

A COMPARISON OF HOME RANGES OF TWO SPECIES OF *PEROMYSCUS* USING TRAPPING AND RADIOTELEMETRY DATA

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We investigated differences between sizes of home ranges using trapping and radiotelemetry data for syntopic *Peromyscus boylii* and *P. truei*. Sizes of home ranges were calculated from the minimum convex polygon of trap locations and radiotelemetry locations and compared between individuals. The 2 estimates of home-range size were significantly correlated, although on an average trapping home ranges were significantly smaller than sizes of radiotelemetry home ranges. Home-range sizes from radiotelemetry were inversely correlated with conspecific density, but home-range sizes from trapping were not. Thus, at low density, radiotelemetry home ranges were significantly larger than trapping home ranges, but at high density there was no difference between radiotelemetry and trapping home ranges. These results indicate that radiotelemetry results in larger estimates of home-range size, particularly at lower densities of conspecifics. The largest size estimates of home ranges were from a combination of radiotelemetry and trapping data.

Key words: home range, minimum convex polygon, *Peromyscus*, radiotelemetry, trapping

The way individuals are spatially organized is a fundamental concern in ecology and evolutionary biology. The most straightforward method for addressing this problem in natural populations is to collect home-range data or data that indicate the areas traveled for normal activities, such as food gathering, mating, and caring for offspring (Burt 1943). Once these data are collected, areas of intra- and intersexual overlap provide evidence for the social organization and mating system of the population (Madison 1980). The sizes and overlaps of home ranges are also helpful in determining density and ecological relationships between resource availability and spatial organization (Conroy 1996). Despite the fundamental nature of the home range, deter-

mining sizes and distribution of home ranges in small, secretive rodents remains problematic.

Whereas radiotelemetry is largely recognized as a superior method for assessing sizes and distributions of home ranges in small rodents (Bergstrom 1988; Cameron and Spencer 1985; Frank and Heske 1992; Madison 1977; Tew and Macdonald 1994), the use of trapping data to ascertain home ranges of rodents continues to be frequently used. In a survey of the last 5 years of the *Journal of Mammalogy* (1995–1999), we found that 73% (8 of 11) of studies of home-range size in small rodents used trapping data rather than radiotelemetry data. Furthermore, 2 studies indicate that trapping data are comparable if not identical to radiotelemetry data (Jones and Sherman 1983; Wolff 1985).

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We have been studying home ranges and social organization of *Peromyscus boylii* and *Peromyscus truei* in northern New Mexico using radiotelemetry and trapping (Ribble and Stanley 1998). In this study, our objective was to compare relationships between sizes of home ranges calculated with radiotelemetry and trapping data. In this study, we were able to limit our comparisons to mice which had >90% of their radiotelemetry home ranges within boundaries of the trapping grids. We also wished to examine the relationships between home ranges determined by trapping and by radiotelemetry relative to density of conspecifics, as home ranges of *Peromyscus* are typically inversely related to density (Wolff 1989).

MATERIALS AND METHODS

During the summers of 1993 through 1998, we studied *P. truei* and *P. boylii* in a canyon located about 5 km north of Mora in Mora County, New Mexico. The study grids were located at about 2,200 m above mean sea level in lower montane coniferous forest habitat (Dick-Peddie 1993), dominated by ponderosa pine (*Pinus ponderosa*) and oak (*Quercus*). The canopy cover of the north-facing slope was dominated by ponderosa pine and the ground cover by kinikinnick (*Arctostaphylos uva-ursi*). The south-facing slope had a more open canopy with shrub cover of gray oak (*Q. grisea*) and gambel oak (*Q. gambelii*).

During the 6 years of study we trapped on 8 live-trapping grids. We studied 2–6 grids during any summer. Two of the 8 were studied continuously. Grid size varied from 2.5 to 5.7 ha with 20 m spacing between trap stations. All grids but 1 were rectangular or square (see Ribble and Stanley 1998, figure 3 for the exception). We live-trapped *Peromyscus* by placing 1 or 2 Sherman live-traps near each trap station from mid-May to mid-August, except in 1996 when trapping ceased in mid-July. Typically, each grid was trapped every 2nd week. During each week, we trapped on alternating nights for 3 nights. Grids were not trapped during radiotelemetry sessions. We used standard mark–recapture techniques (Ribble and Stanley 1998).

