12

Effects of Vegetation Type and Adjacent Agricultural Matrix on Fencerow Use by Small Mammals: A Nonmanipulative Experiment

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Introduction

The increasing scale of agricultural activity over the past several decades has resulted in the destruction of thousands of kilometres of semi-natural strips of wooded vegetation, termed *fencerows,* bordering crop fields. This loss is of concern because fencerows provide habitat for many organisms that might otherwise not be found in agricultural areas, including various plants (Baudry 1988, Marshall 1988, Bunce and Hallam 1993, Fritz and Merriam 1993, 1994, Jobin et al. 1996), insects (Burel 1989), birds (Wegner and Merriam 1979, Arnold 1983, Osborne 1984, Shalaway 1985, Green et al. 1994, Parrish et al. 1994, 1995, MacDonald and Johnson 1995, Sparks et al. 1996), and mammals (Ogilvie and Furman 1959, Pollard and Relton 1970, Eldridge 1972, Wegner and Merriam 1979, Middleton and Merriam 1981, Yahner 1983, Henderson et al. 1985, Bennett et al. 1994, Henein et al. 1998). Although less thoroughly demonstrated, wooded corridors or fencerows are also thought to provide dispersal routes for organisms moving between patches of remnant forest, thus contributing to the recolonization and/or rescue of local populations (Wegner and Merriam 1979, Fahrig and Merriam 1985, Johnson and Adkinsson 1985, Merriam and Lanoue 1990, Bennett et al. 1994).

To maximize the benefits of retaining or restoring fencerows in agro-ecosystems, the features of fencerows that determine fencerow use must be identified. Whereas most researchers have focused on the vegetation within the fencerow (but see Green et al. 1994, Parrish et al. 1994), it seems likely that the landscape context of the fencerow (i.e., the agricultural matrix) may also affect its use by various organisms. In this study we asked: Is fencerow vegetation type sufficient to predict fencerow use by small mammals, or must the type of adjacent agricultural matrix be considered? We sampled six species of small mammals in 44 fencerows in a nonmanipulative experiment. The experimental design included

replicates of all nine combinations of three categories of fencerow vegetation type and three categories of adjacent agricultural land type. Species sampled included *Blarina brevicauda* (the short-tailed shrew), *Microtus pennsylvanicus* (the meadow vole), *Peromyscus leucopus* (the white-footed mouse), *Sorex cinereus* (the masked shrew), *Tamias striatus* (the eastern chipmunk), and *Zapus hudsonius* (the meadow jumping mouse).

Methods

The study was conducted in eight sample periods, one in each month between May 1986 and November 1986, and one in April 1987, on four 50- to 100-ha farms within 40 km of Ottawa, Canada. The farmland was subject to low-to-intermediate intensities of agricultural use as judged by the proportion of area under cultivation and the amount of woody material in fencerows surrounding crop fields. Fencerows were chosen based on two criteria: the predominant vegetation within the fencerow (herbs, shrubs, or trees) and combinations of the adjacent agricultural land types (grain–grain, grain–hay/pasture, or hay/pasture-hay/pasture), which resulted in nine categories. Replicates were obtained for each category (see Table 12.1). Fencerow width and length were also recorded. To avoid possible effects of proximity to forested areas, none of the fencerows selected was directly connected to a forest patch.

Dominant tree species in the fencerows were white ash (*Fraxinus americana*), elm (*Ulmus spp.*), and sugar maple (*Acer saccharum*); the dominant shrubs were *Viburnum spp.*, red osier dogwood (*Cornus stolonifera*), hawthorns (*Crataegus spp.*), and (*Spiraea spp*). The main grass species were timothy (*Phleum pratense*), quack grass (*Agropyron repens*), and brome (*Bromus spp.*); other common herbaceous species included wild parsnip (*Pastinaca sativa*), Queen Anne's lace (*Daucus carota*), vetch (*Vicia spp.*), and goldenrod (*Solidago spp.*). Note that the fencerows

TABLE 12.1. Number of replicates for each combination of fencerow vegetation type and adjacent land type.

