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Use of Corridors and Scale of
Movement in Farmland by Peromyscus leucopus

by

© Alain Lanoue, B.Sc.

A thesis submitted to the Faculty of
Graduate Studies and Research in partial
fulfillment of the requirements for the degree of
Master of Science

Department of Biology

Carleton University

Ottawa, Canada

April, 1988

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Thesis Supervisor

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ABSTRACT

The movement and behavior of Peromyscus leucopus in a low-intensity agricultural landscape were monitored using radiotelemetry for three groups of mice. Over a period of two nights scale of movement was comparable to data obtained in long term home range studies in homogeneous environment. Movement of animals did not differ significantly whether they were transient or resident. Fencerows were used for movement in a significantly higher proportion than any other element of the landscape. Wide fencerows with a high degree of structural complexity and presence of mature trees were used significantly more than all other classes of fencerows available.

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INTRODUCTION

The natural landscape of Eastern Ontario has undergone dramatic modifications during the last century. Extended forests that once covered most of the area have gradually been replaced by urban and agricultural developments with high levels of heterogeneity, introducing new elements such as agricultural fields of various types, farmyard and fencerows (Figure 1 and 2). The transformation towards an agricultural landscape has greatly increased the degree of patchiness of wooded habitat for forest organisms. Populations of white-footed mice (Peromyscus leucopus) living in and moving across these landscapes had to adapt to this rapidly changing environment. Recognized as being predominantly forest dwellers (Adler et al. 1984, Baker 1968, Cooke and Terman 1977), sub-populations of white-footed mice occupying remaining forests patches show high risk of extinctions with patch size reduction and increased isolation. A high degree of connectivity is necessary for patch recolonization. The overall mosaic of sub-groups would in fact function as a "meta-population" consisting of a group of patch populations going extinct locally and being recolonized (Merriam 1984). Within this farmland mosaic

the presence of fencerows has a great potential for enhancing dispersal between patches and therefore can have important effects on meta-population survival (Fahrig and Merriam 1985). A model used to assess the importance of fencerow corridors assumed equal probability of mice successfully using corridors for movement regardless of corridor structure (Fahrig and Merriam 1985, Lefkovich and Fahrig 1985). This assumption has not been tested in the field.

Better understanding of this dynamic system necessitates the consideration of the landscape heterogeneity assessing the relative importance of its elements. It also starts with the utilization of the appropriate scale. Many studies of P. leucopus have been limited to live-trapping in generally homogenous forested areas (Krohne and Baccus 1985, Metzgar 1971, Myton 1974, Stickel 1946) and the scale used may not apply to movement and dispersal in this entirely different farm landscape. The decision to use a certain working scale in studies has often been based on home range size of the white-footed mouse. Stickel (1968) reported results from many such studies often evaluating home range sizes using distances between successive captures to calculate circular areas. Others (Beer 1961, Fitch 1958, Mineau and Madison 1977, Wolff 1985) used the minimum area method to estimate home range. Home range sizes derived from these studies have

also been used to distinguish long movements of "dispersers" from short-range movements of "residents" (Krohne et al. 1984).

This study addresses three main questions:

- 1) What is the spatial scale of movements in fencerow corridors in this landscape?
- 2) Do resident farmland mice use these corridors differently than transient mice with behavioral experience in different habitat?
- 3) Does the diversity in structural types of fencerows in low intensity farmland affect use by P. leucopus of the fencerows as movement corridors?

METHODS

Locations

All experiments were conducted during the summer and fall of 1986 (June 5 to November 16) on low to medium intensity farmland about 25 km south of Ottawa, Canada (W: $75^{\circ} 39'$, N: $45^{\circ} 12'$) (Figure 1 and 2). This farmland is characterized by small agricultural fields, small mechanical implements and moderate use of farm chemicals. The heterogeneity of the study site is well represented by the area surrounding each release point. Within a circle of two hundred meters radius around each point three different types of fencerows are always represented forming a maze with an average of more than eight intersection points. Within the same area, animals have access to an average of eight fields of five different types (Figure 2). The distribution of the four main types of landscape elements: fencerows, fields, farmyards and woods are shown in figure 1 and figure 2.

Three different groups of mice are compared. The first group designated as "residents" is composed of animals captured on site within fencerow corridors in the

vicinity of the experimental release points. The other two groups function experimentally as dispersers because they were geographically displaced from where they were trapped to the experimental release site. The second group designated as "transient from forests" is composed of individuals captured in large deciduous forested areas more than 5 km from the experimental site. The third group designated as "transient from cropland" is composed of mice captured in corn fields within a low intensity farming landscape more than 5 km from the study site. Each group contained 18 adult mice, with varying sex ratios reflecting temporal availability.