During each summer we conducted radiote-

lemetry sessions in late May and again from late July to early August. The radiotelemetry techniques are described in Ribble and Stanley (1998). Briefly, we anesthetized adult mice and fitted them with mouse-style single stage transmitters (AVM Instruments Inc., Livermore, California) in the field. We collected location data using a hand-held Telonics receiver and a 2-element antenna (Telonics Inc., Mesa, Arizona), or an AVM LA12-DSE receiver and a 3-element Yagi antenna. Mice were tracked for 2–14 days, beginning each night at approximately 2100 h and ending at 0100 h. During the night, we allowed at least 30 min to elapse between locations on individual mice which was sufficient to allow an individual to move across its home range and avoid problems of autocorrelation (Ribble and Stanley 1998). We usually radio-located each mouse once during the day to determine the nesting site.

We compared sizes of home ranges from radiotelemetry and trapping data collected during the same summers. We used the minimum convex polygon (MCP) method using CALHOME software package (Kie et al. 1996) to calculate sizes of home ranges, because this technique is less sensitive to independence of successive data points than are other statistical techniques (Swihart and Slade 1985). Furthermore, the small sample sizes of locations for home ranges from trapping prevented us from using more data intensive methods such as kernel-density estimators, which require >20 locations (Seaman and Powell 1996). Jones and Sherman (1983) also found, with *Microtus pennsylvanicus*, that comparisons between radiotelemetry and live-trapping data are more consistent when using MCP methods than with other methods of home-range estimation.

Because adult mice do not tend to change the size (Ribble and Stanley 1998) or location (D. O. Ribble, in litt.) of their home range during summer, we used all unique trapping locations during 1 summer to arrive at an estimate of home-range size using trapping locations. Some mice were radiotracked during 2 sessions in a summer. For these mice, we took the average of the 2 estimates of radiotelemetry home range to compare with the estimate from trapping.

During the course of this study, we noticed that trapping locations were not necessarily in the same places as radiotelemetry locations. In our previous study (Ribble and Stanley 1998),

we included trapping locations the week before and the week after radiotelemetry sessions to calculate home ranges. In this study we used only trapping or radiotelemetry locations, therefore, we also analyzed sizes of home ranges using radiotelemetry data together with trapping data from the weeks before and after the radiotelemetry session. We refer to these home ranges as “radiotelemetry plus trapping.”

Many radiocollared mice had home ranges that extended beyond the boundaries of our trapping grids, making it meaningless to compare to a home range from trapping data. Thus, we used only those radiotelemetry home ranges in which >90% of the MCP was within the boundaries of our study grids. We also used only those trapping home ranges with at least 4 unique locations.

Our primary objective was to compare estimates of home-range size from trapping and radiotelemetry data in *Peromyscus*, not to compare between species and sexes (as in Ribble and Stanley 1998). To accomplish this, we compared the relationships between sizes of radiotelemetry and trapping home ranges with analysis of covariance (ANCOVA) using conspecific density as a covariate, and sex, species, year, and study grid as factors. As species and sex were used as factors in our analysis, we pooled all data. The minimum number alive (Krebs 1966) was used as an index to conspecific density (Ribble and Stanley 1998). We also tested for differences between the MCP estimates of home-range size from radiotelemetry, trapping, and radiotelemetry plus trapping using a paired sample *t*-test.

In order to compare the results of this analysis to our previous study (Ribble and Stanley 1998), we did compare estimates of home-range size between species and sexes using nonparametric Kruskal–Wallis tests and Mann–Whitney *U*-tests (Sokal and Rohlf 1981). Although our sample sizes were limited in some cases (e.g., 3 *P. truei*), we thought it was useful to examine whether trapping data are comparable to radiotelemetry data and other published data. We accepted statistical significance at $P \leq 0.05$. All mean values are presented $\pm 2 SE$.

RESULTS

We radiocollared >60 mice from 1993 through 1998, but we selected only 24 of these that had MCP home ranges that overlapped trapping-grid boundaries by >90%.

