

# Corridor use by small mammals: field measurement for three experimental types of *Peromyscus leucopus*

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## Abstract

Eighteen mice of each of 3 types were radio-tagged and released at 6 standard points in farmland fencerows. Mice were residents (trapped on site) or translocated from distant forest or from distant corn fields. Of total (net) distance moved, most was in fencerows; 77% for residents, 83% for mice translocated from cropland and 92% for mice translocated from forest. Structurally complex fencerows were preferred significantly over intermediate or simple structures by all types of mice. Time spent in movement was not a linear function of distance moved and averaged from 12.5 to 16.5% of total available activity time. Total distance moved in 2 nights averaged 287 to 422 m and area explored averaged 0.67 to 1.15 ha and ranged to 11.0 ha; both exceed literature values for this species in forest. This enlarged scale of landscape use illustrates the potential importance of landscape-specific behaviour. The measurement of rate of corridor use also is discussed.

## Introduction

Attention to corridors has increased due to recently increased knowledge of habitat fragmentation and habitat heterogeneity as potential constraints exerted by landscape configuration on populations (Harris 1984, Nyland *et al.* 1986, Vemer *et al.* 1986, Wilcove *et al.* 1986, Krummel *et al.* 1987, Saunders *et al.* 1987, Schreiber 1988, Simberloff and Cox 1987, Merriam 1988). The metapopulation model proposed for the demography and spatial distribution of populations in fragmented or highly heterogeneous landscapes assumes that several patch populations are interconnected into a single demographic unit by movement of animals between patch populations to recolonize local extinctions and prevent regional extinction (Merriam 1984, Gill 1978, Addicott 1978, Kareiva 1986, den Boer 1981, Levins 1970). Corridors that facilitate movement

across potentially hazardous (isolating) environments between habitat patches can be critical variables in such a model.

Merriam (1984) proposed connectivity as a fundamental measure of the ease of movement among patches of a heterogeneous landscape. Baudry and Merriam (1988) reiterated the need to measure connectivity in terms of the behaviour of organisms. Fahrig and Merriam (1985) demonstrated the critical role of connectivity in a simple corridor model of a four patch metapopulation. Lefkovich and Fahrig (1985) isolated the critical elements of connectivity in the same model with five patches.

Both in fundamental aspects of landscape ecology and in efforts to apply research results to planning and management, there are conflicting views of the effects of fragmentation, connecting corridors and edges (Harris 1988, Yahner 1988). Planning and management applications are made diffi-

cult by unresolved propositions of potential benefits and hazards of corridors (Simberloff and Cox 1987, Noss 1987). Shortage of direct measurements of corridor use underlies these difficulties; there are none for our study species.

The model of Fahrig and Merriam (1985) assumed equal facilitation of movement by all corridors regardless of type or structure. One objective of this study is to examine that assumption by testing the hypothesis that *Peromyscus leucopus* exhibit no differential use of farmland fencerows as movement corridors regardless of the structure of those corridors. The second objective is to measure whether these individuals select fencerows as movement corridors and at what rates do they use corridors. The third objective is to provide some measurements of the spatial scale of these movements with reference to the landscape origins of the individuals and without the potential biases of live-trapping. None of the vast literature for *P. leucopus* provides answers to these questions that can safely be extrapolated to farm landscapes.

## Methods

Radio-tagged mice were released at 6 release points (Fig. 1) in farmland fencerows and were tracked individually for 48 h to record their use of fencerows versus other landscape elements and their relative use of structural fencerow types. Radio-tracking also recorded the temporal distribution and extent of movements. Individuals obtained from woods were compared to those from farmland and individuals translocated at least 5 km were compared with those obtained from the release sites. Translocated mice were used to represent (or to model) transient mice because they were moving in unfamiliar surroundings. Behavioural history of mice obtained from woods was considered to differentiate them from mice obtained from farmland when both were given the choice of moving in brushy fencerows or in farm fields.

