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## Deer Mouse Movements in Peridomestic and Sylvan Settings in Relation to Sin Nombre Virus Antibody Prevalence

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**ABSTRACT:** Prevalence of antibody to Sin Nombre virus (SNV) has been found to be nearly twice as high in deer mice (*Peromyscus maniculatus*) in peridomestic settings as in sylvan settings in two studies in Montana and one in New Mexico. We investigated whether this difference may be related to a difference in deer mouse movements in the two settings. We used radiotelemetry to determine home range size and length of movement for 22 sylvan (1991–1992) and 40 peridomestic deer mice (1995–1999). We also determined the percentage of locations inside versus outside of buildings for peridomestic mice. Though variable, average home range size for female deer mice was significantly smaller for peridomestic deer mice than for sylvan deer mice. The smaller home range in peridomestic settings may concentrate shed SNV, and protection from solar ultraviolet radiation inside buildings may increase environmental persistence of SNV. Both these factors could lead to increased SNV exposure of deer mice within peridomestic populations and result in higher antibody prevalence. Peridomestic deer mice moved between buildings and outside areas, which is evidence that SNV can be transmitted between peridomestic and sylvan populations.

**Key words:** Deer mouse, hantavirus, home range, *Peromyscus maniculatus*, radiotelemetry, Sin Nombre virus, SNV transmission.

In the United States, Sin Nombre virus (SNV, family *Bunyaviridae*, genus *Hantavirus*) causes hantavirus pulmonary syndrome (HPS) in humans (Childs et al., 1994). The deer mouse (*Peromyscus maniculatus*) is the principal reservoir for SNV (Nichol et al., 1993), and the distribution of human HPS cases in the United States coincides with the distribution of deer mice (Douglass et al., 2005). Infected deer mice can shed SNV in saliva, feces, and urine, and humans

become infected by SNV by inhaling aerosolized virus. During early investigations of HPS, it was found that most HPS cases were contracted in peridomestic settings (Armstrong et al., 1995). In an attempt to understand the relationship between human infection and buildings, we initiated studies of the deer mouse–SNV system in peridomestic settings in Montana in 1995 (Kuenzi et al., 2001). We found that prevalence of antibody to SNV in persistent populations of deer mice living in and around buildings was higher than those in sylvan populations (Kuenzi et al., 2000, 2001; Douglass et al., 2001). Others (Zeitz et al., 1995; Jay et al., 1997) have also found high antibody prevalence to SNV in peridomestic settings in other states.

The coexistence of humans and deer mice with high SNV infection rates in peridomestic settings provides ample opportunities for humans to be exposed to SNV by incidentally inhaling aerosolized virus. Peridomestic settings in Montana contain numerous outbuildings (barns, storage sheds, grain bins, etc.), which are notoriously dusty. Because these buildings prevent exposure to direct solar ultraviolet (UV) light, which can kill many types of viruses (Shechmeister, 1991), SNV may persist on dust particles in buildings longer than on outside particles exposed to sunlight.

There is strong evidence that deer mice horizontally infect one another with SNV through biting during intraspecific aggressive encounters (Calisher et al., 2001; Douglass et al., 2001). Peridomestic settings may support higher densities of deer mice than do sylvan settings, and higher

densities may lead to more frequent aggressive interactions.

In addition to being bitten, deer mice can be exposed to SNV by inhaling aerosolized virus (Calisher et al., 2001). Thus, buildings may present a similar milieu of risk of exposure to SNV for deer mice as they do for humans. Smaller peridomestic home ranges and shorter maximum movement patterns may concentrate urine and feces, thus increasing inhalation exposure of SNV for deer mice.

The objectives of this study were to determine whether there are differences in movement patterns between sylvan and peridomestic populations of deer mice; such differences might account for the differences in SNV antibody prevalence between the two populations. We hypothesized that deer mouse home ranges would be smaller in peridomestic settings than in sylvan settings. Secondly, we hypothesized that deer mice living in buildings would travel outside of buildings, which would allow them to interact with sylvan mice and thus maintain a corridor of SNV transmission between the two types of populations.

Because trapping data inadequately delineate deer mouse activity (Douglass, 1989), we used radiotelemetry to determine movements and home range size in both sylvan and peridomestic settings. For comparative purposes, we used sylvan data from a previous study conducted using identical methods (Matlock-Cooley, 1993). We used the previously collected sylvan data to compare to new peridomestic data. We used the previously collected data because it was collected with identical methods and we could use the raw data directly in our home range and movement programs. Twenty-two sylvan deer mice were studied in habitat dominated by Antelope bitterbrush (*Purshia tridentata*) in Silver Bow County, near Anaconda, Montana. Individual mice were captured on a 2.2 ha trapping grid. Forty peridomestic deer mice were captured at two study sites in Silver Bow County, one

located near Anaconda, the other near Butte, Montana. Both study sites were working cattle ranches, and individual mice were captured in ranch buildings (e.g., calving barns, garages, shops, and storage buildings) during most months from 1997 through 1999. Buildings ranged in size from  $8 \times 10$  m ( $80 \text{ m}^2$ ) to  $15 \times 35$  m ( $525 \text{ m}^2$ ). Buildings had multiple doors, windows, and crevices through which deer mice easily moved.