No mice were studied with radiotelemetry in 1996. Of the remaining 5 years of this study, an average of 4.8 mice/year were selected (range 3–8/year). The 24 mice included 21 *P. boylii* (9 males, 12 females) and 3 *P. truei* (3 males), and these mice were found in 5 of 8 trapping grids studied. The percentage of MCP radiotelemetry home ranges on trapping grids ranged from 92% to 100%, with a mean of $99.1 \pm 0.8\%$. The number of unique trap locations ranged from 4 to 19 with a mean of 7.4 (Table 1). The number of unique radiotelemetry locations ranged from 7 to 32 with a mean of 19.4. There were no significant relationships between number of unique sample locations and size of home range for either trapping ($r = 0.04$, $P = 0.86$) or radiotelemetry data ($r = 0.02$, $P = 0.92$). The greater number of locations for radiotelemetry data might possibly lead to larger home-range sizes, but we found no significant correlation between number of locations and home-range size when all data were pooled ($r = 0.26$, $P = 0.07$; Fig. 1).

There was a significant correlation between sizes of home ranges from trapping and radiotelemetry data ($r = 0.66$, $P < 0.01$; Fig. 2). In an analysis of covariance, size of radiotelemetry home ranges did not differ among species, sexes, years, or study grids (all $P > 0.10$). There was, however, a significant interaction between size of trapping home range and conspecific density ($F = 13.7$, $d.f. = 1, 18$, $P < 0.01$), which was because of a lack of homogeneity between estimates of trapping and radiotelemetry home ranges and conspecific density (Fig. 3). Sizes of radiotelemetry home ranges were negatively correlated with conspecific density ($r = -0.66$, $P < 0.01$), whereas sizes of trapping home ranges were not correlated with conspecific density ($r = 0.29$, $P = 0.16$; Fig. 3). These differences indicated that at a conspecific density >15 individuals, there was no significant difference between size of radiotelemetry and trapping home ranges (paired sample *t*-test = 1.78, $d.f. = 14$, $P = 0.10$). But at con-

TABLE 1.—Home-range statistics (mean \pm 2 SE) from radiotelemetry data, trapping data, and radiotelemetry plus trapping data for *Peromyscus boylii* and *P. truei*. Means for home-range estimates followed by the same letters are not different (Mann-Whitney test) at $P \leq 0.05$.

Species	Sex	n	Trapping data		Radiotelemetry data		Radiotelemetry plus trapping data	
			Number of locations	Size—minimum convex polygon (ha)	Number of locations	Size—minimum convex polygon (ha)	Number of locations	Size—minimum convex polygon (ha)
<i>P. boylii</i>	M	9	7.2 \pm 1.8	0.29 \pm 0.12 ^a	19.8 \pm 4.8	0.52 \pm 0.29 ^a	22.7 \pm 4.7	0.64 \pm 0.36 ^a
	F	12	7.5 \pm 2.3	0.13 \pm 0.05 ^b	19.6 \pm 2.9	0.29 \pm 0.19 ^b	23.1 \pm 2.4	0.32 \pm 0.18 ^b
<i>P. truei</i>	M	3	7.3 \pm 2.9	0.41 \pm 0.14 ^a	17.7 \pm 3.5	0.93 \pm 1.02 ^a	21.3 \pm 1.3	1.30 \pm 1.40 ^a
	Overall	24	7.4 \pm 1.3	10.9 ^{**} 0.23 \pm 0.07	19.4 \pm 2.3	6.6 ^{**} 0.46 \pm 0.20	22.7 \pm 2.1	9.4 ^{**} 0.56 \pm 0.25

* $P < 0.05$, ** $P < 0.01$.

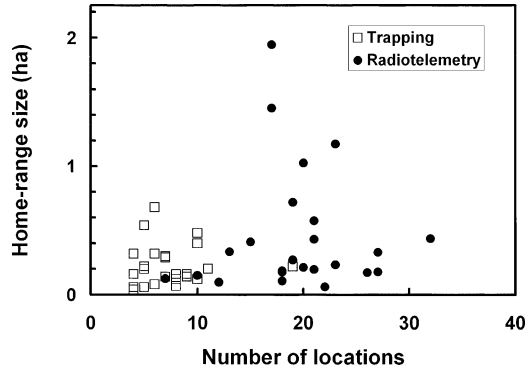


FIG. 1.—Relationships between home-range size and number of locations used in estimates for radiotelemetry and trapping locations for *Peromyscus boylii* and *P. truei*. Home-range size was calculated using the minimum convex polygon method.

specific density <15 individuals, estimates of radiotelemetry home ranges were greater than trapping home ranges (paired sample t -test = 3.14, $d.f.$ = 8, P = 0.01).

