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Establishment of a Deer Mouse (*Peromyscus maniculatus rufinus*) Breeding Colony from Wild-caught Founders: Comparison of Reproductive Performance of Wild-Caught and Laboratory-Reared Pairs

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The deer mouse (*Peromyscus maniculatus*) is a natural reservoir for several human pathogens, but little is known about the mechanisms by which such pathogens are maintained in nature. As a first step toward developing a colony of deer mice that were permissive for infection with Sin Nombre (SN) hantavirus, we collected 68 wild *P. maniculatus rufinus* from central New Mexico. Mice from this cohort were used to establish 26 breeding pairs, of which 85% were fertile. In subsequent generations, fertility decreased slightly to 73% (N = 59) in laboratory-reared F1 and F2 pairs. Wild-caught females delivered 7.2 litters on average (range, 1 to18), whereas laboratory-reared pairs delivered 5.5 (range, 1 to 13). The average time between pairing and first litter was 106 days for wild-caught animals, whereas that for laboratory-reared pairs was 71 days. None of the pairs displayed a seasonal breeding preference. Cannibalistic behavior increased from 5% in founders to 26% in laboratory-reared pairs. Mean litter size for wild-caught females was 4.3, whereas that for laboratory-reared dams was 4. Founding animals have been maintained in captivity for longer than 2 years, with only 2 deaths (4.8%). Our colony is competent for infection with SN virus. Thus, it should be useful for testing of models for maintenance of SN virus in wild rodents, and other aspects of the virus-host relationship.

The genus *Peromyscus* belongs to the family Muridae, subfamily Sigmodontineae. There are currently 49 species recognized within this genus, including the deer mouse, *Peromyscus maniculatus* (1). The deer mouse is a ubiquitous animal in North America, and is probably the most widely distributed indigenous small mammal on the continent (2). There are more than 60 formally described subspecies of deer mice that occupy a wide variety of forest, prairie, and desert habitats, from sea level to elevations of 14,000 feet (3). Deer mice can be divided into two chains of intergrading forms: a large-body, long-tailed group of forest inhabitants and a smaller short-tailed group that lives predominantly on prairies and in other sparsely-forested habitats (2). In New Mexico, there are two subspecies of deer mice, *P. maniculatus blandus*, which lives in the southern part of the state, and *P. maniculatus rufinus*, which is found in the north (4).

Peromyscus spp. are among the easiest of small mammals to maintain in captivity, which has made them popular for laboratory experimentation (1). Several groups have brought wild-caught deer mice into the laboratory and successfully established breeding colonies (3, 5-8). These colonies have been used to better understand various aspects of mammalian reproduction, growth and development, endocrinology, behavior, mammalian thermoregulation, torpor, metabolism, alcohol catabolism, immunology, and genetics (3). By establishing laboratory colonies of wild rodents, it is possible to cross-test models and observations involving natural populations in topics ranging from ecology, metabolism, and energetics to pathogen-host relationships (3).

Members of the genus *Peromyscus* serve as natural reservoirs for several important human pathogens, including the etiologic agents for Lyme disease, granulocytic ehrlichiosis, babesiosis, bartonellosis, and hantavirus cardiopulmonary syndrome (3, 9-15). As a result, experimental models using *Peromyscus* species have assumed a substantial role in investigations of the ecology and host-parasite relationships of zoonotic diseases (9, 12, 16-18).

In 1993, deer mice were found to be the predominant carrier of the highly pathogenic Sin Nombre (SN) hantavirus (10, 11). This discovery led to promulgation of new guidelines for safe collection and handling of wild rodents. The guidelines state that, to establish a new deer mouse colony, one should subject the founders to quarantine and test them for antibodies to SN virus. Only specimens that lack such antibodies after a five-week quarantine period should be brought into a laboratory facility (17, 19-21).

The objective of the study reported here was to describe the establishment and reproductive performance of the first breeding colony of *Peromyscus maniculatus rufinus* using wild-caught founding mice of New Mexico origin. Our first use of this colony was to establish an animal infection model for SN virus, which we are using to study the pathogenesis of this virus in its reservoir host (18).