Experiments were done in summer and fall 1986 on farmland subject to low to medium intensity agriculture 5 km south of Ottawa, Canada (N:45° 12', W:75° 39') (Fig. 1). This landscape is a mosaic

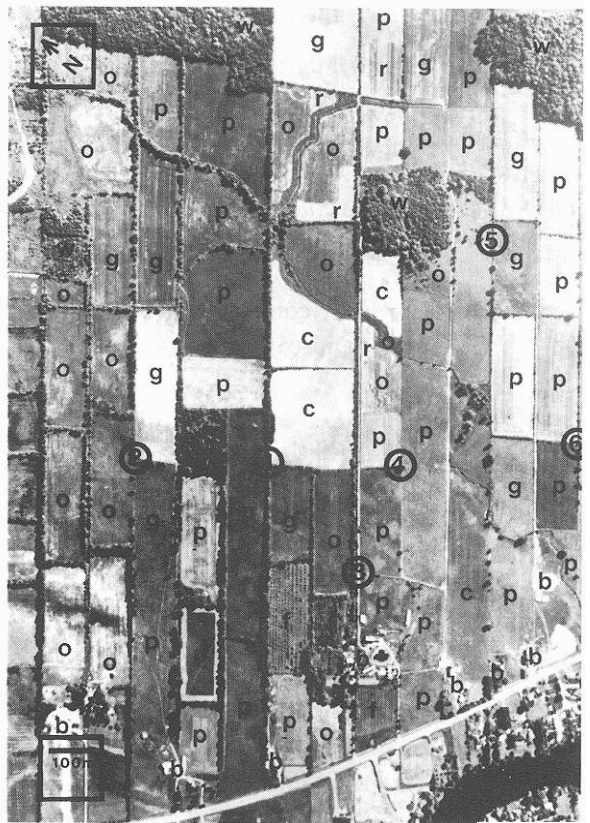


Fig. 1. Study area showing release points and land use at the time of the study: b = farm buildings, c = corn, f = fruit orchard, g = oats/barley, o = old field, p = pasture/hay, r = vegetable row crops, w = woods.

of small fields of grain, corn, hay and pasture with scattered deciduous or mixed-wood forest fragments. Fencerows form a dominant infrastructure throughout the farmland (Fig. 1) and many have developed a very complex woody structure simply by neglect. *Peromyscus maniculatus* do not occur in this study area; sampled individuals have been identified by electrophoresis of salivary enzymes (Merriam *et al.* 1989).

Experimental animals were either resident (trapped on the study area at or near release points) or non-resident (trapped at least 5 km from release points). There were two types of transients. "Transients from forests" were trapped from deciduous forest fragments. "Transients from cropland" were trapped from low to medium intensity corn fields (*Zea mays*). There were 18 adults (by size and fur) in each of these three experimental groups. The

only females were: 4 residents, 2 transients from forest and 4 transients from cropland. These did not differ significantly in measured characteristics within their types and each type is therefore treated as a single group. All mice were obtained from daily checks of Sherman-type live-traps with **dacron** wool bedding and sunflower seed bait.

Three mice of each of the 3 types were released at each of six designated release points (Fig. 1). Resident mice were kept in individual **shoebox** cages in a trailer lab on the study area from capture time until the next sunset and then were released at the release point nearest to their capture point. Transient mice were held for no more than two nights in individual **shoebox** cages in a vivarium before transport to the study area and a release point.

Each mouse was equipped with a radio-transmitter with crystal-controlled identifying frequency between 173.81 and 174.09 MHz (Holohil model **BD1**). Transmitters weighed 0.95 to 1.00 g and had an 11 cm stainless whip antenna. They were attached by a collar made from plastic straps with self-buckles used commercially to bundle electronic wiring. To keep the transmitter in a cervical position dorsal to the scapulae, a drop of "Skin Bond" surgical cement anchored the tag to the fur. This method of attachment has not been used previously for this species (cf. Mineau and Madison 1977, Wolff 1985).

Radio-tagged mice were normal based on **behaviour** of test animals observed in cages, behaviour and condition of mice recaptured after 2 days of radio-tracking, and based on the similarity in scale of distances measured telemetrically and in another, longer-term, independent live-trapping study (Wegner and Merriam in prep.).