Fencerow vegetation	Field 1	Field 2	No. replicates
Herb	Grain	Grain	6
	grain	hay/pasture	6
	hay/pasture	hay/pasture	5
Shrubs	Grain	Grain	4
	grain	hay/pasture	7
	hay/pasture	hay/pasture	4
Trees	Grain	Grain	2
	grain	hay/pasture	7
	hay/pasture	hay/pasture	3
Total fencerows			44

that contained trees also contained shrubs and herbaceous vegetation and that the shrubby fencerows also contained herbaceous vegetation. Structural complexity of the vegetation, therefore, decreased from treed to shrubby to herbaceous fencerows.

Three hundred and thirteen tubes, each 30 cm in length, were cut from 4-cm polyethelene water pipe and placed in 44 fencerows at 20-m intervals. Strips of white paper (30 × 8 cm) bearing a square of waxed paper (6 × 8 cm) painted with a suspension of carbon black and paraffin oil were placed inside each tube. Sunflower seeds were used as bait. An animal entering a tube had to walk through the carbon black suspension to reach the bait and, subsequently, left footprints on the white portion of the paper. Tubes remained in place for 7 days, after which the papers were removed and tracks of small mammals were identified. This technique gives a positive record of the presence of a species in a particular fencerow (for more details on the technique see van Apeldoorn et al. 1993).

We used seven response variables in the statistical analyses of the data. For each of the six species detected, we calculated the proportion of the total possible number of tracking records (i.e., number of tubes in the fencerow × eight sample periods) in which the species was present for each fencerow. The seventh response variable was a species diversity measure: the proportion of the total possible number of tracks (i.e., number of tubes × eight sample periods × six species) recorded for each fencerow. We used the statistical package SAS (SAS Institute 1990) to conduct a two-way analysis of covariance with interaction for each of the seven response variables, with fencerow vegetation type and adjacent land type as the two predictor variables. Fencerow length and width were also included as covariates. The response variables were arcsin-square-root transformed to stabilize the variance.

Results

We obtained 2168 track records in 300 tubes (96% of tubes present) over the study period. Table 12.2 summarizes the proportion of tracking events for which each small mammal species was detected in each fencerow category (defined by vegetation type and adjacent agricultural matrix types), and for all fencerows combined.

Inclusion of fencerow width and/or length did not significantly improve the fits of any of the models. Three species showed a significant response to vegetation type within the fencerows, and one species showed a significant response to the adjacent agricultural matrix (Table 12.3). *P. leucopus* was most prevalent in fencerows with trees, less prevalent in shrubby fencerows, and least prevalent in herbaceous fencerows. *B. brevicauda* was most prevalent in herbaceous or shrubby fencerows and less prevalent in fencerows with trees. *T. striatus* was most prevalent in fencerows with trees and less prevalent in herbaceous or shrubby fencerows. Only *T. striatus* showed an interaction effect between vegetation type and adjacent land use: There were significantly more *T. striatus* in treed fencerows with

TABLE 12.2. Proportion of possible tracking events (i.e., number of tubes in the fencerow × eight sample periods) at which each small mammal species was detected.

	Blarina brevicauda	*Sorex cinereus*	*Peromyscus leucopus*	*Zapus hudsonius*	*Tamias striatus*	*Microtus pennsylvanicus*
VEG						
Herb	0.495	0.213	0.070	0.028	0.004	0.005
Shrubs	0.476	0.287	0.239	0.042	0.003	0.001
Trees	0.261	0.272	0.408	0.064	0.058	0.006
ADJ						
fld/fld	0.460	0.340	0.245	0.040	0.014	0.002
fld/grn	0.350	0.235	0.259	0.047	0.037	0.008
grn/grn	0.478	0.214	0.151	0.038	0.004	0.001
All tubes	0.416	0.252	0.125	0.109	0.019	0.003

VEG = fencerow vegetation type. ADJ = land type adjacent to fencerow; fld = hay or pasture; grn = grain.

grain on one side and hay/pasture on the other than there were in treed fencerows with the same kind of field on both sides of the fencerow. *S. cinereus* was more likely to be found in fencerows bordering hay or pasture fields than in those bordering grain fields. More than 65% of the variance in the presence of *P. leucopus* and *T. striatus* in the fencerows was explained by the models.