Experiment

All mice were captured using identical live-trapping techniques. Transient mice were kept in a vivarium for no more than two consecutive nights. Resident mice were released on location at sunset on the night after they were trapped. Every mouse was equipped with a radio-transmitter and released one hour after sunset at one of the six release points (Figure 1 and 2). Radiotelemetry has been shown to be a very reliable technique and it does not seem to affect mouse movement (Chute et al. 1974, Madison 1974, Mineau and Madison 1977). The six release points were distributed evenly among three adjacent properties. The central property is characterized by low intensity farming

with land farmed more intensively on its northern and southern sides. Each release point is situated at the intersection of three fencerows so that all types of fencerows (discussed below) are present. No more than one individual was released at a particular point during any two night period. Radio transmitters were crystal controlled Holohill model BD-1 with frequencies varying between 173.81 M.Hz. and 174.09 M.Hz., a weight varying between 0.95 g. and 1.00 g. and equipped with a flexible 11 cm stainless whip antenna. Transmitters were attached by a collar made from plastic cable ties used to bundle electronic wiring and were glued dorsally to the fur of the mouse with "Skin Bond" cement.

Merlin 12 receivers with a yagi antennae were used to monitor the movement of each individual by one person. The exact location of the mouse (± 1 m.) was determined by triangulation sightings every ten minutes. P.leucopus is usually nocturnal (Falls 1968) data were therefore collected on each individual from one hour after sunset on release until dawn the first night when the mice normally took cover and remained through the day. On the following night tracking resumed from that point and continued until dawn. Most experimental mice were then retrieved by surrounding the last tracking location with live-traps.

Data included: characterization of every landscape element utilized, time spent in each element, time used in

actual movement and locations of all points visited. Total number of meters moved and net distances moved were calculated from measurement of fencerow lengths in the field. To investigate the importance of structural differences in fencerows, three types were distinguished. "Simple" fencerows were characterized by the presence of trees, shrubs or important structural elements such as logs, stone piles or walls on less than 10% of their total length and were always less than two meters wide at ground level. They often consisted of grassy division lines between fields usually accompanied by some type of man-made fence. "Intermediate" fencerows contained unlimited shrubs and/or structural elements, with 10% or less of the total length overhung by tree canopies and with a width of less than two meters at ground level. "Complex" fencerows are overhung by tree canopies on more than 10% of their total length and were more than two meters wide at ground level. This classification is definitely biased towards complex types which include a much larger range of structural diversity than do either of the other classes. The reason for this will be presented in the discussion.

RESULTS

The data collected during the experimental period are presented here in four sections. The first three sections present the data from three experiments in the same format using identical calculations. The fourth section presents general results from all the experiments taken together. Before presenting those results some of the terms and calculations are explained.

Terms and calculations

Distance and area covered

Total number of meters moved was calculated by adding up the straight line distances travelled between location points recorded during the total movement activity of the mice. Net distances were calculated by excluding all repeated coverage of any one meter segment. In an attempt to make data comparable with those from previous studies I developed a third way of describing mouse exploration. The two most distant points recorded over a period of two nights were chosen as the extremities of a straight line representing the largest dimension of an ellipse and measured from a 1:1111 airphoto. The length of the

shortest dimension was fixed to be 25% of the largest one. An elliptical configuration for the "home range" of mice in this study would be more realistic than a circle considering the linear shape of fencerow corridors. The smaller dimension is reasonable considering the widths of many fencerows on the experimental site.

Time moving

Because of the variable length of nights which controlled the activity period over the study period, time had to be standardized. All calculations of activity as a time fraction are reported as a percentage of the total activity period over two nights. Activity period was defined as beginning one hour after official time of sunset, when the animals were released and ending at sunrise. This procedure was based on preliminary observations from experiments conducted during the year preceding this study.

Landscape elements

I calculated the time spent in each of four landscape elements available to the mice. Comparison of distances travelled in each landscape element would be a doubtful measure of preference considering the differences in the relative total areas of the elements and the linear nature of the fencerows. When moving along fencerows the mouse

always has the possibility to enter and spend time in adjacent fields but not always other landscape elements. The respective time utilization of fields and fencerows was compared using non-parametric statistics.

Fencerow types

To compare the relative use of three different fencerow types (described earlier) by released mice required some measure of relative availability of fencerow types. A circle of two hundred meters radius was drawn on an air photo around each of the six release points. This radius approximated the average distance travelled in any direction from each release point by all mice. Within this circle all fencerows between fencerow intersections were characterized according to the three categories described earlier as "simple", "intermediate" and "complex". To describe utilization, each meter of fencerow was then categorized as used or not by at least one mouse. The repeated use of any section of fencerows is not considered. This established which of the available sections of fencerows of every structural type were acceptable to the animals as movement corridors. If repeated visits were included, the preference for complex fencerows would increase greatly; making this a conservative method of testing. A G-test was performed on the data.

Experiment 1: "resident" mice

As can be seen in Table 1, two females were captured for this experimental group. Only ten females were captured over the entire experimental period. Data from both sexes were calculated and discussed as a whole since data did not show significant differences according to sex. The activity of resident mice as shown by the total distances they moved (Table 1) varied greatly among individuals. This is also reflected in the net distances explored and the estimation of the area covered. In each case the standard deviation exceeds the group average. Eleven animals moved for a total of more than 100 meters and one moved over 1600 meters. The evaluation of net distances moved still showed eleven individuals exploring more than 100 meters. Resident mice covered an average area of 1.15 hectares. In linear terms, this area covered would mean that only two resident animals moved less than 100 meters over a two night period.