For trapping radiotelemetry and radiotelemetry plus trapping data, there were significant differences in the sizes of home ranges for *P. boylii* and *P. truei* (Table 1). In all cases, female *P. boylii* had smaller home ranges than male *P. truei* and male *P. boylii* which were not significantly different from each other.

The sizes of trapping home ranges were

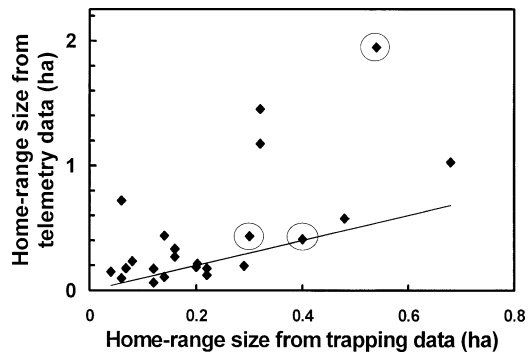


FIG. 2.—Relationships between radiotelemetry and trapping home-range size for *Peromyscus boylii* and *P. truei* (values for *P. truei* are circled). Straight line indicates equality for comparisons of home-range size.

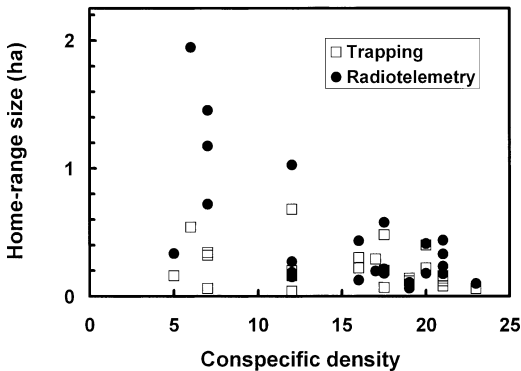


FIG. 3.—Relationships between conspecific density and home-range size estimated from radiotelemetry and trapping locations for *Peromyscus boylii* and *P. truei*.

on an average significantly smaller than radiotelemetry home ranges (mean difference = 0.23 ± 0.16 ha, paired t -test = -2.89 , $P < 0.01$). Sizes of trapping home ranges ranged from 0.04 to 0.68 ha with a mean of 0.23 ha (Table 1). Sizes of radiotelemetry home ranges ranged from 0.06 to 2.0 ha with a mean of 0.46 ha. The sizes of radiotelemetry plus trapping home ranges were larger than the radiotelemetry home ranges (mean difference = 0.10 ± 0.08 ha, paired t -test = 2.62 , $P = 0.01$). The median difference between all home ranges from radiotelemetry and radiotelemetry plus trapping was 0.02 ha and the mode was 0.

DISCUSSION

Sizes of home ranges were qualitatively similar to those reported by Ribble and Stanley (1998) in that male *P. boylii* had larger home ranges than female *P. boylii*. However, Ribble and Stanley (1998) reported a mean of 1.27 ± 0.48 ha for MCP estimates of male *P. truei*, which was greater than mean size of male *P. boylii* home ranges (mean = 0.47 ± 0.17 ha). Because male *P. truei* had such large ranges, much of their home ranges extended beyond the boundaries of our trapping grids resulting in their omission from this study. In this

study we analyzed only 3 male *P. truei* ranges that were $>90\%$ on trapping grids, and these ranges were not significantly larger than male *P. boylii*. Nevertheless, data from both radiotelemetry and trapping showed results that were qualitatively similar to those of Ribble and Stanley (1998).

Sizes of trapping home ranges in this study are similar to those reported from trapping data in the literature for other species of *Peromyscus*. For *P. truei*, Scheibe (1984) recorded mean sizes of home ranges of 0.48 and 0.28 ha for males and females, respectively, and Douglas (1969) estimated sizes of home ranges of 0.43 and 0.38 ha for males and females, respectively. Storer et al. (1944) reported mean values of 0.11 ha for male and 0.16 ha for female *P. boylii*. Sizes of radiotelemetry home ranges in this study were larger than those reported based on trapping data. Sizes of *P. truei* home ranges from radiotelemetry were comparable to radiotelemetry home ranges recorded by Hall and Morrison (1997). Kalcounis-Rueppell (2000) recorded radiotelemetry home ranges of *P. boylii* that are smaller (0.13 ± 0.03 ha for males and 0.11 ± 0.2 ha for females) than in this study. The home-range estimates for *P. boylii* in this study and in that of Ribble and Stanley (1998) may prove to be the largest recorded for this species of *Peromyscus*.

