosses made between individuals of *P. melanotis* from the same locality resulted in 33 of 77 attempted crosses being successful (43%).

Thus, the populations in southern Arizona isolated on the tops of the Chiricahua, Pinaleno and Santa Catalina mountains have 30 acrocentrics, are monomorphic for Alb-D and Trf-C and do not

readily interbreed with other populations of *P. maniculatus*. These characteristics are the same as those of populations of *P. melanotis* from within its currently recognized distribution. Cross-fertility of the populations of *P. melanotis* with those of southern Arizona further argues their conspecific nature.

Rasmussen (1970) argued that the relatively high degree of genetic monomorphism was due to drift in these isolated mountain populations. Our study suggests this is an artifact produced by combining data from two species, *P. melanotis* being monomorphic and *P. maniculatus* polymorphic for the loci that happened to be studied. However, *P. melanotis* shows variability in other genetic systems that were not presented in his paper (e.g., phosphoglucosmutase-3). There is no evidence for the occurrence of genetic drift in these isolated mountain populations, and the danger of using only a limited number of loci and improper species identification should be apparent. Jensen and Rasmussen (1971) and Brown and Welser (1968) concluded

that albumin migration patterns would be of little or no taxonomic value. Our study and those of Smith et al. (1973) indicate this conclusion was premature and that albumin patterns may actually be quite useful.

We have studied only a small part of the *P. maniculatus* complex, but certain karyotypic patterns have become evident and breeding studies have supported the genetic reality of these patterns. The agreement between karyotypic and electrophoretic mobilities characteristic of these populations and the taxonomic lines suggested by the karyological and breeding data is impressive. Our study reveals that when preliminary data from a character obviously do not fit present taxonomic lines, it should not be concluded that the character will be of no apparent taxonomic or phylogenetic value. We believe that more intensive study of the karyotypes of *P. maniculatus*, (especially with heterochromatin and Giemsa banding techniques) taken in conjunction with breeding and electrophoretic studies, will result in a much better understanding of the evolution and systematics of this species. Certainly no character can be unconditionally accepted to imply a close phylogenetic relationship. For instance, the karyotype of *Peromyscus floridanus* as published by Hsu and Arrighi (1968), is very similar to that shown for *P. melanotis* (Figs. 1-3). These two species are presently placed in separate subgenera, and we do not know if this similarity of karyotypes has resulted from convergent evolution or from both remaining unchanged since divergence from a common ancestor. The point is that this is only one character.

As far as the relationship of *P. maniculatus* to *P. melanotis* is concerned, we have no data to suggest natural hybridization. Further, none of the animals with 30 acrocentrics have been successfully crossed with any *P. maniculatus* from a southwest desert population or from the adjacent mountain populations of New Mexico or

Arizona. The one successful cross reported in the literature involved specimens from the Ann Arbor, Michigan, area times *P. melanotis* from El Salto, Mexico (Clark, 1966). One of our laboratory stocks is from El Salto, Durango, and, as indicated above, all crosses of this stock (16 attempted) times various *P. maniculatus* were negative. In Clark's study (1966), only one of four attempted matings was successful, and this mating produced all males (Clark does not mention the number of young produced). It may be that in the zone where the two species have been in contact for some time, isolating mechanisms have evolved; however, where the two forms are more distantly associated from a geographical point, their isolating mechanisms may not have been established. Also, this may represent an isolated instance of compatibility between the two species. If this cross is valid, it certainly suggests some interesting implications; however, additional work is in order before we place too much importance on the data.

Blair (1950:270) discussed the evolution and speciation of *P. maniculatus* and related species. He concluded that species on the margins of the range of *P. maniculatus* have resulted from "peripheral isolates" which have undergone "both adaptive and nonadaptive differentiation in morphological, physiological and psychological characters." Blair concluded that *P. maniculatus* was the parental stock that gave rise to *melanotis*, *polionotus*, *sitkensis*, *slevini* and *sejugis*. We agree with this interpretation. In addition, we feel that the preliminary data indicate that the *P. maniculatus* complex may closely fit the "centrifugal speciation" model proposed by Brown (1957) which involves the classical concept of adaptation of these groups to local conditions. A critical component of the "centrifugal speciation" hypothesis is that the center is the principal source of evolutionary change leading to "potential new species." In our particular case, we

interpret "the center" to be the species *Peromyscus maniculatus*. In Brown's model, the peripheral populations will be more primitive than the central stock, and it is possible that the peripheral populations may be more genetically compatible with each other than with the more rapidly evolving central stock.