Over this experimental period, "residents" spent an average of 16.5% of their time moving (Table 2). Almost half of them (8) moved during more than 20% of the total period while one mouse used more than half of it (52.5%) moving through the landscape. In addition to moving in

fencerows, these "residents" also explored crop fields. Eight mice spent an average of 13.3% of the recorded period visiting fields (Table 3). However fencerows still were strongly preferred ($p \leq 0.01$) when compared with a non-parametric Mann-Whitney U-test (Sherrer 1984).

When moving in fencerows, residents used less than 10% of simple and intermediate fencerows available and clearly preferred ($G = 285.9$; $p < 0.005$) the complex types. Over 15% of the available length of complex fencerows was used while simple fencerows were used much less than expected (Table 4). The trend is the same at any individual release point.

Experiment 2: "Transient" mice from forest

Table 5 demonstrates again a high level of variability among individuals for each evaluation of distances covered. Transient mice with experience in forested areas moved on average a total of 421 meters. Fourteen animals moved more than one hundred meters and four mice each moved more than one thousand meters. However only eleven mice travelled for a net distance greater than 100 meters. All the animals except two explored a calculated area of more than 100 square meters, on average covering more than 1.15 ha. The animals only

spent a fraction of their activity period in measurable movements; on average they moved during only 12.5 % of the two nights recorded (Table 6). Movement within each of the four landscape elements described is shown in Table 7 in terms of time. On average they restricted their activity to fencerows for 92 % of the total experimental period. Less than 3 % of the two nights was spent in fields, woods or farmyard. A Mann-Whitney U-test showed a highly significant preference ($p \leq 0.01$) for fencerows over fields. The distribution of distance moved in three types of fencerows shows a very significant preference ($G = 721.3$; $p \ll 0.005$) for high structural complexity (Table 8). Simple fencerows were used only at release points 3 and 4 where the proportion of complex types of fencerows is minimal. Use of the intermediate fencerows follows the same pattern. Only the three release points with low availability of complex fencerows show any use of intermediate fencerows by mice with behavioral experience from forest habitats.

Experiment 3: "Transient" mice from cropland

Mice with experience in cropland moved for a total of 287 meters on average during two nights. One individual moved more than 1400 meters in total distance while eleven

others moved more than 100 meters, a distribution similar to the resident mice. Variability is high again with standard deviations exceeding the mean for total distance, net distance and estimated area covered in Table 9. Half of these transient mice explored a net distance of more than one hundred meters. On average mice from cropland were estimated to cover less than 0.68 ha. Three mice each covered a calculated area of more than one hectare. Table 10 shows that animals from this group averaged 13.1 % of the time moving and only three individuals spent more than 20 % of the activity period moving.

A mean of almost 94 % of the total recorded time was spent within fencerows (Table 11). In fact 14 animals out of 18 remained exclusively within fencerows. Farmyards were never explored by this group, only three visited fields and one visited a wood. A Mann-Whitney U-test showed highly significant preference ($p \leq 0.01$) for utilization of fencerows over fields.

When the three different levels of complexity in fencerows are compared the preferences are obvious. Less than 5 % of "simple" fencerows available in the vicinity were visited while almost 20 % of the complex type ($G = 627.4$; $p \ll 0.005$) were explored (Table 12). Transient mice from cropland made use of intermediate and complex fencerows at each release point, while only at points 1

and 6 were no sections of simple fencerows used.

General results

Inter-group comparisons

Total distances, net distances, area covered, percentage of time moving and percentage of time in fencerows were compared among the three groups of mice. All tests showed no significant differences ($p \leq 0.05$).

Movement and time

Following are some descriptive examples of typical use of time by mice in an agricultural landscape:

Example 1, Mouse # 52 (resident)

For the two nights movement was restricted to the first half of the activity period. Continuous sequences of movement never lasted more than 20 minutes and were always followed and preceded by equally or longer periods of time remaining still.

Example 2, Mouse # 12 (transient from forest)

Close to 80 % of movement was restricted to the first night of the experiment. During this initial night all perceptible movement was regrouped within a single hour.

covering important distances.

Example 3, Mouse # 30 (transient from cropland)

Movement of this mouse was restricted to five distinctive activity periods for the two experimental nights.

Predation

Some of the animals recovered following the experimental period were found dead. Of this number, four animals were undoubtedly killed by predators. Three of them were transient mice from forest and one was transient mouse from cropland. No resident mouse was found dead following the experiment.

DISCUSSION

The aim of this study was to gather information on movement of white-footed mice and record their utilization of the landscape as precisely as possible. Prior to any experiment on habitat utilization, one must first acquire knowledge on the extent of land utilization by the animals in order to determine the appropriate working scale. The use of radiotelemetry to study three groups of mice with specific differences allowed me to achieve these objectives. Animals from each group can be distinguished according to the original landscape they were inhabiting, the specific landscape element at the trapping location and the distance from experimental site. Mice with no previous experience in agricultural landscapes were expected to be less likely to venture in open fields and more attracted to wooded sections of the landscape than animals already living in a farming environment. No existing data indicates whether or not all mice living in the same heterogeneous landscape will use landscape elements at the same rate. However it was expected that mice trapped in the middle of a corn field would be more prone to venture out of the wooded areas than mice captured within woods or fencerows. Finally, the two groups of experimental transient mice were expected to use the habitat differently and probably to move greater distances than resident mice

limited to a specific home range. The study of these three groups gives more information on the scale of movement of P. leucopus moving and dispersing in a very heterogeneous habitat. The main objective was then to assess the importance of fencerows as movement corridors. Subsequently, it was possible to determine if the utilization of fencerows was influenced by the wide gradient of complexity of corridors on the experimental site.