Materials and Methods

Trapping and quarantine of founder animals. Wild deer mice used to found our colony consisted of two geographically distinct populations from New Mexico: one trapped near Gallup

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("Gallup" colony: latitude, 35°31.85'N; longitude, 108°46.07'W; elevation, 1972 m); and the other originating from the Manzano mountains ("Manzano" colony: latitude. 34°37.37' N; longitude, 106°24.78' W; elevation, 2621 m). The two trap sites were separated by 240 km. We did not interbreed the two colonies in this study. Each founding animal was quarantined for a minimum of five weeks after capture from the field and tested for anti-SN virus antibodies at the conclusion of quarantine to ensure that no infected mice were used in the establishment of the breeding colony. The protocol for capture and quarantine of these animals has been described (17).

Animal maintenance. Mice were maintained in the Biology Animal Research Facility at the University of New Mexico, which is a non-pathogen-free facility, using an approved IACUC protocol. All mice studied were used and cared for humanely. The temperature of the suite used to maintain the colony was maintained at a constant 21.1°, with a 15:9-h light:dark cycle. We housed the mice in standard polypropylene lab cages (48.3× 26.7 × 15.6 cm; Ancare Corp., Bellmore, N.Y.) equipped with recycled paper bedding (Care Fresh, Harlan, Madison, Wis.) and two cotton nestlets (Ancare Corp.) and a wire top. Care Fresh bedding was used in place of the more standard wood shavings because mice create effective nests in this material, which served to increase privacy during breeding as well as avoid dust associated with some alternative types of bedding. Formulab Diet 5008 (Lab Diet, PMI Nutrition International Inc., Brentwood, Mo.) was provided ad libitum within the cage. We also provided lettuce twice weekly and sunflower seeds three times weekly. The Formulab Diet consisted of 23% crude protein and 6.5% crude fat. Water bottles were replaced every seven to 10 days. Bedding was changed every two weeks for non-breeding mice and every three weeks for breeding pairs or at the time of weaning of a litter to minimize stress to the breeding pair and pups. The unusual absorbency of the bedding allowed the nests to remain sanitary for longer periods, which allowed us to lessen the stress associated with more frequent changes of bedding.

Animal husbandry and maintenance of data. Wild-caught deer mice brought to the laboratory from the field were initially housed individually for seven to 10 days to acclimate to the laboratory setting. Following this acclimation period, we paired females with males of approximately equal mass. We arranged 26 breeding pairs, with 20 from the Manzano group and 6 from the Gallup group. Once a male and female were paired, we did not remove the males from the cage. We established laboratory-reared pairs in non-random fashion. To maintain heterozygosity in the colony, we did not pair mice that shared common laboratory ancestors. In addition, we selected the offspring of the most prolific parents for subsequent pairings. We isolated the breeders into separate cubicles and limited visitations to a maximum of one per day to limit stress to the breeders.

We recorded the data for each breeding pair on a note card attached to the cage. Each card contained the identification number of each breeder (ear tag number), the generation of the breeding pair, the date paired, the date each litter was born, the number of pups in each litter and their sex, cannibalism of a litter, and the date each litter was weaned. We weaned litters at 21 to 28 days of age, after they were shown to be self-feeding. To ensure that they were able to obtain water after we moved them to new cages, we provided weaned pups a generous quantity of lettuce. Pups were ear tagged either on the day of weaning or within a week after being weaned, using identification tags and pliers (Gey Band and Tag Co., Norristown, Pa.). Some groups discourage the use of ear tags because they can be inadvertently torn from the ear (22). However, in our experience with over 1,400 mice, not a single ear tag has been lost from a tagged animal.

Sentinel testing of colony mice. To screen our colony for common mouse pathogens, we euthanized an adult male and an adult female mouse of the F2 generation animals by use of methoxyfluorane anesthesia followed by exsanguination. Blood was collected by cardiac puncture. Serum was diluted fivefold with phosphate-buffered saline for serologic testing. Enzyme-linked immunosorbent assays were done to screen for the following pathogens: mouse hepatitis virus, Sendai virus, pneumonia virus of mice, reovirus 3, Theiler's murine encephalomyelitis virus, murine ectromelia virus, murine adenoviruses 1 and 2, polyoma virus, *Mycoplasma pulmonis*, parvovirus, rotavirus epizootic diarrhea of infant mice (EDIM), lymphocytic choriomeningitis virus, *Entamoeba cuniculi*, cilia-associated respiratory bacillus, and *Clostridium piliforme*. Parasitology testing included examination of a tape preparation for pinworm ova, subgross examinations of pelage and cecal contents for parasites, and use of the concentration method for ova and parasite examination of feces. Bacteriology tests included culture of cecal specimens for *Salmonella* and *Citrobacter* spp., *Pseudomonas aeruginosa*, and *Campylobacter* spp.; and of the nasopharynx for *Haemophilus*, *Pasteurella* and *Bordetella* spp. Histopathologic changes were was assessed by screening sections of lung, liver, kidney, stomach, duodenum, pancreas, jejunum, ileum, cecum, and colon for lesions.

