# A Longitudinal Study of Sin Nombre Virus Prevalence in Rodents, Southeastern Arizona

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We determined the prevalence of Sin Nombre virus antibodies in small mammals in southeastern Arizona. Of 1,234 rodents (from 13 species) captured each month from May through December 1995, only mice in the genus *Peromyscus* were seropositive. Antibody prevalence was 14.3% in 21 white-footed mice (*P. leucopus*), 13.3% in 98 brush mice (*P. boylii*), 0.8% in 118 cactus mice (*P. eremicus*), and 0% in 2 deer mice (*P. maniculatus*). Most antibody-positive mice were adult male *Peromyscus* captured close to one another early in the study. Population dynamics of brush mice suggest a correlation between population size and hantavirus-antibody prevalence.

We examined the role of rodent species as natural reservoirs for hantaviruses in southeastern Arizona to identify the species infected with hantavirus, describe the characteristics of infected animals, and assess temporal and intraspecific variation in infection rates.

## Trapping Procedures

Beginning in May 1995, we established four permanent trapping webs on the Santa Rita Experimental Range in the Santa Rita Mountains of southeastern Arizona (Pima County). The design of these webs, as well as details on mark-recapture trapping procedures, are described by Mills et al. (this issue, pp. 95-101). Elevations of the trapping webs are approximately 1,250 m to 1,379 m. All trapping webs contained approximately equal amounts of two main vegetation types, semidesert grassland (characterized by Lehmann lovegrass [*Eragrostis lehmanniana*], three-awn [*Aristida* spp.], prickly pear cactus [*Opuntia* spp.], and mesquite [*Prosopis velutina*]) and oak riparian (characterized by deciduous trees including Arizona white oak [*Quercus arizonica*] and netleaf hackberry [*Celtis reticulata*]; occurs in drainage areas where water flow is seasonally intermittent), occur at these elevations. Web 1 was operated from May 1995 through September 1996, when trapping was discontinued because of low trap success, and webs 2, 3, and 4 were operated from May 1995 through December 1997.

From May 1995 through September 1996, webs 1 and 4 were considered controls. Captured mice from these webs were identified, marked, weighed, and measured, but not bled. Beginning in November 1996, we began collecting blood samples from mice on web 4. The bleeding process had little effect on survival (1). The methods for obtaining blood samples and the serologic testing of samples for hantavirus antibodies are described in Mills et al. (this issue, pp. 95-101).

We examined population dynamics of common species infected with Sin Nombre virus (SNV) using data from three webs that were trapped continuously from May 1995 through December 1997. Using the minimum number of rodents known to be alive during a 3-day trapping session, we calculated an index of population size by taking the total number of rodents captured during each 3-day trapping session and adding to that sum the number of rodents captured on at least one previous and one subsequent session (2). The minimum number of hantavirus antibody–positive rodents was calculated in the same way. We estimated standing prevalence for each trapping session by dividing the minimum number of antibody-positive rodents by the minimum number of rodents known to be alive.

Capture histories were used to estimate survivorship of the trappable population. These estimates were calculated as the percentage of

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rodents known to be alive a given number of months after initial capture. Although we refer to these estimates as survival rates, they are more accurately described as trapping web residency rates, as deaths cannot be distinguished from emigration.

## Trapping Results

Between May 1995 and December 1997, 1,234 rodents were captured a total of 3,226 times, and 1,231 blood samples were obtained (Table 1). Bailey's pocket mouse (*Chaetodipus baileyi*) was the most common species captured (57% of rodents captured). Common murid rodents captured included white-throated wood rat (*Neotoma albigula*) (10%) and four species in the genus *Peromyscus* (27%). The cactus mouse (*P. eremicus*) was the most common *Peromyscus* species captured (12%) followed closely by the brush mouse (*P. boylii*) (11.5%). Deer mice (*P. maniculatus*) and white-footed mice (*P. leucopus*) were also captured but in low numbers (<3% each). Other species captured infrequently (<1%) included the fulvous harvest mouse (*Reithrodontomys fulvescens*), yellow-nosed cotton rat (*Sigmodon ochrognathus*), desert pocket mouse (*C. penicillatus*), and Merriam's kangaroo rat (*Dipodomys merriami*).

## Prevalence of Antibody-Positive Rodents

Only rodents in the genus *Peromyscus* had antibodies reactive with SNV; however, antibody prevalence varied considerably among species within this genus (Table 1). Most (13 of 17) antibody-positive rodents were brush mice. One cactus mouse and three white-footed mice were also antibody positive. With the exception of one white-footed mouse, all antibody-positive rodents were captured in oak riparian vegetation. Antibody-positive rodents were captured on all three webs from which animals were bled; however, most (65%) were first captured on web 2 early in the study (May to June 1995). The farthest distance between trap stations where these web 2–rodents were captured was approximately 190 m, and half were captured at three adjacent trap stations along one transect line.