The following discussion will serve to show the relationship of our data to Brown's model.

1) Hsu and Arrighi (1968) and Baker and Mascarello (1969) hypothesized that the primitive karyotype for *Peromyscus* was 48 with a large number of acrocentrics. In the *P. maniculatus* complex the populations with higher numbers of acrocentrics are found in the peripheral isolates (Fig. 7) and in the more peripheral populations. *Peromyscus melanotis* has 30 acrocentrics; *P. polionotus* has 24–26 acrocentrics. In these two species, which are composed of numerous populations that are completely isolated from each other, only one minor chromosomal polymorphism and no chromosomal races have been described (Te and Dawson, 1971). When the chromosomal data for these two species are contrasted with the many races and polymorphisms of *P. maniculatus*, one is forced to conclude that *P. maniculatus* is in a more dynamic evolutionary state.

2) *Peromyscus melanotis* is not genetically compatible with the nearest populations (from the Mogollon rim, Arizona, or the Sacramento Mountains of New Mexico) or with its ecological equivalent, *P. maniculatus rufinus* or with the geographically adjacent grassland population *P. maniculatus blandus*. *Peromyscus melanotis* will hybridize with *P. maniculatus bairdii* from Michigan (Clark, 1966). Bowen (1968) suggested that *P. maniculatus bairdii* gave rise to *P. polionotis*. Clearly additional data are needed. However, should the peripheral isolates and other peripheral populations be more genetically compatible with each other than with the central stock of *P. maniculatus* from the central U.S.

and Mexico, then this complex will closely fit the model for centrifugal speciation.

#### SUMMARY

An unusual amount of chromosomal polymorphism and geographic variation in chromosomes and electrophoretic pattern have been reported for *Peromyscus maniculatus*. Karyological, electrophoretic and breeding data indicate that populations of *Peromyscus* from the Chiricahua, Pinaleno and Santa Catalina Mountains in southern Arizona are conspecific with *P. melanotis*, not with *P. maniculatus*. These data also argue against the assumptions that monomorphism in the isolated populations arose by drift. Rather they support a model of centrifugal speciation.

#### ACKNOWLEDGMENTS

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#### APPENDIX

##### *Specimens Examined*

*Peromyscus maniculatus*: *P. m. blandus* Osgood. TEXAS: Jeff Davis County, 9.3 mi. W. Balmorhea on Texas 17, one female, 13580. ARIZONA: Cochise County, 6.5 mi. S.E. Portal, 3 males, 13567, 13573, 13575; 2.5 mi. S.E. Portal, eight males, 13564–13566, 13569, 13570, 13572, 13576, 13579, one female, 13574; 2.2 mi. S.E. Portal, 4 males, 13568, 13571, 13577, 13578. MEXICO: CHIHUAHUA: 47.2 mi. S. Jiminez, 2 males, not yet catalogued. ZACATECAS: 7 mi. E. Mazapil, one female, not yet catalogued. *P. m. fulvus* Osgood. MEXICO: VERACRUZ: 7 mi. S.S.W. Perote, one male, 10345, two females,