Small (1.8 g with collar) transmitters (AVM Instrument Co., Colfax, California, USA) were placed on the necks of sylvan and peridomestic deer mice using methods described by Douglass (1989). Only adult deer mice ( $\geq 18$  g) that had been trapped at least once before (2–4 wk previously) were radio-collared. We kept handling time to a minimum to avoid stress. On average, mice were radio-collared and released within 3 min of being removed from traps. Radio-collared mice were tracked nightly for 10 to 12 nights, after which time, the mice were recaptured, and their transmitters removed. We tried to locate each mouse from 10 to 15 times per night (their active period) and intervals between locations were  $>15$  min. Most radio-tracking occurred between sunset and 3 AM; however, some individuals were radio-tracked from sunset until sunrise. The additional locations determined after 3 AM did not significantly change home range sizes or maximum lengths of movement. Recorded locations represented sites ( $<1 \text{ m}^2$ ) where mice stopped moving for up to 1 min. In sylvan areas, by continuously increasing receiver attenuation as we moved closer to the mouse, locations were identified at distances from 5 to 10 m. Once an animal was located, we moved to within 2 m south of the mouse's location and marked the location with a flag. This distance was chosen to reduce disturbance to the mouse. Locations were then mapped the following morning using the grid stakes as reference points. Grid locations were recorded as  $x$ - $y$  coordinates. Locations in

peridomestic settings were marked on scale drawings of the buildings present at the study site, with overlying  $x$ - $y$  coordinates. Locations for both sylvan and peridomestic deer mice were later entered into a spreadsheet using 1 m interval coordinates; home range area and maximum length of movement were determined using the 95% minimum convex polygon method in program Calhome (Kie, 1996). Maximum length of movement was calculated as the distance between the two locations furthest apart. We only used data for mice that were located 10 or more times in our home range calculations. We used nonoverlapping, 95% confidence intervals (CI) (Graybill and Iver, 1994; Johnson, 1999) to identify significant differences in average home range sizes and maximum lengths of movements.

For peridomestic deer mice, we used chi-square analysis (Zar, 1984) to compare the proportion of locations that were inside of buildings compared to outside of buildings.

Home range size and length of home range were determined for 22 sylvan deer mice on 2.2 ha grids with population size based on MNA values (minimum number alive; Chitty and Phipps, 1966) between 40 and 60. The number of peridomestic deer mice ranged from two per small building (80 m<sup>2</sup>) to 10 per large building (525 m<sup>2</sup>). Female sylvan deer mice had significantly larger home ranges (2663 m<sup>2</sup>, 95% CI = 1956–3372 m<sup>2</sup>) than did females in both peridomestic (174 m<sup>2</sup>, CI = 66–282 m<sup>2</sup> and 566 m<sup>2</sup>, CI = 80–1052 m<sup>2</sup>) sites and than males at one of the peridomestic sites (754 m<sup>2</sup>, CI = 0–1673 m<sup>2</sup>) (Fig. 1). Sylvan male deer mouse home range sizes were considerably more variable than were female home ranges and were significantly larger than female home ranges at one peridomestic site. The smallest home ranges were found in peridomestic sites, and the largest occurred in sylvan environments.

Differences among maximum lengths of

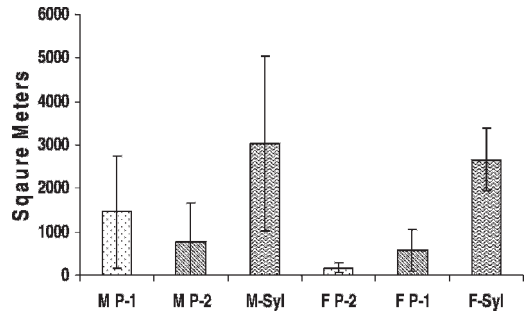


FIGURE 1. Average and 95% confidence intervals of sylvan and peridomestic deer mouse home ranges in Montana. P-1 and P-2 represent two different ranches, and SYL represents sylvan. M represents males, and F represents females.

movements (Fig. 2) were similar to the differences among home range sizes. Males and females had similar home range length in both sylvan and peridomestic settings (sylvan males 77.4 m [95% CI = 46–108 m] vs. 80.3 m [95% CI = 67–93 m] for sylvan females; peridomestic males, 34.6 m [95 CI = 13–57 m] vs. 23.5 m [12–34 m] for peridomestic females), but sylvan females had significantly longer ranges than either males or females in peridomestic settings. Male home range lengths were more variable than female home range lengths in both sylvan and peridomestic settings.