Statistical calculations. We used an unpaired two-tailed *t* test to make comparisons of average numbers of litters per breeding pair, pups per litter, days between pairing and first litter, mass, total body length, tail length, ear length, and right hind foot length. A paired two-tailed *t* test was used to compare average mass before and after quarantine. Comparisons of fertility, cannibalism, and male-to-female ratio of offspring produced were carried out, using a two-by-two table. If any given value in the table was less than five, a two-tailed Fisher's exact *P* value was used, or if all values were greater than five, a Mantel-Haeszel two-tailed *P* value was used. A difference was considered significantly different if $P < 0.05$.

Results

Morphologic characteristics. Since little information is available in literature about the characteristics of *P. maniculatus rufinus*, we examined the Gallup and Manzano groups of mice morphologically (Table 1). Upon capture, sexually mature founders had a mean mass of 20.1 ± 3.4 g (Manzano) or 19.4 ± 1.8 g (Gallup) and tail (65.3 ± 5.8 mm versus 58.1 ± 4.3 mm) and hind foot (20.2 ± 0.9 mm versus 19.1 ± 0.7 mm) lengths. The differences in tail length and right hind foot length between Gallup and Manzano founders were significant ($P < 0.0001$ for both categories). Males and females were indistinguishable in these characteristics. During the five-week quarantine period, sexually mature adults (N = 22) gained 3.0 ± 2.9 g ($P = 0.0001$) from their weight at capture, perhaps reflecting the availability of food. By the F1 and F2 generations, however, mean adult body mass for Manzano laboratory-reared mice was 28.6 ± 8.2 g, with a range of 15.2 to 48.0 g. Mean body mass of Manzano founders was 8.5 g less than that of Manzano laboratory-reared mice ($P < 0.0001$). Mean weight at weaning (21 to 28 days old) for Manzano labo-

Table 1. Mean (± SD) morphologic characteristics of wild-caught and laboratory-reared *Peromyscus maniculatus rufinus*

	Mass (g)	Total length (mm)	Tail length (mm)	Ear length (mm)	Hind foot length(mm)
Wild-caught (Gallup and Manzano)	20.0 ± 3.1 (12.0 - 29.5) (N = 83)	ND	64.0 ± 6.2 (52.0 - 84.0) (N = 84)	ND	20.0 ± 1.0 (16.0 - 21.0) (N = 84)
Manzano wild-caught	20.1 ± 3.4 (12.0 - 29.5) (N = 68)	155.7 ± 8.5 (134.0 - 178.0) (N = 69)	65.3 ± 5.8 (55.0 - 84.0) (N = 84)	17.8 ± 1.7 (13.0 - 21.0) (N = 68)	20.2 ± 0.9 (16.0 - 21.0) (N = 69)
Gallup wild-caught	19.4 ± 1.8 (17.0 - 23.0) (N = 15)	ND	58.0 ± 4.3 (52.0 - 65.0) (N = 15)	ND	19.1 ± 0.7 (18.0 - 20.0) (N = 15)
Manzano vs. Gallup: (wild-caught)	$P = 0.42$	ND	$P < 0.0001$	ND	$P < 0.0001$
Lab-reared Manzano (F1-F2)	28.6 ± 8.2 (15.2 - 48.0) (N = 24)	158.6 ± 10.3 (140.0 - 187.0) (N = 23)	65.8 ± 4.7 (58.0 - 76.0) (N = 23)	17.9 ± 1.4 (15.0 - 20.0) (N = 24)	20.7 ± 0.8 (19.0 - 22.0) (N = 24)
Lab-reared Manzano (F1-F2) vs. wild-caught Manzano	$P < 0.0001$	$P = 0.17$	$P = 0.69$	$P = 0.73$	$P = 0.03$
Lab-reared Manzano (F1-F2) at weaning (21-28 d old)	14.1 ± 1.8 (10.5 - 21.0) (N = 129)	ND	ND	ND	ND

ND = Not done.
Values in parentheses for each category: the upper set of values listed in parentheses indicates the maximum and minimum values reported; the lower set of values listed in parentheses indicates the sample size.

ratory-reared mice was 14.1 ± 1.8 g. Difference was not significant between males and females for this category.