Merlin 12 receivers with hand-held yagi antennas were used by a single worker to monitor released mice by triangulation at least every ten minutes. Tests showed accuracy of  $\pm 1$  m for locations of transmitters.

All mice were released one hour after official sunset and were tracked until full daylight when the mice normally took cover and remained inactive through the day. Tracking was resumed at that location the following sunset and continued until dawn of the second night when the mouse's **loca-**

tion was saturated with live-traps to recover the transmitter and release the mouse. Total period available for activity was effectively dusk to dawn **totalled** for the two nights.

Time spent in each landscape element was recorded over the two nights. Locations were recorded every ten minutes. Total meters moved and net distances (eliminating repeated coverage of any route segment) were calculated by adding straight line distances between plotted location points. The most distant points on a mouse's movement path over the two nights (Table 3) were measured as a straight line on a 1:1111 **airphoto** enlargement and this also was the longest dimension of the elliptical area in Table 3. The lesser elliptical dimension was set (according to travel patterns along linear landscape elements) at 25% of this long axis.

Fencerows were grouped into three structural classes. Simple fencerows had trees, shrubs or other structural elements, such as logs, stone piles or stone walls on less than 10% of their total length and were less than 1 m wide (field vegetation to field vegetation). Simple fencerows often consisted solely of a fence and a strip of vegetation dominated by grasses but distinguishable from the adjacent fields. Intermediate fencerows were less than 2 m wide at ground level. They contained unlimited amounts of shrubs and/or structural elements (as above) but trees taller than 10 m covered less than 10% of their total length. The last class, complex fencerows, contained unlimited shrubs and structural elements and had trees on more than 10% of the total length and a width greater than 2 m at ground level.

The six release points were chosen to ensure availability of all 3 **fencerow** classes (Fig. 1) to mice moving out from each release point. Availability of each **fencerow** type around each release point was measured in a circle of 200 m radius centered on the release point. Preference for **fencerow** type was measured by comparison of length of each type used compared to length of each type available in this circle. Preference data exclude all repeated travel over any section of **fencerow** by the same or different mice so that only use or rejection of the available sections of each structural type was recorded. Frequency of use data would have elevated the preference for complex fencerows.

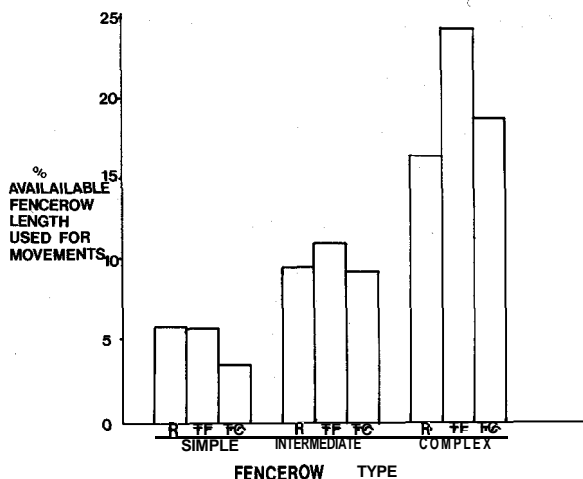


Fig. 2. Percentages of the available amount of each fencerow type that were used for movement at all 6 release points by 18 mice of each type: R = resident, TF = transients from forest, TC = transients from cropland.

Statistical tests followed Sokal and Rohlf (1981). G-tests utilize the log-likelihood ratio  $\sum f_i \ln(f_i/f_{\text{expected}})$  in place of Chi-square by referring 2 times the ratio to the Chi-square distribution with (r-1) (c-1) degrees of freedom.

## Results

Resident farmland mice used all structural types of fencerows as movement corridors (Fig. 2). Total length of fencerows available was very similar at all six release points (1725 to 2610 m) and did not have any clear effect on the total number of meters used by resident mice released at each point. However there was a clear pattern of preference for structurally complex fencerows ( $G = 254.3$ ,  $p < 0.005$ ) when relative availability of all structural types is considered. Resident mice used 5.8% of simple fencerows, 9.3% of intermediate and 16.2% of complex fencerows. The trend was the same at all individual release points. Use of simple fencerows was usually higher where complex fencerows were least available.