Live-trapping, widely used in small mammal studies is inadequate for our experiment. Radiotelemetry is superior because it allows continuous tracking of animals without stopping their movement. Unlike methods such as smoked paper tracking (Fahrig and Merriam 1985, Morrison 1986, Sheppe 1965), radio-tracking does not necessitate the predetermination of a limited sampling area. Radiotelemetry will therefore allow determination of the scale of movements of the animal in a particular habitat without any artificial spatial restrictions.

This method has rarely been used in the past for small mammal tracking because of the large size of the transmitters. With recent improvements in microelectronics, this technique has been increasingly employed, especially to study dispersal in small mammal populations (Banks et al. 1974, Chute et al. 1974). It has been used rarely in the study of P. leucopus (Madison 1977,

Mineau and Madison 1977, Wolff 1985, Wolff and Hurlbutt 1982). However the methodology I used presents certain limitations. The main one being the duration of the experiment. Movements calculated over only two experimental nights are likely to be underestimated when compared to other radiotelemetry or live-trapping studies which last for weeks (Krohne and Burgin 1987, Madison 1977, Myton 1974, Nadeau et al. 1981). The reduced length of the experiment probably has an effect on the high variability observed in scale of movement among individuals. It is directly related to the fact that most mice restricted their movement to only short portions of the entire activity period. The main advantage of this methodology is that all experiments are standardized so that individuals and groups of mice are directly comparable over the entire experimental period. Nevertheless the situation occurring through the first two nights may also represent the most important portion of the dispersal activity for P. leucopus. A recent study (Graves et al. 1988) showed the average distance travelled by P. leucopus within four hours after release to be around 78 meters. Mice may well remain within the same area during the subsequent days. But, for future studies I would still recommend an increase in the duration of the experiment in order to decrease the degree of variability and make the data more realistic and comparable to live-trapping experiments.

Scale of movement

Numbers calculated here for scale of movement of P. leucopus are not directly comparable with any previously published data because I recorded the movements in much greater detail. Records of mouse position every ten minutes allow for a precise calculation of distances travelled. Calculations of total distances travelled by resident mice in my study represent a very good index of their real exploratory activity. If collars and radio-transmitters had any effect on behavior of the experimental mice, it did not stop any resident mouse from moving. However the scale of this activity was extremely variable, ranging between 15 and 1643 meters. Similar variability among individual untagged mice was recorded in preliminary laboratory observations in behavioural arenas (grid boxes).

In this present experiment many males and all females moved for a total of well over 100 meters in only two nights. Since this activity is restricted to a very small portion of the entire activity period (less than 17 % on average), movement is actually quite fast. This probably constitutes an understatement since the mouse can move on the ground and along three dimensional structures within the region perceptible by radio-tracking (around one

square meter). Restriction of movement in time drastically reduces the exposure to possible predation. In fact none of the 18 mice that were familiar with the study area was found dead as a result of predation during the two night experimental period or even in the following days sometimes required to recapture the animals.

To better assess the scale of the landscape exploration by a mouse I eliminated the repeated passages over the same area resulting in records of net distances covered. Net distance is the best representation of the extent of the area explored by the animal. It is an accurate measure of the real distance moved by the mouse and takes into account movement in any direction. Such is not the case with live-trapping data where it is usually assumed that travel between two points of capture is done in straight line. Calculation of net distances moved are based on direct and continuous observations without any bias due to extrapolation and unverified assumptions. It also has the advantage of giving a clear representation of the total pattern of movement with the exact utilization of different landscape elements. This last aspect appears crucial when the study is conducted in a heterogeneous habitat.

In the present experiment I discovered that all resident mice explored a minimum of 15 meters of the

surrounding habitat over a period of two nights. The animals that showed little activity when the total distances covered were considered (less than 100 meters) all remained within a limited area and covered 50 meters or less. All the other mice used over 100 meters of the available landscape. Variations in total and net distances among mice are most often correlated. This seems to indicate that, in the case of animals familiar with the surrounding habitat movement is rarely in one direction but most often shows a good utilization of every patche visited.

Live-trapping methods do not allow for precise data such as net and total distances as calculated here. The same is true for other radiotelemetry studies on the white-footed mouse (Mineau and Madison 1977, Wolff 1985) which recorded the position of the animal every hour or only once or twice within the nightly period of activity. To compare the scale of movement here with other studies, data has to be analysed differently. Home range studies of *P. leucopus* are numerous and use various methods of evaluating the living area of the mice. Recently, Krohne (1986), from his and other previous studies, estimated the greatest dimension of a resident white-footed mouse home range to be around 75 meters and with areas regularly smaller than one hectare. The linearity of the routes followed by most of

the animals during my experiments dictated the method used to calculate home range sizes. Construction of polygonal areas was often unattainable from linearly distributed data points and assumption of circular areas was very unrealistic. Elliptic shape better represented the area of mouse activity associated with linear landscape elements.