Temperament. The mice described in this study proved considerably more difficult to handle than common laboratory mice (*Mus musculus)*. They were extremely quick and agile, and capable of jumping a vertical height of approximately 30 cm. The wild-caught mice did not permit themselves to be handled, and it was not uncommon for these animals to attempt to bite the handler. The laboratory-reared (F1 and F2 generation) animals were more tolerant of handling, but became aggressive after experiencing several manipulations (injections, phlebotomy). Despite the aggressive tendencies of these animals, if handled properly, the risk to the handler of being bitten was negligible. We found that the best technique for handling a mouse was as follows: immobilize the mouse by covering the head and shoulders with the palm of one hand; pick up the mouse by the scruff of the neck, using the thumb and first finger of the other hand, being careful not to collapse the trachea; and immobilize the mouse by placing the second and third fingers along the mouse's back and securing the tail between the third and fourth fingers. Deer mice that were experimentally infected with hantavirus were handled using the aforementioned technique (18). When handling infected deer mice, workers wore thick neoprene/latex gloves (Cat. No. 11 392 33C, Fischer Scientific, Palatine, Ill.) to prevent a bite from breaking the skin.

Longevity and health. After roughly two years of captivity (until July 2000), only two (3.9%) of 52 breeders died of natural causes. A single animal developed a neoplastic disease, a thoracic mass that grew markedly to a final dimension of 4 cm within 8 days. This tumor resembled a benign Schwannoma by microscopic examination. Overall, we have experienced no appreciable health problems, including outbreaks of infectious diseases. Periodic spot testing of groups of animals did not reveal SN virus antibodies, as expected, in any of the wild-caught or laboratory-reared mice. A sentinel screen for common murine pathogens and pathologic evidence of infection was conducted on two F2 generation animals (a male and a female), but evidence of bacterial, viral, or parasitic pathogens was not found. Furthermore, histologic screening revealed no significant lesions in the lung, liver, kidney, stomach, duodenum, pancreas, jejunum, ileum, cecum, or colon.

Reproductive performance. The reproductive performance of our mice is summarized in Table 2. To increase statistical power, we pooled the data for wild-caught pairs and laboratory-reared pairs from the Gallup and Manzano colonies since there were no significant differences between the 2 colonies, either for the wild-caught or the laboratory-reared (F1 or F2 generation) animals.

Wild-caught pairs had a higher incidence of fertility (percentage of fertile pairs) than did laboratory-reared pairs. Of the 26 wild-caught pairs, 21 (85%) were fertile, and 43 (73%) of the 59 laboratory-reared pairs were fertile (Table 2). The wild-caught pairs were also better parents than the laboratory-reared pairs, with cannibalism or desertion of young occurring in 5% of the wild-caught pairs, compared with 26% in the laboratory-reared pairs (Table 2). However, these differences were not significant (NS). In each case where cannibalism or desertion of young was observed, no offspring survived to weaning age.

The number of pups born per litter in the wild-caught pairs and laboratory-reared pairs ranged from 1 to 8 (Table 2). Mean litter size for wild-caught pairs was 4.3 ± 1.3 pups/litter, whereas laboratory-reared pairs averaged 4.5 ± 1.7 pups/litter (NS). The ratio of female to male pups was 1.00:1.10 for the wild-caught pairs and 1.01:1.00 for the laboratory-reared pairs (NS). The productivity of fertile pairs was similar for wild-caught and laboratory-reared pairs. The 22 wild-caught pairs that were fertile produced 721 pups in a span of roughly two years (1.4 pups/female/month), whereas the 43 laboratory-reared pairs that were fertile produced 740 pups in a period of approximately one year (1.4 pups/female/month) (Table 2). We kept our colony size at roughly 300 mice.