Although, qualitatively similar between species and correlated (Table 1; Fig. 2), the sizes of home ranges from radiotelemetry were consistently larger than those from trapping locations. These results are contrary to at least 2 other studies of small rodents. Wolff (1985) analyzed MCP home ranges from radiotelemetry and trapping data for 13 *P. leucopus* and 4 *P. maniculatus* in southwestern Virginia and found no difference in size between the 2 types of data. The average size of home ranges in his study was 0.05 ± 0.01 ha. Jones and Sherman (1983) compared MCP home ranges from female *Microtus pennsylvanicus* and found no difference between radiotelemetry and trapping data. Average

size of home ranges in their study was 0.037 ha (no *SE* provided).

Other studies have demonstrated that data from trapping consistently underestimate sizes of home ranges relative to radiotelemetry data. Bergstrom (1988) noted a 6-fold difference between sizes of home ranges from radiotelemetry and trapping data for *Tamias*. Others have argued that radiotelemetry data provide an understanding of home-range dynamics that is superior to that from trapping (Cranford 1977; Frank and Heske 1992; Tew and Macdonald 1994). None of these studies, however, has examined relationships between radiotelemetry and trapping data and their relationships to density. Numerous studies have demonstrated that sizes of *Peromyscus* home ranges are usually inversely related to population density (Madison 1977; Ribble and Salvioni 1990; Taitt 1981; Wolff and Cicirello 1990). We observed that home ranges from trapping are not inversely related to conspecific density, whereas home ranges from radiotelemetry are. Because of these different relationships, at low density of conspecifics (<15; Fig. 3) there were significant differences in sizes of home ranges from radiotelemetry and trapping data. At high density of conspecifics (>15; Fig. 3), there were no differences in sizes of home ranges from radiotelemetry and trapping data.

Based on observations from this study, we question conclusions from studies that show a similarity in sizes of home ranges from radiotelemetry and trapping data without exploring these relationships relative to population density. Furthermore, as some individuals live near the edges of trapping grids, it is not possible for their entire home range to lie within the study grid. In this study, 60% of individuals (36 of 60) had home ranges that extended >10% beyond grid boundaries.

In our previous study (Ribble and Stanley 1998), we included trapping locations during the week before and the week after radiotelemetry sessions to calculate home ranges. The radiotelemetry plus trapping

home-range estimates were, on an average, significantly larger than radiotelemetry estimates alone. However, the median difference between these two estimates was small (0.02 ha) and the most frequent difference was 0 (mode = 0).

Whereas the use of radiotelemetry to explore home range dynamics may be preferred, this technique has limitations. Of primary concern is the impact on natural behaviors of carrying the added weight of a radiotransmitter. Ribble and Stanley (1998) demonstrated that the sizes of home ranges with radiotelemetry data were larger than other estimates reported in the literature. The present study demonstrates that sizes of home range from radiotelemetry are larger than those from trapping data for individual mice. Recent evidence from *M. pennsylvanicus* (Berteaux et al. 1996) indicates that radiocollars do not influence energy budgets under natural conditions. Thus, we suggest that radiotelemetry is a superior method for investigating home range dynamics compared with trapping, and the potential effects of carrying radiocollars are outweighed by the benefits in terms of data acquisition in small rodents.

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LITERATURE CITED

- BERGSTROM, B. J. 1988. Home ranges of three species of chipmunks (*Tamias*) as assessed by radiotelemetry and grid trapping. *Journal of Mammalogy* 69: 190–193.