I used the longest straight line distance as the longest dimension as has often been done in the past (Stickel 1968). The decision to fix the width of the ellipse at 25 % of its length was based on the fact that area of a fencerow 100 meters long and 10 meters wide (common width) was very similar to the corresponding area of an ellipse 100 meters long and 25 meters wide. Since movement was primarily along complex and wide fencerows this assumption is realistic. However, because the study extended over only two nights the area is probably often underestimated when compared to other studies using longer periods of exploration. Nevertheless the average calculated for resident animals here was over one hectare. One must be very cautious when comparing home range sizes estimated from live-trapping data between two different experiments. One factor to consider is the potential for variable home range shapes (Jenrich and Turner 1969). Limitations of the technique also have to be kept in mind (Stickel 1968). Live-trapping is affected by the variable

trappability of an individual through time and the movement is clearly affected. Tracking techniques such as feeding marker bait to the animal (Randolph 1973) probably gives a more accurate description of home range. However I still consider radio-tracking to be superior because of the absence of any attractor element (bait) or disruption in animal movement.

Shape of home range is possibly variable among habitats. The presence of linear structures (fencerows) in agricultural landscapes could delimit an area quite different in shape from what can be found in an homogeneous forest. The kind of variability seen in my study might even suggest variation in shape of living area among individuals related to heterogeneity of habitat. In these experiments it would be directly related to the willingness of the animal to expand its travel in fields adjacent to the linear fencerow corridors. When they are available, net distances travelled are a very precise and much better means of comparing movement among individuals within a landscape with a diversity of structural elements.

Movement and behavior of transient mice

Dispersal is an important aspect of population survival in patchy environments. Dispersal is defined by Gaines and McClenaghan (1980) as movements of only a short distance made by individuals away from a natal site. But defining dispersal as movement of an individual away from a home range frequently resulting in the establishment of a new home range (Lidicker 1975) is more realistic. Approaches to the study of dispersal are diverse and dispersing mice usually have been designated arbitrarily. In some studies dispersers were defined experimentally (Metzgar 1967) or by depopulating patches (Stickel 1946, Sullivan 1977), but in many cases individuals were defined only by their low rate of recapture in a specific area and time period (Golley 1960, Dickson 1982, M'Closkey and Lajoie 1975). More recently, the status of dispersers has been determined according to distance travelled. Krohne and Burgin (1987) described as dispersers any mouse moving more than 75 meters based on their evaluation of typical home range size. Considering the results collected here the validity of this approach seems rather doubtful.

In this experiment mice were displaced from their home range to the experimental site. They were automatically introduced into an unfamiliar landscape making them forced dispersers. Since no consensus has been

made on the best way to determining the status of a mouse on a certain location this was believed to be the least biased methodology. Visual and olfactory cues have been shown to be very important (Parsons and Terman 1978, Sheppe 1965) for P. leucopus moving across the landscape. However in my experiment, distances of over five kilometers between capture and release sites added to the presence of important paved roads with high traffic flow between the sites helped to prevent presence of recognizable cues for homing by these mice. Homing studies on P. leucopus show that in some instances they can travel over 600 meters (longest straight line distance) within seven days (Cooke and Terman 1977). Transient mice in my study would then be expected, over the same time period to cover more ground than resident animals. No significant differences were found among the three groups of mice for total distances, net distances or area covered. Mice with experience from forest covered on average an area similar to resident mice while mice with experience in cropland covered even less on average. There was high variance in distances travelled by both types of transient mice. This can be explained partly by the short duration of the experiment. Longest straight line distances travelled represented in the estimation of the area covered were much lower than expected not being significantly higher than for resident mice. However transient mice from forest travelled greater distances on

average than the other two groups. Mice with previous experience in agricultural landscape did not move longer distances than transient mice from forest.

Fencerow corridors

Fencerow corridors were the most important structured elements of the landscape for transient and resident white-footed mice alike. All transient mice tested spent at least half of the activity period in fencerows. Two resident mice spent more than 50 % of the two nights in fields. A total of eight resident mice visited the open fields while only three transient mice previously captured in corn fields, ventured out of the wooded regions. Their behavior seems more related to the other group of animals moving across an unfamiliar site. There is a definite trend for greater utilization of fields by resident mice. Woods and farmyards were very rarely visited by transient mice while resident animals never moved in these two landscape elements, spending all their time in fencerows or fields. This use of fields by mice living in agricultural landscape has usually been considered as exceptional but the evidence is growing that this is common. Studies conducted in the area using live-trapping (Wegner unpublished data) seem to indicate that fields are commonly used by *P. leucopus* for moving, feeding

and also as a breeding site. Occasional use of fields has been recorded by some authors (Adler et al. 1984, Geluso 1971, Mineau and Madison 1977). However the animals usually remain close to wooded sites. This was not the case for at least four resident mice in my study including even one lactating female (mouse # 43).

Transient mice from forests might have been expected to move towards familiar wooded areas regularly but they did not. They ~~did not~~ behave differently than transient mice with previous experience in farmland and rarely explored woods. Mice captured in cropland were expected to behave more like resident mice and venture into fields more often than animals from forested area. Only three transient mice from cropland ever used fields and most of them remained exclusively in fencerows. In an unfamiliar landscape fencerows seem to represent a secure place for dispersers.