All antibody-positive rodents were positive upon first capture, and most (58%) were never recaptured. Antibody-positive animals that were recaptured were caught an average of 3.8 times (standard deviation = 2.03, n = 7, range 2 to 8). All but one of the recaptured animals remained antibody positive on subsequent captures. The exception, a male brush mouse, was antibody negative on its three recaptures.

## Characteristics of Infected Populations

Antibody-positive rodents were more likely to be male than female and were predominately adult (Table 2). The ratio of male to female among antibody-positive brush mice was significantly higher than that among the total sample (chi-square with Yates' correction = 7.97,

Table 1. Prevalence of antibodies to Sin Nombre virus among wild rodents in southeastern Arizona, May 1995-December 1997

| Family/Species | Common name | No. rodents trapped and released (total captures)[a] | No. tested | No. positive (%) |
|---|---|---|---|---|
| Heteromyidae | | | | |
| *Dipodomys merriami* | Merriam's kangaroo rat | 1 (2) | 0 | 0 (0.0) |
| *Chaetodipus* spp. | Pocket mice | | | |
| *C. baileyi* | Bailey's pocket mouse | 704 (715) | 329 | 0 (0.0) |
| *C. penicillatus* | Desert pocket mouse | 25 (27) | 7 | 0 (0.0) |
| Subtotal | | 730 (744) | 336 | 0 (0.0) |
| Muridae | | | | |
| *Neotoma albigula* | White-throated wood rat | 126 (126) | 51 | 0 (0.0) |
| *Onychomys torridus* | Southern grasshopper mouse | 7 (7) | 7 | 0 (0.0) |
| *Peromyscus* spp. | White-footed mice | | | |
| *P. boylii* | Brush mouse | 137 (142) | 98 | 13 (13.3) |
| *P. eremicus* | Cactus mouse | 151 (152) | 118 | 1 (0.8) |
| *P. leucopus* | White-footed mouse | 29 (30) | 21 | 3 (14.3) |
| *P. maniculatus* | Deer mouse | 6 (6) | 2 | 0 (0.0) |
| *Reithrodontomys fulvescens* | Fulvous harvest mouse | 16 (16) | 12 | 0 (0.0) |
| *Sigmodon ochrognathus* | Yellow-nosed cotton rat | 11 (11) | 5 | 0 (0.0) |
| Subtotal | | 483 (490) | 314 | 17 (5.4) |
| Total | | 1,213 (1,234) | 650 | 17 (2.6) |

[a]Total captures include rodents trapped and released and those that died during handling.

Table 2. Distribution of antibody-positive versus all brush mice, cactus mice, and white-footed mice, by sex and age

| Characteristic | Brush mice No. (%) positive | Brush mice Total no. (%) | Cactus mice No. (%) positive | Cactus mice Total no. (%) | White-footed mice No. (%) positive | White-footed mice Total no. (%) |
|---|---|---|---|---|---|---|
| Sex | | | | | | |
| Male | 12 (92) | 51 (52) | 0 | 59 (50) | 3 (100) | 10 (48) |
| Female | 1 ( 8) | 47 (48) | 1 (100) | 59 (50) | 0 | 11 (52) |
| Age | | | | | | |
| Juvenile | 0 | 12 (12) | 0 | 22 (18) | 0 | 2 (10) |
| Young adult | 1 (8) | 38 (40) | 0 | 48 (41) | 0 | 3 (14) |
| Adult | 12 (92) | 48 (48) | 1 (100) | 48 (41) | 3 (100) | 16 (76) |

degrees of freedom = 1, p = 0.005), and significantly more adults were antibody positive than would be expected from the distribution of age classes among the total sample (chi-square = 9.69, df = 2, p = 0.002). Although the sample size is too small for significance testing, these patterns hold for white-footed mice as well (Table 2).

## Brush Mice Population Dynamics and Temporal Pattern of Infection

The number of brush mice varied both by season and by year. The minimum number known to be alive was relatively high during the first 10 months of the study, May 1995 through March 1996 (Figure 1). The number of brush mice declined during the spring of 1996 and remained low until the fall, when the numbers increased but never reached the levels of the previous year. Captures for the next year followed a similar pattern with increased numbers during fall and winter (October through March), followed by a steady spring decline and summer low.