10343, 10344. *P. m. luteus* Osgood. TEXAS: Andrews County, 18 mi. E. and 2 mi. N. Andrews, one male, 10393. Ector County, 10 mi. E. Odessa, one male, 10387. Hale County, 1.5 mi. W. Plainview, 3 females, 13582-13584. 3.2 mi. N. Plainview, 3 males, 10352, 10395, 13858, 8 females, 10359, 10360, 10362, 10363, 10386, 13587, 13588, 13586. Hardeman County, 2.5 mi. N.E. Quanah, 2 males, 10372, 13592, 6 females, 10370, 10371, 10385, 13589, 13590, 13591. Hockley County, 8.5 mi. N.W. of Levelland, two males, 10378, 10379, three females, 10377, 13593, 13594. Lamb County, 7.2 mi. S. Olton on F. M. 168, four males, 10366, 10382-10384, four females, 10364, 10365, 10380, 10381. Lubbock County, 0.5 mi. N. of Lubbock Lake Site, six males, 10368, 13597-13601, nine females, 10367, 10369, 13596, 13602-13607. McCulloch County, 5 mi. S.E. Brady, two males, 10391, 10392, one female, 13595. OKLAHOMA: Texas County, 10 mi. E. Hardesty, one male, 10361. Washita County, 2 mi. W. Burns Flat, five males, 10373-10376, 13581. *P. m. ozarkiarum* Black. TEXAS: Wichita County, Spillway of Lake Wichita, Wichita Falls, one male and one female, uncatalogued. *P. m. rufinus* (Merriam). COLORADO: Larimer County, 13 mi. W. Ft. Collins, one male, 13623. Weld County, 25 mi. N.E. Ft. Collins, one male, 13624. NEW MEXICO: Taos County, Taos, two females, 13649, 13650. Torrance County, Red Canyon, Cibola National Forest, three males, 10357, 10358, 13651, two females, 10355, 10356. Lincoln County, 2 mi. W. Bonita Lake, Lincoln National Forest, five males, 10353, 13625, 10354, 13626, 13628, one female, 10350. Otero County, Cloudcroft, thirteen males, 13629-13632, 13635-13637, 13642-13646, 13648, five females, 13633, 13634, 13639, 13640, 13641. ARIZONA: Coconino County, 2 mi. E. U.S. Hwy. 89 on the Sunset Crater Road, fourteen males, 13609-13622. *Peromyscus melanotis*: Allen and Chapman. ARIZONA: Pima County, Santa Catalina Mountains, Bear Wallow Campground, one male, 13661. Graham County; Coronado National Forest, Arcadia Campground, two males, 13657, 13658, one female, 13660. 35.0 mi. W. junction of U.S. Hwy. 666 and Arizona 366, one male, 13659. Cochise County, 14 mi. W. Portal, four males, 13653-13656. MEXICO: CHIHUAHUA: 8.2 mi. S. San Juanita, one male, 13662, one female, 13663. DURANGO: 25.2 mi. W. El Salto, six males, 13664-13666, 13673, 13675, 13676, one female, 13674. 29.1 mi. W. El Salto, four males, 13677-13680. 31 mi. W. El Salto, four males, 13667, 13668, 13670, 13671, two females, 13669, 13672. VERACRUZ: 4 mi. E. Perote, three males, 13682-13684, one female, 13681. DISTRICTO FEDERAL, 17.3 mi. S.E. Amecameca on the road to Popocatepetl, six males, 13686-13688, 13691-13693, two females, 13689, 13690.

The following specimens were processed electrophoretically and are preserved in the laboratory of Dr. Robert K. Selander, Department of Zoology, The University of Texas at Austin. The specimens are identified by Dr. Selander's laboratory catalogue numbers:

*Peromyscus melanotis* — ARIZONA: Graham County, Coronado National Forest, Arcadia Campground, 2(3615-16); Cochise County, 14 mi. W. Portal, 8(2404, 2410, 2415, 2420, 2422, 2426, 2430, 2432); MEXICO: DURANGO, 52 km W. El Salto, 3(3602-04); VERACRUZ, 7 km E. Perote, 3(3605-7); DISTRICTO FEDERAL, 29 km S.E. Amecameca on the road to Popocatepetl, 3(3608-10); F<sub>1</sub> hybrids, ARIZONA; Cochise County, 14.0 mi. W. Portal times MEXICO: Durango, 4(3611-14).

## LITERATURE CITED

- ARAKAKI, D. T., AND R. S. SPARKES. 1967. The chromosomes of *Peromyscus maniculatus hollesteri* (deer mouse). Cytologic 32:180-183.
- ARAKAKI, D. T., I. VEOMETTI, AND R. S. SPARKES. 1970. Chromosome polymorphism in deer mouse siblings (*Peromyscus maniculatus*). Experientia 26:425-426.
- BAKER, R. J. 1970. Karyotypic trends in bats, p. 65-96. In W. A. Wimsatt (ed.), Biology of Bats, Academic Press, London/New York.
- BAKER, R. J., AND J. T. MASCARELLO. 1969. Karyotypic analyses of the genus *Neotoma* (Cricetidae, Rodentia). Cytogenetics 8:187-198.
- BIRDSALL, D. A., J. A. REDFIELD AND D. G. CAMERON. 1970. White bands on starch gels stained for esterase activity: A new polymorphism. Biochemical Genetics 4:655-658.
- BLAIR, W. F. 1950. Ecological factors in the speciation of *Peromyscus*. Evolution 4:253-275.
- BOWEN, W. W. 1968. Variation and evolution of gulf coast populations of beach mice, *Peromyscus polionotus*. Bull. Fla. State Mus. 12: 1-91.
- BRADSHAW, W. N., AND W. W. GEORGE. 1969. The karyotype in *Peromyscus maniculatus nubiterrae*. J. Mamm. 50:822-824.
- BROWN, J. H., AND C. F. WELSER. 1968. Serum albumin polymorphisms in natural and laboratory populations of *Peromyscus*. J. Mamm. 49:420-426.
- BROWN, W. L., JR. 1957. Centrifugal speciation. Quart. Rev. Biol. 32:247-277.
- CANHAM, R. P., D. A. BIRDSALL AND D. G. CAMERON. 1970. Disturbed segregation at the transferrin locus of the deer mouse. Genet. Res. 16:355-357.
- CLARK, D. L. 1966. Fertility of a *Peromyscus maniculatus* × *Peromyscus melanotis* cross. J. Mamm. 47:340.