Before assessing the importance of various levels of complexity of fencerows in their utilization by mice it was necessary to determine the most appropriate classification. A preliminary study showed that mice did not distinguish among a great range of complex fencerow types containing easily observable structural differences. Fencerows were first classified according to clear differences assumed to have an effect on the use of corridors by mice. Fencerows were mainly differentiated by the nature of their ground

cover (presence or absence of logs, stone walls and man made fence). However, it was shown that these observable differences did not affect the decision of the mouse to chose or not a certain fencerow as a movement corridor. For this reason the new classification is based on the relative amount of certain structural elements present in the fencerows instead of their presence or absence. Trees, shrubs and ground covering elements were considered. Even though the availability of fencerow types on the entire experimental site is biased towards complex structures, every class of fencerow is represented at each release point. The use of a G-test standardizes the variable proportions of fencerow types at each release point and allows unbiased comparisons.

This classification was clearly appropriate, the analysis was simplified and the results were clarified. Mice from all origins did distinguish among fencerow types available. Out of all types of fencerows, complex ones were strongly and significantly preferred by all mice whether they were transient or resident on the site. P. leucopus will use simple and intermediate fencerows to move but will more frequently venture in adjacent fields than when moving along complex fencerows.

In order to understand these preferences for complex corridors, one has to consider the multiple aspects of complexity of fencerow structures. This type of fencerow

contains the largest range of different three-dimensional structures. I sprayed fluorescent powder on mice in preliminary experiments and the resulting data showed the importance of these structures for movement of P. leucopus. The trace left behind gives precise information on the substrate used by the animal. Movement on top of unprotected artificial fencerows made of snow fence as well as use of natural three-dimensional structures, primarily trees and shrubs, by the white-footed mouse was observed regularly. Recent experiments on P. leucopus using the same technique (Graves et al. 1988), showed frequent occurrence of the same behavior. On average 15 % of the movement occurred in trees or shrubs. However 79 % of all three-dimensional tracking was observed in shrubs or trees of less than 10 cm diameter at breast height (Graves et al. 1988). Utilization of trees and shrubs by the white-footed mouse was already well documented (Horner 1954, M'Closkey 1975, Nicholson 1941). The important number of small trees and shrubs in most intermediate fencerows would also make them very attractive for mice. However P. leucopus still seems to spend more time on structure at the ground level (Graves et al. 1988) which were more abundant in the third type of fencerows (complex) making it a major factor in explaining their preferential use by mice.

Another important aspect of fencerows for mice dispersing in an unfamiliar landscape is protection. The

important canopy and dense shrub coverage of most complex fencerows represent a good insurance against birds of prey. In an experimental study of screech owl predation on P. leucopus Metzgar (1967) showed that transient mice were very vulnerable, significantly more than resident mice. I arrived at the same conclusion when all predators are taken into consideration. The high complexity of some fencerows plays a dual role by also helping population of ground predators, mainly weasels, often captured on the experimental site. Domestic cats are also present in good numbers due to proximity of numerous farms. It appears that transient mice were disadvantaged even though they remained in the fencerows most of the time.

Fencerows were also used during the day by all experimental mice. Day refuges predominantly consisted of burrows within or under stone piles or walls mostly found in complex fencerows for resident or transient mice. Old tree stumps and fallen trees were used, but to a significantly lesser extent. Madison (1977) in a study of P. leucopus in woodlots observed the utilization of the same type of refuges. He also observed the same type of behavior when the white-footed mouse chooses its nesting site (Madison et al. 1984) using mostly protected areas and also trees, especially within squirrel nests. Finally the important diversity of food sources in complex fencerows certainly had an attracting effect on white-footed mice.

Perspective

The necessity of considering the heterogeneity of the environment is recognized by many scientists (Adler and Wilson 1987, August 1983, Clark et al. 1987). Agricultural landscapes are composed of various elements but very little is known about the relative importance of the role they might play for animal populations. The concept of connectivity is gaining in consideration and, in agricultural environments fencerow corridors probably are one of the key component to a dynamic landscape. Their role in the equilibrium of the ecosystem has been recognized (Forman and Baudry 1984) and their effect on small-mammal populations has already been subject to some studies (Pollard and Relton 1970). Contrary to the findings of Yahner (1983) it seems that P.leucopus using agricultural fields is not an exceptional event. Increasing evidence of use of fields by mice in my study, other studies on the site and other published data (Clark et al. 1987) seems to indicate that fields should not necessarily be considered as very "hard edges" or oceans surrounding isolated forested islands (Stamps et al. 1987). However my experiment indicates that fencerow corridors are frequently used for movement and therefore can play a crucial role in survival of meta-populations of white-footed mice in agricultural landscape. Statements that

plants and small mammals are living forms that do not move efficiently along fencerow corridors (Forman and Baudry 1984) should be seriously reconsidered.

It has been shown that the quality of fencerows is very important and has to be taken into consideration in the construction of population dynamic models for small mammals populations. Complex fencerows are favoured for their multiple roles. They are closer to the original habitat of P. leucopus and they may represent a good shelter and a source of food for dispersing mice. White-footed mice in low-intensity agricultural landscape can travel long distances, and they appear to have home ranges of unusual shape and dimension compared to forest inhabitants.