The minimum number of brush mice known to be infected was highest during the initial part of our study (Figure 1). Eleven of the 13 hantavirus antibody–positive mice were first captured between May and September 1995, gradually disappearing from the population. By October 1996, no animals were known to be infected on any of our trapping webs. One new antibody–positive brush mouse was captured in November 1996 and another in November 1997. Similarly, the estimated standing prevalence of hantavirus antibody ranged from 40% in May 1995 to 0% in both October 1996 and April through October 1997 (mean = 8.25%).

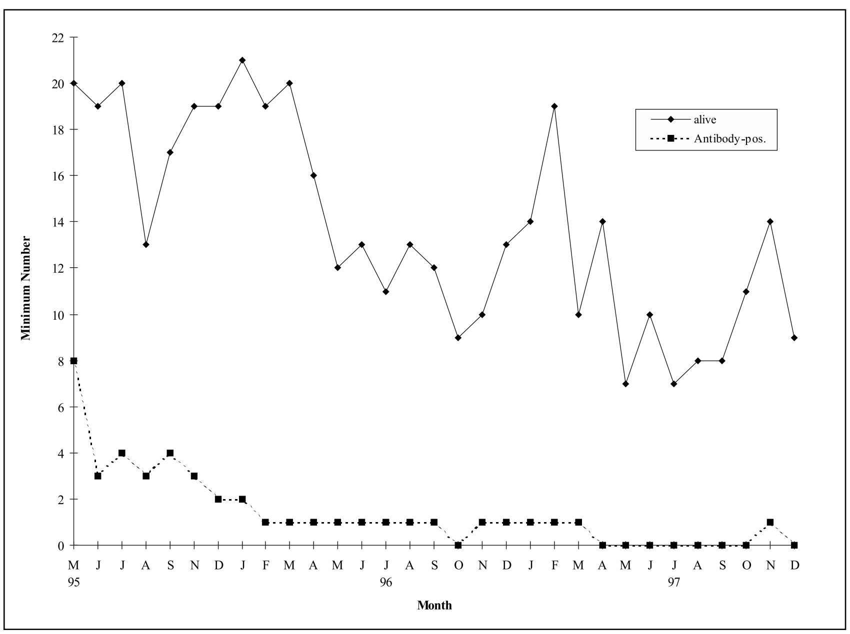


Figure 1. Population trends of brush mice, as determined by the minimum number known to be alive, Santa Rita Experimental Range, southeastern Arizona, May 1995–December 1997.

Male and female brush mice showed similar rates of survivorship with an approximately 50% turnover rate around 2 months after initial capture (Figure 2). Hantavirus antibody–positive mice did not survive quite as long; the 50% turnover rate occurred approximately 1 month after initial capture. By 6 months after first capture, approximately 80% of all rodents had disappeared. A small percentage of brush mice continued to be captured for more than 1 year after tagging.

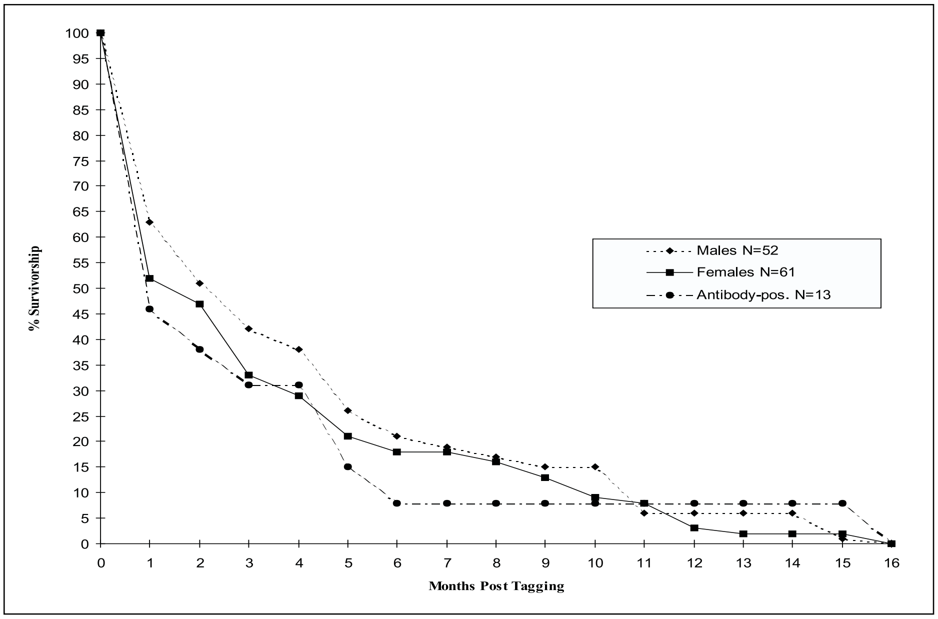


Figure 2. Survivorship functions (percentage of brush mice known to be alive after initial capture) based on recapture data, Santa Rita Experimental Range, southeastern Arizona, May 1995–December 1997.