Table 2. Reproductive characteristics of wild-caught and laboratory-reared breeders

	Wild-caught founding pairs	Laboratory-reared pairs	Wild-caught vs. laboratory-reared pairs
Total pairs	26	59	
Fertility incidence (percent pairs fertile)	0.85 (22/26)	0.73 (43/59)	$P = 0.24$
Days (mean) between pairing and first litter	106 ± 130 (24 - 530)	71 ± 68 (24 - 342)	$P = 0.22$
Mean number of litters/pair	7.2 ± 5.9 (1 - 18*)	5.5 ± 4.0 (1 - 13*)	$P = 0.21$
Total litters	166	171	
Mean number of pups/litter	4.3 ± 1.3 (1 - 8)	4.5 ± 1.7 (1 - 8)	$P = 0.4$
Total pups born	721	740	
Incidence of cannibalism	0.05	0.26	$P = 0.07$
Female pups, male pups	291, 323 (1.00 : 1.10)	221, 219 (1.01 : 1.00)	$P = 0.36$

For groups percentage of fertile and percentage cannibalized: in parenthesis is number with given trait over total number tested. For female and male pups, the value in parentheses indicates the proportion of female to male pups. The remaining values in parenthesis indicate the maximum and minimum values reported for a given category. The asterisk (*) indicates that some breeders are still actively producing litters. All mean values list ± SD.

The average number of days between pairing animals to breed and the birth of the first litter was 106 ± 130 days for wild-caught pairs and 71 ± 68 days for laboratory-reared pairs (NS; Table 2). In both groups, the shortest interval was 24 days; the longest interval was 530 days for wild-caught pairs and 342 days for laboratory-reared pairs (Table 2).

The wild-caught pairs averaged 7.2 ± 5.9 litters/pair, and the laboratory-reared mice averaged 5.5 ± 4.0 litters/pair (NS; Table 2). The largest number of litters produced by a dam was recorded for a wild-caught animal that delivered 18 consecutive litters between November 1998 and February 2000. This female also delivered a single litter shortly after being trapped in the wild, bringing the total to 19 litters overall. Several laboratory-reared dams have produced 13 litters and may eventually reach totals similar to or greater than those seen for the wild-caught dams.

Discussion

Although at the time of this writing, wild-caught and laboratory-reared pairs continue to breed, we have thus far noticed a trend in fertility. Although the difference was not significant, the incidence of fertility in our wild-caught pairs (85%) appeared to be higher than that of our laboratory-reared pairs (73%) (NS). This finding is in contrast to Price's study where it was found that only 67.4% of the wild-caught pairs of *P. maniculatus bairdii* were fertile, whereas the semi-domestic (mice bred in captivity for 17 years) pairs had a 93.3% incidence of fertility (6). The fertility in our wild-caught mice supports the observation that desert-caught deer mice are more prolific breeders than are prairie and woodland deer mice from latitudes above 46 degrees (5, 22). Other colonies of deer mice have retained endogenous rhythms of breeding in the laboratory among wild-caught specimens, with a preference for spring to early fall and a lag in breeding during the late fall and winter months (22). Several of our wild-caught pairs (N = 13) that were established between October 1998 and December 1998 did not have noticeable lag in breeding. Since our colony is housed in a basement room devoid of natural lighting, the animals were not exposed to natural light-dark cycles. The absence of such cues for breeding cessation may explain why we did not see a lag in breeding during the winter months.

Although the differences in reproductive performance between our wild-caught and laboratory-reared pairs were not significant, we did notice several trends. The incidence of cannibalism increased, and the time between pairing to first litter decreased in our laboratory-reared pairs. The average number of pups per litter, the average number of litters produced per dam, and the ratio of female to male pups produced per litter were not affected by laboratory breeding. Similar observations have been reported for other deer mouse colonies (6, 8, 23). Differences in these characteristics may become apparent as our colony continues to breed to later generations. However, laboratory breeding resulted in an increase in cannibalization and abandonment of offspring. An increase in cannibalistic behavior associated with domestication has been reported for *P. m. bairdii* (6). Price speculated that cannibalism increased with domestication because in the wild a dam will rarely deliver more than 3 or 4 litters, but in a laboratory colony, a dam is capable of producing more than 10 litters. If dams were to cannibalize an equal proportion of litters in both cases, the wild dam will leave considerably fewer offspring to potentially breed than a laboratory female. Therefore, the chance that an offspring from a cannibalistic dam will survive long enough to reproduce is greater in a laboratory setting. This theory assumes that a genetic association exists for cannibalistic behavior. In the laboratory, the problems posed by the increase in cannibalistic behavior, which is seen to accompany domestication, are offset by the ease by which cannibalistic parents can be replaced with new pairs.