CONCLUSIONS

- 1) Peromyscus leucopus living in low to medium intensity farming landscape move greater distances than previous records for mice living in homogeneous forested area and consequently may explore much larger areas.
- 2) Transient mice moving across unfamiliar landscape do not behave differently than resident mice when areal scale of movement and distance travelled are considered.
- 3) The assumption of equal utilization of fencerows of different structures proposed in models by Fahrig and Merriam (1985) and Lefkovitch and Fahrig (1985) is incorrect. Diversity in structural types of fencerows in farmland affects use by P. leucopus of the fencerows as dispersal corridors.

Table 1. Distances moved and estimated area covered by resident mice over a two night period.

Individual	Release point	Total distances (m)	Net distances (m)	Area covered (m ²)
37*	1	165	105	1425
38	1	174	130	3325
39	1	30	30	175
40	2	427	230	8650
41	2	41	25	125
42	2	87	45	400
43*	3	1643	950	110448
44	3	50	40	325
45	3	175	110	1600
46	4	265	120	2825
47	4	20	15	50
48	4	67	52	250
49	5	815	500	49101
50*	5	197	143	2376
51	5	405	190	5026
52*	6	320	280	15402
53	6	300	195	4725
54	6	15	15	50
$\bar{x}$		289	176	11460
s.d.		392	228	27262

* female

Table 2. Percentage of time allocated for movement by resident mice over a two night period.

Individual	Release point	Fraction of time moving (%)
37	1	12.3
38	1	4.0
39	1	5.7
40	2	22.6
41	2	7.1
42	2	8.6
43	3	52.5
44	3	9.8
45	3	21.3
46	4	26.7
47	4	2.1
48	4	11.0
49	5	31.2
50	5	13.2
51	5	26.1
52	6	20.1
53	6	20.9
54	6	1.6
$\bar{x}$		16.5
s.d.		12.7

Table 3. Relative distribution of time (%), over a two night period in four types of landscape elements by resident mice.

Individual	Release point	Landscape Elements			
		Fencerow (%)	Field (%)	Wood (%)	Farmyard (%)
37	1	91.4	8.6		
38	1	100.0			
39	1	100.0			
40	2	53.0	47.0		
41	2	100.0			
42	2	100.0			
43	3	27.1	72.9		
44	3	100.0			
45	3	87.8	12.2		
46	4	100.0			
47	4	100.0			
48	4	96.3	3.7		
49	5	100.0			
50	5	77.3	22.1		
51	5	39.5	60.5		
52	6	100.0			
53	6	88.4	11.6		
54	6	100.0			
x		86.7	13.3		
s.d.		22.9	22.9		

Table 4. Use of fencerow structural types by resident mice (meters used in movement available meters of each type).

Release point	Fencerow type			Totals
	simple	intermediate	complex	
1	<u>0</u> 215	<u>40</u> 80	<u>175</u> 1880	<u>215</u> 2175
2	<u>40</u> 250	<u>10</u> 85	<u>120</u> 1390	<u>170</u> 1725
3	<u>115</u> 1030	<u>40</u> 180	<u>155</u> 745	<u>310</u> 1955
4	<u>20</u> 1355	<u>15</u> 600	<u>60</u> 655	<u>95</u> 2610
5	<u>0</u> 430	<u>35</u> 435	<u>355</u> 1085	<u>390</u> 1950
6	<u>54</u> 635	<u>80</u> 995	<u>201</u> 835	<u>335</u> 2465
Totals	<u>229</u> 3915	<u>220</u> 2375	<u>1066</u> 6590	<u>1515</u> 12880
(%) used	(5.9)	(9.3)	(16.2)	(11.8)

Table 5. Distances moved and estimated area covered by transient mice from forest over a two night period.

Individual	Release point	Total distances (m)	Net distances (m)	Area covered (m ²)
1	1	1090	567	31427
2	1	725	140	3850
3	1	165	72	700
4	2	25	187	5026
5	2	257	25	125
6*	2	105	75	1100
7	3	107	103	2075
8	3	340	300	775
9	3	15	4	3
10	4	1396	900	70702
11*	4	5	5	5
12	4	448	150	4425
13	5	1102	530	55152
14	5	86	26	125
15	5	229	170	2375
16	6	1029	230	10401
17	6	351	300	17676
18	6	112	55	600
$\bar{x}$		421	213	11475
s.d.		445	237	20510

* female

Table 6. Percentage of time allocated for movement by transient mice from forest over a two night period.

Individual	Release point	Fraction of time moving (%)
1	1	21.3
2	1	15.6
3	1	9.1
4	2	6.5
5	2	11.3
6	2	5.6
7	3	6.0
8	3	11.4
9	3	21.0
10	4	34.5
11	4	1.2
12	4	12.5
13	5	19.4
14	5	4.2
15	5	8.3
16	6	25.7
17	6	7.0
18	6	3.9
$\bar{x}$		12.5
s.d.		8.8

Table 7. Relative distribution of time (%), over a two night period in four types of landscape elements by transient mice from forest.