Transient mice brought from distant forests and croplands showed an even stronger preference ( $G = 614.8$ ,  $p < 0.005$ ) for complex structures than did resident farmland mice (Fig. 2). Up to 24.0% of

the available complex fencerows were visited compared to only 11.0% of intermediate and 5.8% of simple fencerows. The proportion of all available fencerows used by these forest mice was greater than for the residents and the only significant increase was along complex fencerows. Simple fencerows were used only at release points where the available proportion of complex fencerows was low. Use of the intermediate fencerows followed the same pattern. Only the three release points with low availability of complex fencerows showed any use of intermediate fencerows by mice with behavioral experience from forest habitats.

Transient animals brought from cropland used fencerows similarly to resident farmland mice. The total length of fencerow visited was very similar and the distribution of use among the three types, 3.4% of simple, 9.1% of intermediate and 18.5% of complex fencerows, showed the same trends (Fig. 2). Complex fencerows were again preferred significantly over any other type ( $G = 254.0$ ,  $p < 0.005$ ). Transient mice from cropland used intermediate and complex fencerows at each release point and used simple fencerows at all but two points..

In comparing use of fencerows with use of other landscape elements it is impossible to specify the available length of travel path in elements such as cropland. Hence net distances moved in each landscape element are compared in Table 1 among the experimental types of mice without adjustment for availability. Only net distances travelled are reported; repeated use of any travel path is not included. Accessibility to farmyards and woods is not comparable at all release points which accounts for extreme variance in use of these two elements (Fig. 1). Fields are accessible from all release points but unpublished live-trapping and tracking data show that *P. leucopus* prefers not to use hay and pasture fields (J. Wegner, pers. comm.). Therefore accessibility to specific crop fields from each release point also can affect the use of fields (Table 1, Fig. 1). Residents moved 23% of total net distance in fields compared to 17% for cropland transients and 8% for forest transients. Previous landscape experience and translocation itself both could be effective variables.

All three types of mice clearly preferred fence-

**Table 1.** Use of fencerows and other landscape elements by resident mice compared to transients from other landscapes. Data are meters moved (net) by all experimental mice.

Mouse type	Release point	Landscape element			
		Fencerow	Field	Forest	Farmyard
Resident n = 18	i	245	20	0	0
	2	220	80	0	0
	3	680	420	0	0
	4	170	17	0	0
	5	680	153	0	0
	6	450	40	0	0
	Total	2445	730	0	0
Transient forest n = 18	1	600	29	150	0
	2	260	27	0	0
	3	307	0	0	100
	4	755	150	150	0
	5	666	60	0	0
	6	585	0	0	0
	Total	3173	266	300	100
Transient cropland n = 18	1	650	12	0	0
	2	310	0	100	0
	3	275	0	0	0
	4	400	15	0	0
	5	385	420	0	0
	6	155	0	0	0
	Total	2175	447	100	0

rows over other landscape elements although the available crop field area greatly exceeded the area of fencerows (Table 1). In most cases, significant differences among mouse types cannot be demonstrated because standard deviations usually exceed means. Total distance travelled in fields was greatest for resident farmland mice, intermediate for transient **cropland** mice and least for transient forest mice.

Percentages of the total activity period spent in each landscape element do not differ significantly among mouse types because of excessive variances. The mean percentage of total activity period spent in fencerows was near 90% for all mouse types. Resident mice spent 13.26% of their total activity period in fields, whereas transient mice from **cropland** spent 3.80% and transient mice from forest spent only 2.55% in fields. Eight residents visited fields; two of them spent more than half their available activity time there. **Cropland** tran-

sients spent most of their time in brushy fencerows. Only three **cropland** transients and five forest transients visited fields.

Distance moved and activity time used in the movement were not linearly related. Mean percentage of total available activity time actually used in moving (over 2 nights) were: 16.5 (sd = 12.7) for residents, 12.5 (sd = 8.8) for forest transients, and 13.1 (sd = 10.4) for **cropland** transients.