Discussion

The presence of semi-natural features such as fencerows in the agricultural landscape increases native biodiversity (Bunce and Hallam 1993, Bignal and McCracken 1996). It also provide protection against wind and water erosion (Ryszkowski and Kedziora 1987). Plant species from preclearing times and from remnant wooded areas may persist in these areas (Fritz and Merriam 1993, 1994, Jobin et al. 1996), providing habitat, shelter, food, and dispersal routes for a variety of animal species (Rosenberg et al. 1997). The high proportion of tubes tracked in our study confirms the extensive use of fencerows by small mammals in this low-to-intermediate intensity agricultural landscape. The results indicate that the predominant vegetation type in the fencerow itself has a greater influence on small mammal diversity than the adjacent agricultural land use. For four out of the six small mammal species sampled in our study, more of the variance in presence was explained by fencerow vegetation type.

Species Responses

B. brevicauda was the largest contributor of tracks in this study. Many studies suggest that this species shows little preference for specific habitat (Getz 1961, Wrigley 1969, Asher and Thomas 1985), but Adler (1985) found this species to be positively associated with density of grass stems and forbs in his

TABLE 12.3. Two-way analyses of variance of effect of vegetation type (VEG) and adjacent land type (ADJ) on relative use of fencerows by each of six small mammal species, and all six combined.

Source	DF	R^2	SS	F	P
P. leucopus					
VEG	2	0.66	1.6	26.71	<0.0001
ADJ	2		0.02	0.27	0.77
VEG × ADJ	4		0.23	1.89	0.13
B. brevicauda					
VEG	2	0.32	0.50	4.71	0.016
ADJ	2		0.07	0.71	0.50
VEG*ADJ	4		0.09	0.44	0.78
S. cinereus					
VEG	2	0.33	0.04	1.05	0.36
ADJ	2		0.18	4.93	0.01
VEG*ADJ	4		0.13	1.71	0.17
Z. hudsonius					
VEG	2	0.15	0.08	2.13	0.13
ADJ	2		0.003	0.09	0.91
VEG*ADJ	4		0.02	0.22	0.92
M. pennsylvanicus					
VEG	2	0.21	0.004	0.68	0.51
ADJ	2		0.02	3.13	0.06
VEG*ADJ	4		0.004	0.33	0.86
T. striatus					
VEG	2	0.72	0.16	32.84	<0.0001
ADJ	2		0.01	2.92	0.07
VEG*ADJ	4		0.02	4.89	0.003
All Species					
VEG	2	0.19	0.02	1.23	0.30
ADJ	2		0.02	1.41	0.26
VEG*ADJ	4		0.02	0.60	0.66

Response variables are arcsin square-root transformed proportions. Total number of fencerows = 44. SS = sums of squares; P = probability of type I error.

study sites in Massachussetts. *B. brevicauda* was most frequently tracked in fencerows that were predominantly herbaceous or shrubby and was not significantly affected by type of adjacent land use.

P. leucopus is a semi-arboreal habitat generalist found in woodland, fencerows, and corn and small grain fields in this region (Wegner and Merriam 1979, 1990, Wegner 1995). In his 1983 study, Yahner suggested that there are lower energetic costs for *P. leucopus* associated with foraging in areas with more woody species or with greater vertical vegetative complexity. The type of fencerow vegetation predicted the presence of *P. leucopus* in our study.

T. striatus avoids old fields, pastureland, and cropland in the agricultural landscape in our region (Wegner and Merriam 1979, Henderson et al. 1985, Henein 1995), but uses fencerows as an extension of its traditional woodland habitat, preferring those with good canopy cover (Bennett et al. 1994). Consistent with these findings, the presence of trees in fencerows was a predictor of use by *T. striatus* in our study. The interaction between adjacent land type and vegetation type, however, was unexpected and has not been reported previously. The possibility that adjacent land use in the agricultural matrix influences choice of fencerows by *T. striatus,* despite their reluctance to cross open fields, requires further investigation.