Our mice have proven to be robust. In over two years of captivity, only two of 52 (3.9%) wild-caught mice have died of natural causes. In addition, the average mass of adult mice increased by 8.5 g in the laboratory-reared Manzano mice, compared with the Manzano wild-caught mice. We saw a single neoplasm, a benign Schwannoma, in our population. We may observe additional neoplasms as our mice live to an older age than would be expected in the wild. Sentinel testing revealed our colony to be free of common viral, bacterial, and parasitic pathogens. Our mice may prove to be useful for studies of aging or other applications that require long life spans. In addition, we have used the majority of our laboratory-reared mice (N > 800) in experiments where they were housed in an outdoor biocontainment facility (17). Our mice routinely survive extreme summer and winter temperatures (41.1°, -7.6°) for periods of 5 weeks to 1 year (data not shown). During the winter, we have found that mice we have exposed to outdoor temperatures are often found in torpor, indicating that our mice have not lost this desirable physiologic response during laboratory breeding (data not shown).

Considering the widespread distribution of *Peromyscus* spp. in North America and the role of *Peromyscus* spp. as carriers of important human pathogens, their adaptation to the laboratory will advance our understanding of these host-pathogen relationships and may contribute to the development of new strategies that could lessen the impact of these pathogens on humans (18). To our knowledge, our deer mouse colony is the first that is known to be competent for infection with SN virus, and has allowed us to carry out a number of studies that have expanded our understanding of the pathogenesis of SN virus, ranging in scope from the natural history of infection to the development of vaccines (18, 24). Deer mice also have many other desirable

qualities for research purposes. They have been used in studies of mammalian reproduction, growth and development, endocrinology, behavior, thermoregulation, torpor, metabolism, alcohol catabolism, immunology, imprinting, and genetics (3, 25, 26).