Total distance moved, including retracing of previous routes, gives a useful relative measure of the dimensional extent of activity for each mouse in the landscape. All locations, hence all distances were estimated very accurately and continuously, unlike live-trapping data. The mean values (Table 2) are not significantly different among mouse types primarily due to variance among individuals. In all groups, 22% of individuals moved less than 50 m but 18.5% moved more than 500 m. The skew of this distribution shifted among groups so that

Table 2. Total distances (m) moved by radio-tagged resident and transient mice released in farm landscape. Entries are means of 3 individuals followed by range in parentheses.

Release point	Residents	Transients	
		Forest	Cropland
1	123 (30-174)	660 (165–1090)	338 (165-642)
2	185 (41-427)	129 (2.5-257)	180 (88-271)
3	623 (50–1643)	154 (15-340)	319 (12-915)
4	117 (20-265)	613 (5-1396)	291 (147-415)
5	472 (197-815)	472 (86–1102)	525 (50-1403)
6	212 (15-320)	497 (112-1029)	67 (10-107)
$\bar{X}$	289	422	287
sd	392	445	364
n	18	18	18

Table 3. Straight line distances between most distant points on movement path, and resultant elliptical area estimates for resident (R), transients from forest (TF) and transients from cropland (TC). Entries are means of 3 trials at each release point. Overall mean areas are not calculated values corresponding to overall mean distances because overall means were calculated from 18 original measured distances and their calculated areas.

Release point	Distance (m)			Areas (m <sup>2</sup> )		
	R	TC	TF	R	TC	TF
1	82	217	200	1642	12109	11992
2	93	117	87	3058	3197	2084
3	294	94	55	37458	3834	951
4	57	133	250	1042	4226	25044
5	257	195	222	18834	16609	19217
6	150	52	195	6726	767	9559
$\bar{X}$	156	135	168	11460	6190	11475
sd	190	132	179	27262	12578	20510
n	18	18	18	18	18	18

forest transients moved more than 500 m more commonly (27.7%) and moved less than 50 m less commonly (16.6%). Differences between the other groups were smaller. The total activity was highest for transient animals from the forest and lower for mice from farmland whether resident or transient.

Because data in Table 2 are total distances moved, some transformation to an area measurement facilitates comparisons with literature data on areal scales of movement. By setting each individual's two most distant locations as the ends of the long axis of an ellipse with its lesser dimension equal to 25% of that value, area estimates were calculated (Table 3). These areas will be overestimates compared to the actual area known to have been ex-

plored. However, considering that most locations were along linear landscape elements, and that only two night's activities were monitored, we offer these as reasonable estimates of the areal scale that should be used in planning studies for this species in this type of landscape.

For resident mice this area ranged up to 11 ha with a mean of 1.14 (sd = 2.72). For transient forest mice the mean was very similar (1.14, sd = 2.05) with a maximum of 7 ha. Transient cropland mice had the lowest maximum area (almost 5 ha) and mean (0.67 ha, sd = 1.26). These mean areas do not differ significantly.

## Discussion

As movement corridors, fencerows were clearly important for these mice (cf. Simberloff and Cox 1987, Daniels 1988). The majority of individuals moved only in these corridors and, in terms of both time and distance, most movement was in the fencerows. However this does not mean that these mice do not use farmland as habitat. We have conclusive evidence that they do (Wegner unpubl., Wegner and Merriam in prep.) and not just occasionally by animals staying close to wooded habitat as reported by Adler *et al.* (1984), Mineau and Madison (1977) and Geluso (1971). We expected residents (not translocated) to spend more time in familiar, adjacent fields. We created transients by translocation and used them to model dispersers in unfamiliar surroundings. We prefer this definition to those based on low recapture frequencies (Dickson 1982, M'Closkey and Lajoie 1975, Golley 1960) or based on arbitrary movement length (Krohne and Burgin 1987). Our transients seldom left the fencerows and showed no difference related to habitat occupied previously. About half of the residents used adjacent fields and two spent most of their time there. The evidence for effects of previous habitat experience is unclear.

Our results deny the assumption that all fencerows are equally useful for movements across the landscape by *P. leucopus* (cf. Fahrig and Merriam 1985, Lefkovitch and Fahrig 1985). These mice make much greater use of structurally complex fencerows. Use of complex fencerows is consistent with behavioural preferences of this species for shelter structures such as stone piles or logs and for shrub and tree strata in fencerows (Graves *et al.* 1988, Barry and Francq 1980).