- BERTEAUX, D., F. MASSEBOFF, J.-M. BONZAM, J.-M. BERGERON, D. W. THOMAS, AND H. LAPIERRE. 1996. Effect of carrying a radiocollar on expenditure of energy by meadow voles. *Journal of Mammalogy* 77:359–363.
- BURT, W. H. 1943. Territoriality and home range concepts as applied to mammals. *Journal of Mammalogy* 24:346–352.
- CAMERON, G. N., AND S. R. SPENCER. 1985. Assessment of space-use patterns in the hispid cotton rat (*Sigmodon hispidus*). *Oecologia* 68:133–139.
- CONROY, M. J. 1996. Abundance indices. Pp. 179–192 in *Measuring and monitoring biological diversity. Standard methods for mammals* (D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, eds.). Smithsonian Institution Press, Washington, D.C.
- CRANFORD, J. A. 1977. Home range and habitat utilization by *Neotoma fuscipes* as determined by radiotelemetry. *Journal of Mammalogy* 58:165–172.
- DICK-PEDDIE, W. A. 1993. *New Mexico vegetation, past, present, and future*. University of New Mexico Press, Albuquerque.
- DOUGLAS, C. L. 1969. Comparative population ecology of pinyon mice and deer mice in Mesa Verde National Park, Colorado. University of Kansas Publications, Museum of Natural History 18:421–504.
- FRANK, D. H., AND E. J. HESKE. 1992. Seasonal changes in space use patterns in the southern grasshopper mouse *Onychomys torridus torridus*. *Journal of Mammalogy* 73:292–298.
- HALL, L. S., AND M. L. MORRISON. 1997. Den and relocation site characteristics and home ranges of *Peromyscus truei* in the White Mountains of California. *Great Basin Naturalist* 57:124–130.
- JONES, E. N., AND L. J. SHERMAN. 1983. A comparison of meadow vole home ranges derived from grid trapping and radiotelemetry. *Journal of Wildlife Management* 47:558–561.
- KALCOUNIS-RUEPPELL, M. C. 2000. Breeding systems, habitat overlap, and activity patterns of monogamous and promiscuous mating in *Peromyscus californicus* and *P. boylii*. Ph.D. dissertation, University of Western Ontario, Ontario, Canada.
- KIE, J. G., J. A. BALDWIN, AND C. J. EVANS. 1996. CALHOME: a program for estimating animal home ranges. *Wildlife Society Bulletin* 24:342–344.
- KREBS, C. J. 1966. Demographic changes in fluctuating populations of *Microtus californicus*. *Ecological Monographs* 36:239–273.
- MADISON, D. M. 1977. Movements and habitat use among interacting *Peromyscus leucopus*. *Canadian Field Naturalist* 91:273–281.
- MADISON, D. M. 1980. Space use and social structure in meadow voles, *Microtus pennsylvanicus*. *Behavioral Ecology and Sociobiology* 7:65–71.
- RIBBLE, D. O., AND M. SALVIONI. 1990. Social organization and nest co-occupancy in *Peromyscus californicus*, a monogamous rodent. *Behavioral Ecology and Sociobiology* 26:9–15.
- RIBBLE, D. O., AND S. STANLEY. 1998. Home ranges and social organization of syntopic *Peromyscus boylii* and *P. truei*. *Journal of Mammalogy* 79:932–941.
- SCHEIBE, J. S. 1984. Sexual differences in the home ranges of *Peromyscus truei* and *Dipodomys panamintinus* (Rodentia). *Southwestern Naturalist* 29:7–13.
- SEAMAN, D. E., AND R. A. POWELL. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology* 77:2075–2085.
- SOKAL, R. R., AND F. J. ROHLF. 1981. *Biometry: the principles and practice of statistics in biological research*. 2nd ed. W. H. Freeman and Company, San Francisco, California.
- STORER, T. I., F. C. EVANS, AND F. G. PALMER. 1944. Some rodent populations in the Sierra Nevada of California. *Ecological Monographs* 14:165–192.
- SWIHART, R. K., AND N. A. SLADE. 1985. Testing for independence of observations in animal movements. *Ecology* 66:1176–1184.
- TAITT, M. J. 1981. The effect of extra food on small rodent populations. I. Deermice (*Peromyscus maniculatus*). *Journal of Animal Ecology* 50:111–124.
- TEW, T. E., AND D. W. MACDONALD. 1994. Dynamics of space use and male vigour amongst wood mice, *Apodemus sylvaticus*, in the cereal ecosystem. *Behavioral Ecology and Sociobiology* 34:337–345.
- WOLFF, J. O. 1985. The effects of density, food, and interspecific interference on home range size in *Peromyscus leucopus* and *Peromyscus maniculatus*. *Canadian Journal of Zoology* (London) 63:2657–2662.
- WOLFF, J. O. 1989. Social behavior. Pp. 271–291 in *Advances in the study of Peromyscus* (Rodentia) (G. L. Kirkland, Jr. and J. N. Layne, eds.). Texas Tech University Press, Lubbock.
- WOLFF, J. O., AND D. M. CICIRELLO. 1990. Mobility versus territoriality: alternative reproductive strategies in white-footed mice. *Animal Behaviour* 39:1222–1224.

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