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References

1. **Millar, J. S. 1989.** Reproduction and development, p. 169-132. *In* G. L. Kirkland, Jr., and J. N. Layne (ed.), Advances in the study of *Peromyscus*. Texas Tech University Press, Lubbock, Tex.
2. **King, J. A. (ed).** 1968. Biology of *Peromyscus* (Rodentia). American Society of Mammalogists, Washington, D. C.
3. **Joyner, C. P., L. C. Myrick, J. P. Crossland, and W. D. Dawson.** 1998. Deer mice as laboratory animals. ILAR J. **39:**322-330.
4. **Findley, J. S., A. H. Harris, D. E. Wilson, and C. Jones (ed.).** 1975. Mammals of New Mexico, 1st ed. University of New Mexico Press, Albuquerque, N. Mex.
5. **Dice, L. R.** 1933. Fertility relationships between some of the species and subspecies of mice in the genus *Peromyscus*. J. Mammal. **14:**298-305.
6. **Price, E.** 1966. The effect of reproductive performance on domestication of the prairie deer mouse, *Peromyscus maniculatus bairdii*. Evolution **21:**762-770.
7. **Dark, J., P. G. Johnston, M. Healy, and I. Zucker.** 1983. Latitude of origin influences photoperiodic control of reproduction of deer mice (*Peromyscus maniculatus*). Biol. Reprod. **28:**213-220.
8. **Millar, J. S., and D. A. L. Threadgill.** 1986. The effect of captivity on reproduction and development in *Peromyscus maniculatus*. Can. J. Zool. **65:**1713-1719.
9. **Telford, S. R. III, and A. Spielman.** 1993. Reservoir competence of white-footed mice for *Babesia microti*. J. Med. Entomol. **30:**223-227.
10. **Childs, J. E., T. G. Ksiazek, C. F. Spiropoulou, J. W. Krebs, S. Morzunov, G. O. Maupin, K. L. Gage, P. Rollin, J. Sarisky, R. Enscore, C. J. Peters, and S. T. Nichol.** 1994. Serologic and genetic identification of *Peromyscus maniculatus* as the primary rodent reservoir for a new hantavirus in the southwestern United States. J. Infect. Dis. **169:**1271-1280.
11. **Nerurkar, V. R., J. W. Song, K. J. Song, J. W. Nagle, B. Hjelle, S. Jenison, and R. Yanagihara.** 1994. Genetic evidence for a hantavirus enzootic in deer mice (*Peromyscus maniculatus*) captured a decade before the recognition of hantavirus pulmonary syndrome. Virology. **204:**563-568.
12. **Kosoy, M. Y., R. L. Regnery, T. Tzianabos, E. L. Marston, D. C. Jones, D. Green, G. O. Maupin, J. G. Olson, and J. E. Childs.** 1997. Distribution, diversity, and host specificity of *Bartonella* in rodents from the Southeastern United States. Am. J. Trop. Med. Hyg. **57:**578-588.
13. **Mills, J. N., T. G. Ksiazek, B. A. Ellis, P. E. Rollin, S. T. Nichol, T. L. Yates, W. L. Gannon, C. E. Levy, D. M. Engelthaler, T. Davis, D. T. Tanda, J. W. Frampton, C. R. Nichols, C. J. Peters, and J. E. Childs.** 1997. Patterns of association with host and habitat: antibody reactivity with Sin Nombre virus in small mammals in the major biotic communities of the southwestern United States. Am. J. Trop. Med. Hyg. **56:**273-284.
14. **Nicholson, W. L., S. Muir, J. W. Sumner, and J. E. Childs.** 1998. Serologic evidence of infection with *Ehrlichia* spp. in wild rodents (*Muridae: Sigmodontinae*) in the United States. J. Clin. Microbiol. **36:**695-700.
15. **Stafford, K. C., 3rd, R. F. Massung, L. A. Magnarelli, J. W. Ijdo, and J. F. Anderson.** 1999. Infection with agents of human granulocytic ehrlichiosis, Lyme disease, and babesiosis in wild white-footed mice (*Peromyscus leucopus*) in Connecticut. J. Clin. Microbiol. **37:**2887-2892.
16. **Song, J. W., L. J. Baek, D. C. Gajdusek, R. Yanagihara, I. Gavrilovskaya, B. J. Luft, E. R. Mackow, and B. H. Hjelle.** 1994. Isolation of pathogenic hantavirus from white-footed mouse (*Peromyscus leucopus*). Lancet **344:**1637.
17. **Botten, J., R. Nofchissey, H. Kirkendoll-Ahern, P. Rodriguez-Moran, I. A. Wortman, D. Goade, T. Yates, and B. Hjelle.** 2000. Outdoor facility for quarantine of wild rodents infected with hantavirus. J. Mammal. **81:**250-259.
18. **Botten, J., K. Mirowsky, D. Kusewitt, M. Bharadwaj, J. Yee, R. Ricci, R. M. Feddersen, and B. Hjelle.** 2000. Experimental infection model for Sin Nombre hantavirus in the deer mouse (*Peromyscus maniculatus*). Proc. Natl. Acad. Sci. USA **97:**10578-10583.
19. **Centers for Disease Control and Prevention.** 1994. Laboratory management of agents associated with hantavirus pulmonary syndrome: interim biosafety guidelines. Morbid. Mortal. Wkly. Rep. **43:** RR-7, 1-7.
20. **Mills, J. N., J. E. Childs, T. G. Ksiazek, C. J. Peters, and W. M. Velleca.** 1995. Methods for trapping and sampling small mammals for virologic testing. United States Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, Atlanta, Ga.
21. **Mills, J. N., T. L. Yates, J. E. Childs, R. Parmenter, T. G. Ksiazek, P. E. Rollin, and C. J. Peters.** 1995. Guidelines for working with rodents potentially infected with hantavirus. J. Mammal. **76:**716-722.
22. **Barry, W. J.** 1975. Bringing the deer mouse from the field to the lab. Lab. Anim. **14:**20-23.
23. **Ribble, D. O. and J. S. Millar. 1992**. Inbreeding effects among inbred and outbred laboratory colonies of *Peromyscus maniculatus*. Can. J. Zool. **70:**820-824.
24. **Bharadwaj, M., K. Mirowsky, J. Botten, B. Masten, J. Yee, C. R. Lyons, and B. Hjelle.** Submitted for publication.
25. **Vrana, P. B., X. J. Guan, R. S. Ingram, and S. M. Tilghman.** 1998. Genomic imprinting is disrupted in interspecific *Peromyscus* hybrids. Nat. Genet. **20:**362-365.
26. **Vrana, P. B., J. A. Fossella, P. Matteson, T. del Rio, M. J. O'Neill, and S. M. Tilghman.** 2000. Genetic and epigenetic incompatibilities underlie hybrid dysgenesis in *Peromyscus*. Nat. Genet. **25:** 120-124.