If complex fencerows provide lower mortality of moving mice, then differential use of complex corridors can critically affect the value of connectivity. Henein and Merriam (in press) have shown that without such preferential use, low quality corridors can affect metapopulation survival.

How should rate of use of fencerows as corridors be measured? The first important point is that distance moved and activity time used for movement were not linearly related. These mice moved in

bursts so that although they moved long distances, they were exposed for very little time. If mortality risk is proportional to exposure while moving, then distances moved (both means and variances) cannot be proportional to mortality risk and should not be used as an index of risk of predation.

For these mice, temporal rates probably are needed mainly to get mortality values for landscape models. Rates based on the distance scale will be needed to drive the spatial dynamics of models and results will be discussed below under our third objective. Rates of corridor use per head of population will be the most debated. Critical evaluation of data available in the literature for this species indicates that production of transients or dispersers is not density dependent (Krohne and Burgin 1987, Stenseth 1983). If this is so then we need simple rates per head of each age-sex group in the population supplying the moving animals. Our results give no answers here. We can only suggest that these sex/age-specific rates also may need to be patch-specific, *i.e.*, for the woods subpopulation, the fencerow subpopulation, the grain field subpopulation, etc.

Rate of corridor use also can be measured in terms of availability. For transient mice there was a significantly greater probability of use of wooded fencerow corridors than predicted by the area of fencerows as a component of the landscape.

What was the spatial scale at which these mice used this landscape? Total distances moved have large variances. The cause of these large variances and shifts in the distributions may involve differences in exploratory or movement behaviour: among individuals, within individuals over time, or among groups (landscape experience types). Because our experiments ran for only two nightly activity periods, variation within individuals over time could easily have been effective. Longer radio tagging experiments could only increase the mean of distances moved.

To compare the scale used here with results from other studies, some areal transformation is helpful because many give home range area. Because most movements followed linear landscape elements (mainly fencerows), we used ellipsoid approximations rather than the usual polygonal estimates. The

length of the principal axis was empirical and the secondary axis was set at 25% of the longer axis based on known fencerow widths compared to movement distances. This overestimates the area actually explored by some individuals but is realistic for this comparison. The distances and areas used by these mice in farmland clearly are large compared to other published estimates. The mean home range area calculated from all values tabulated by Stickel (1968) from live-trapping was 0.103 ha for 103 *P. leucopus novaboracensis* and 0.191 ha for 1164 *P. leucopus* of all subspecies. Madison (1977) reported 0.10 ha for 9 males and 0.11 ha for 6 females from radio tagging. All these results came primarily from woody or brushy habitat. Krohne and Burgin (1987) suggested 0.44 ha as a safe overestimate for purposes of choosing trap grid size.

In contrast we found the most distant points on all movement paths averaged 153 m apart along a straight line and ellipsoid areas calculated around those lines averaged 1.15 ha, 0.68 ha and 1.15 ha for the three mouse types. Clearly these are not home range equivalents; some of these mice were manipulated to make them transient. However the residents were not translocated and have 155.5 m movements and 1.15 ha area so that argument fails.

These mice used areas an order of magnitude larger than those for most woodland mice. This has significant implications for minimum size of study area useful in landscape-scale studies of species known from other habitats or disturbance regimes. This is not a function of the methodology of this telemetry study; the same scale difference is evident in extensive live trapping results to be published elsewhere (Wegner and Merriam). The movement behaviour of this species in farmland is so different that study areas must include 3 or 4 farms of 50 ha to encompass the maximum distances moved and the areas explored. In contrast, study areas in wooded habitat may be 75 m in diameter and under 0.5 ha. The apparent adjustment of behaviour by these animals when using heterogeneous mosaics of farmland makes very clear that behavioural factors are critical elements in ecological processes at the landscape scale. It also seems possible that behavioural flexibility in adapting to landscape-scale habitat changes may be a more critical predictor of

potential for species survival under human impact than is the rigid habitat specificity which is often used in this prediction.

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