Individual	Release point	Landscape Elements			
		Fencerow (%)	Field (%)	Wood (%)	Farmyard (%)
1	1	76.1	2.9	21.0	
2	1	100.0			
3	1	88.3	11.7		
4	2	100.0			
5	2	95.8	4.2		
6	2	100.0			
7	3	100.0			
8	3	50.0			50.0
9	3	100.0			
10	4	65.0	12.5	22.5	
11	4	100.0			
12	4	100.0			
13	5	100.0			
14	5	100.0			
15	5	85.4	14.6		
16	6	100.0			
17	6	100.0			
18	6	100.0			
x		92.3	2.6	2.4	2.8
s.d.		14.5	4.9	7.0	11.8

No entry means 0.0 measured.

Table 8. Use of fencerow structural types by transient mice from forest (meters used in movement
available meters of each type).

Release point	Fencerow type			Totals
	simple	intermediate	complex	
1	<u>0</u> 215	<u>0</u> 80	<u>405</u> 1880	<u>405</u> 2175
2	<u>0</u> 250	<u>0</u> 85	<u>160</u> 1390	<u>160</u> 1725
3	<u>100</u> 1030	<u>5</u> 180	<u>216</u> 745	<u>321</u> 1955
4	<u>125</u> 1355	<u>85</u> 600	<u>90</u> 655	<u>300</u> 2610
5	<u>0</u> 430	<u>0</u> 435	<u>360</u> 1085	<u>360</u> 1950
6	<u>0</u> 635	<u>170</u> 995	<u>353</u> 835	<u>523</u> 2465
Totals	<u>225</u> 3915	<u>260</u> 2375	<u>1584</u> 6590	<u>2069</u> 12880
(%) used	(5.8)	(11.0)	(24.0)	(16.1)

Table 9. Distances moved and estimated area covered by transient mice from cropland over a two night period.

Individual	Release point	Total distances (m)	Net distances (m)	Area covered (m ²)
19*	1	642	380	28351
20	1	206	180	6376
21	1	165	102	1600
22	2	271	200	3850
23	2	88	45	400
24	2	180	165	5350
25*	3	12	5	25
26	3	915	240	11301
27	3	30	30	175
28	4	415	210	8652
29*	4	147	75	700
30	4	310	130	3325
31	5	50	40	325
32*	5	122	45	400
33	5	1403	720	49101
34	6	85	50	500
35	6	107	95	1775
36	6	10	10	25
$\bar{x}$		287	151	6791
s.d.		364	172	12578

* female

Table 10. Percentage of time allocated for movement by transient mice from cropland over a two night period.

Individual	Release point	Fraction of time moving (%)
19	1	23.1
20	1	10.4
21	1	12.9
22	2	18.2
23	2	5.7
24	2	11.0
25	3	2.5
26	3	29.4
27	3	4.3
28	4	13.9
29	4	12.1
30	4	14.5
31	5	6.7
32	5	7.0
33	5	43.4
34	6	11.2
35	6	8.6
36	6	0.8
$\bar{x}$		13.1
s.d.		10.4

Table 11. Relative distribution of time (%), over a two night period in four types of landscape elements by transient mice from cropland.

Individual	Release point	Landscape Elements			
		Fencerow (%)	Field (%)	Wood (%)	Farmyard (%)
19	1	100.0			
20	1	100.0			
21	1	96.5	3.5		
22	2	60.3		39.7	
23	2	100.0			
24	2	100.0			
25	3	100.0			
26	3	100.0			
27	3	100.0			
28	4	100.0			
29	4	81.2	18.8		
30	4	100.0			
31	5	100.0			
32	5	100.0			
33	5	52.7	47.3		
34	6	100.0			
35	6	100.0			
36	6	100.0			
$\bar{x}$		93.9	3.9	2.2	
s.d.		14.4	11.7	9.4	

Table 12. Use of fencerow structural types by transient mice from cropland (meters used in movement
available meters of each type).

Release point	Fencerow type			Totals
	simple	intermediate	complex	
1	<u>0</u> 215	<u>20</u> 80	<u>420</u> 1880	<u>440</u> 2175
2	<u>20</u> 250	<u>5</u> 85	<u>182</u> 1390	<u>207</u> 1725
3	<u>40</u> 1030	<u>10</u> 180	<u>162</u> 745	<u>212</u> 1955
4	<u>60</u> 1355	<u>70</u> 600	<u>155</u> 655	<u>285</u> 2610
5	<u>12</u> 430	<u>60</u> 435	<u>238</u> 1085	<u>310</u> 1950
6	<u>0</u> 635	<u>50</u> 995	<u>65</u> 835	<u>115</u> 2465
Totals	<u>132</u> 3915	<u>215</u> 2375	<u>1222</u> 6590	<u>1569</u> 12880
(%) used	(3.4)	(9.1)	(18.5)	(12.2)

Figure 1.
Study area.

- _____ : Fencerows
- - - : Farm lane
- . - : Gully, creek
- 1 : Release point
- FY : Farmyard
- W : Woodlot

Appx. scale : 1:10000

Figure 2.

Air photo.

P : Hay/pasture

G : Small grains

C : Corn

O : Old field

V : Vegetables

X : Orchard

: Release point : 200 meters

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