## Conclusions

The overall prevalence of antibodies reactive with SNV antigen varied considerably among wild rodents captured in southeastern Arizona between May 1995 and December 1997, from 0% for Heteromyidae to 5.4% for Muridae. Low prevalence within the heteromyids has been commonly documented (3-5). Of mice, only *Peromyscus* were seropositive at our study site. The mean antibody prevalence of 7% for all *Peromyscus* was similar to the mean prevalence reported from Kansas (6) and Montana (7), although lower than that at many other sites in Arizona and New Mexico (3,4). The low hantavirus-antibody prevalence at our site may be related to its location in Sonoran Desert semigrassland and its relatively low rainfall; Mills et al. (4) found that prevalence of SNV was lowest at altitudinal and climatic extremes.

The primary *Peromyscus* species with evidence of hantavirus infection at the Santa Rita Experimental Range was the brush mouse, recently shown to be an important carrier of SNV or an SNV–related virus throughout the southwestern United States (4). Even within a single species, overall prevalence of hantavirus antibodies has been reported to vary widely among different regions and habitats and in different seasons and years. In samples of deer mice from sites throughout the southwestern United States, Mills et al. (4) found antibody prevalence of 0% to 50%. Within states, overall prevalence in deer mice was 9.5% to 38.6% at 10 sampled sites in New Mexico (3) and 0% to 50% in 34 counties in California (5).

Several studies have indicated, as does ours, that the presence and number of antibody-positive mice are not evenly distributed. Although *Peromyscus* were trapped in both vegetation types within our study site, all but one of the antibody-positive mice were trapped in oak riparian vegetation, and most were trapped in one portion of one web. Similarly, Mills et al. (4) captured antibody-positive deer mice in only 21 of 41 sites where deer mice were captured, and hantavirus antibody–positive brush mice in only 9 of 17 sites. Our results suggest that the prevalence of antibody-positive animals may be correlated with different habitats and provide additional evidence for focality of hantavirus in “reservoir” populations (4).

While our sample sizes are too small to determine statistical significance, they suggest a correlation between population size and prevalence of hantavirus antibody. The number of antibody-positive animals was highest when the population was decreasing from an abundance of *Peromyscus* in the spring of 1995, the most recent peak. This finding is in contrast to local studies in the Channel Islands (8), Montana (7), and the regional study of Mills et al. (4), which found no relationship between antibody prevalence and density of deer mice. However, Childs et al. (3) found higher antibody prevalence in pinyon-juniper vegetation in 1993, when evidence suggests that rodent densities were unusually high (9).

Additional data from our long-term study and other studies should help determine whether any relationship between density and antibody prevalence exists and if so, what the related temporal patterns are. Population sizes of rodents in the Sonoran Desert of southeast Arizona, as in other areas with climatic extremes, are highly variable. The number of *P. boylii* at Santa Rita Experimental Range was initially high but declined over the course of our study (perhaps because of changes in annual rainfall). To reproduce, many desert rodents require green vegetation (10), often not available in semidesert grasslands and xeroriparian areas. Total annual rainfall at Santa Rita Experimental Range was higher than normal in the 2 years before the start of our study. Since 1995, annual rainfall has been approximately 8 cm to 10 cm below the norm (unpub. data). Petryszyn (11) has linked high variability of *Peromyscus* populations in the Sonoran Desert with extreme fluctuation in winter rainfall. Others (12) have indicated local population expansion and retraction in response to wetter and drier conditions.

Finally, our results are consistent with those of other studies that show a higher prevalence of infection (as indicated by antibody) in male and sexually mature rodents. However, we did not observe direct signs of aggressive encounters or fighting among infected males, as observed by Childs et al. (13) for hantaviral infection in *Rattus norvegicus*.

Field studies of hantavirus infection and wild rodent populations provide a rare opportunity for public health officials, virologists, and ecologists to better understand the dynamics of rodent populations and the interactions between disease, humans, small mammals, habitat, and climatic factors. The few long-term datasets in ecology are invaluable for their contributions to the understanding of processes that vary in complex ways over time but are also relevant to management of both the natural environment and human health.

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