We located peridomestic deer mice a total of 1,624 times (Fig. 3). Except for two deer mice tracked during winter months, deer mice frequently left the buildings in which they were originally captured. However, a significantly higher proportion of their locations occurred inside buildings (1056 inside vs. 568 outside,  $\chi^2 = 138.35$ ,  $P < 0.001$ ; Fig. 3).

The average (both genders) telemetry-determined sylvan home range size in our study (2,813 m<sup>2</sup>) was considerably larger than those found for four deer mice in a deciduous forest in Virginia (500 m<sup>2</sup>) by Wolff (1985). However, our peridomestic home range sizes for female deer mice (174 m<sup>2</sup> and 566 m<sup>2</sup>) were similar to those found by Wolff (1985). In a coniferous forest in Alberta, Canada, Ribble and

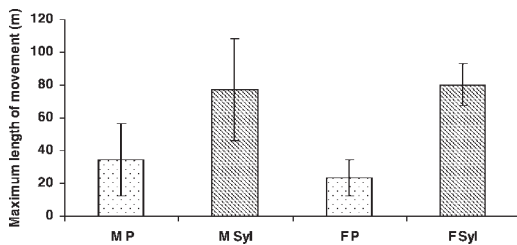


FIGURE 2. Average and 95% confidence intervals of sylvan and peridomestic deer mouse maximum lengths of movement in Montana. P represents peridomestic, SYL represents sylvan, M represents males, and F represents females.

Millar (1996) found deer mouse home ranges that were larger than either of our sylvan or peridomestic home ranges (males = 11,800 m<sup>2</sup> [95% CI = 10,206–13,394 m<sup>2</sup>], females = 6,300 m<sup>2</sup> [95% CI = 4,940–7,660 m<sup>2</sup>]). The structure of buildings and resource concentration may have been similar, at least to a deer mouse, to that of a deciduous forest. The semiarid shrub land in our sylvan study probably had less concentrated food resources than ranch buildings or deciduous forests, while resource concentration in the coniferous forest was probably less than either our sylvan or peridomestic sites.

Even though deer mice may not be more intraspecifically aggressive in peridomestic settings, as indicated by similar wounding rates between sylvan and peridomestic deer mice (Kuenzi et al., 2001), the smaller home ranges and the shorter movements of female deer mice in peridomestic as opposed to sylvan settings observed in this study could aid in concentrating shed SNV in peridomestic settings. Presumably, the hourly rate at which mice defecate and urinate remains fairly constant, and, if they use a smaller peridomestic home range, then shed virus is more likely to be concentrated in peridomestic settings than in a larger sylvan home range. Because average female peridomestic home range sizes were only 6% to 21% (at each of two peridomestic sites) of the size of sylvan

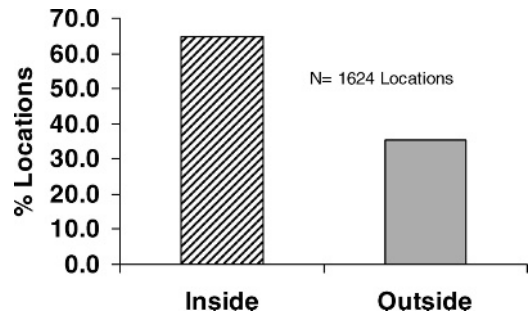


FIGURE 3. Distribution of inside versus outside locations of deer mice radio-collared inside ranch buildings in western Montana.

home ranges, the concentration of urine and feces (and therefore virus) could have been from five to nearly seventeen times denser than in sylvan areas. This potentially higher concentration of shed virus combined with extended persistence (due to blocked UV radiation) may put deer mice in peridomestic areas at considerably higher risk of inhalation and direct contact exposure to SNV than those in sylvan settings.

We also found that peridomestic deer mice spent most (>60%) of their active time in buildings, and thus most of the virus shedding for these mice likely occurs inside buildings. Again, this likely increases the concentration of shed SNV in peridomestic settings as opposed to sylvan settings.

Although deer mice spent most of their lives in buildings, they also spent significant amounts of time outside where they could come in contact with sylvan deer mice. The ultimate origin of SNV in buildings, after the original construction, would be from sylvan deer mice entering them. The movement of peridomestic deer mice into and out of buildings provides a source for maintaining SNV inside buildings.

Both spatial activity and temporal distribution of activity likely increase the concentration of shed SNV in peridomestic settings over that found in sylvan areas. Movements in and out of buildings may



ensure that the virus is spread between sylvan and peridomestic settings. This potentially increased concentration of virus along with the lack of UV found in peridomestic settings may help to explain the higher antibody prevalence found in peridomestic deer mice in our earlier work (Kuenzi et al., 2001). The same factors that increase prevalence of antibodies to SNV in peridomestic deer mice likely would increase potential exposure to humans and increase the probability that humans would become infected by SNV in outbuildings as well.

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