- DUFFEY, P. A. 1972. Chromosome variation in *Peromyscus*: A new mechanism. *Science* 176: 1333-1334.
- HALL, E. R., AND K. R. KELSON. 1959. The mammals of North America. The Ronald Press Co., New York, Vols. 1 and 2.
- HSU, T. C., AND F. E. ARRIGHI. 1968. Chromosomes of *Peromyscus* (Rodentia, Cricetidae). I. Evolutionary trends in 20 species. *Cytogenetics* 7:417-446.
- JENSEN, J. N., AND D. I. RASMUSSEN. 1971. Serum albumins in natural populations of *Peromyscus*. *J. Mamm.* 52:508-514.
- KING, J. A. (ed.). 1968. Biology of *Peromyscus* (Rodentia). American Society of Mammalogists, Special Publication No. 2.
- KREIZINGER, J. D., AND M. W. SHAW. 1970. Chromosomes of *Peromyscus* (Rodentia, Cricetidae). II. The Y chromosome of *Peromyscus maniculatus*. *Cytogenetics* 9:52-70.
- OHNO, S., D. WEILER, J. POOLE, L. CHRISTIAN AND C. STENIUS. 1966. Autosomal polymorphism due to pericentric inversions in the deer mouse (*Peromyscus maniculatus*) and some evidence of somatic segregation. *Chromosoma* 18:177-187.
- PATTON, J. L. 1967. Chromosome studies of certain pocket mice, genus *Perognathus* (Rodentia—Heteromyidae). *J. Mamm.* 48:27-37.
- RASMUSSEN, D. I. 1964. Blood group polymorphism and interbreeding in natural populations of the deer mouse, *Peromyscus maniculatus*. *Evolution* 18:219-229.
- . 1968. Genetics in biology of *Peromyscus* (Rodentia), p. 340-372. In King, J. A. (ed.), Publ. 2, American Society of Mammalogists.
- . 1970. Biochemical polymorphisms and genetic structure in populations of *Peromyscus*. *Symp. Zool. Soc. Lond.* 26:335-349.
- RASMUSSEN, D. I., J. N. JENSEN AND R. K. KOEHN. 1968. Hemoglobin polymorphism in the deer mouse, *Peromyscus maniculatus*. *Biochemical Genetics* 2:87-92.
- RASMUSSEN, D. I., AND R. K. KOEHN. 1966. Serum transferrin in polymorphism in the deer mouse. *Genetics* 54:1353-1357.
- SAVAGE, E., AND D. G. CAMERON. 1971. Blood group complexity: the Pm locus in *Peromyscus maniculatus*. *Anim. Blood Groups Biochem. Genet.* 2:23-29.
- SELANDER, R. K., M. H. SMITH, S. Y. YANG, W. E. JOHNSON AND J. B. GENTRY. 1971. Biochemical polymorphisms and systematics in the genus *Peromyscus*. I. Variation in the old-field mouse (*Peromyscus polionotus*). *Studies in Genetics VI. Univ. Texas Publ.* 7103:49-90.
- SINGH, R. P., AND D. B. McMILLAN. 1966. Karyotypes of three subspecies of *Peromyscus*. *J. Mamm.* 47:261-266.
- SMITH, M. H., R. K. SELANDER, W. E. JOHNSON AND Y. J. KIM. 1973. Biochemical polymorphism and systematics in the genus *Peromyscus*. III. Variation in the Florida deer mouse (*Peromyscus floridanus*), a Pleistocene relict. *J. Mamm.* 54:(in press).
- SPARKES, R. S., AND R. S. ARAKAKI. 1966. Intra-subspecific and intersubspecific chromosomal polymorphism in *Peromyscus maniculatus* (deer mouse). *Cytogenetics* 5:411-418.
- TE, G. A., AND W. D. DAWSON. 1971. Chromosomal polymorphism in *Peromyscus polionotus*. *Cytogenetics* 10:225-234.