The presence of *S. cinereus* was better explained by adjacent agricultural land use than by fencerow vegetation. *S. cinereus* was found most frequently in fencerows with adjacent hay or pasture fields, and least frequently in fencerows bordered on both sides by grain fields. This is consistent with Yahner's (1983) finding that the percentage grass cover was positively associated with higher densities of *S. cinereus*. This species may use parts of the fencerows as an extension of its habitat, foraging there for small invertebrates in moist areas without particular regard for vegetation type.

Z. hudsonius and *M. pennsylvanicus* showed no significant association with either fencerow type or adjacent land use. *Z. hudsonius* is not usually associated with any particular vegetation type, and may be trapped in its range anywhere there is adequate moisture (Getz 1961, Iverson et al. 1967, Wrigley 1969). The herbivorous *M. pennsylvanicus* is a field dweller (Reich 1981) and it may be trapped in all three types of fields used in this study (Wegner unpubl. data). It is not surprising, therefore, that no strong preference was shown for adjacent land use. The presence of large numbers of *B. brevicauda* in the fencerows may have contributed to the small numbers of *M. pennsylvanicus* detected, because the meadow vole is sometimes preyed upon by *B. brevicauda* (Fulk 1980, Lomolino 1984).

Few other studies have investigated both fencerow habitat and adjacent matrix habitat effects on small mammals in an agricultural landscape. Green et al. (1994), Parrish et al. (1994, 1995), and Sparks et al. (1996) found both fencerow attributes and adjacent land use were predictors of bird abundances in farmland. Fitzgibbon (1997) found that the presence of *Apodemus sylvaticus* in British farm woodlots was influenced by adjacent crops as well as by within woods vegetation, but the presence of *Clethrionomys glareolus* was not.

Spatial Scale and Study Design

There are three ways to directly study the relationship of small mammal species to landscapes, and these can be characterized by the scale of the study and the degree of manipulation by the researcher. Each method has its strengths and weaknesses.

Manipulative experiments are usually done at relatively small scales (<1-ha) and involve randomized replicates (e.g., see Schweiger et al., Chapter 9

this volume). The main advantage of manipulative experiments is that randomization reduces the chance that unmeasured variables, which happen to covary with the "treatment" variables, are actually responsible for the variation attributed to the treatment effects. Manipulative experiments also avoid the costs and time constraints associated with covering large areas of countryside to obtain data and replicates. The appropriate scale of a study, however, is related to the behavior and range of the species in question, and there is a risk of trivialization if the scale chosen is smaller than the process of interest. Pavuk and Barrett (1993) suggested that the lack of treatment effects in their study investigating the rates of parasitism of *Plathypena scabra* may have been due to the small plot size of replicates. Even with a careful choice of scale (e.g., Bowers and Dooley, Chapter 8), there is always the possibility that behavior in small experimental areas will not reflect behavior and interactions in large regional landscapes, because patterns of movement and home range sizes are known to change with changing scale of landscape pattern (Mares et al. 1976, Kramer and Weary 1991, Henein 1995, Wegner 1995). It remains uncertain whether it is possible to generalize from results of small-scale experimental studies to the landscape scale.

Nonmanipulative experiments, such as the one presented here, can be done at larger scales than manipulative experiments while also including replicates. The strength of this approach lies in matching the scale of the study to the life histories of the organisms and to the structural scale of the landscape elements. Responses are more likely to reflect processes, such as dispersal behavior or survivorship, in the real landscape; however, there are limitations. Because the treatments are not randomized in space, spurious correlations with unmeasured variables may sometimes be responsible for apparent treatment effects. In addition, it may be difficult, and sometimes impossible, to find adequate replicates for all possible combinations of independent variables of interest within a local area. In our study, we were restricted in the number of variables we could include because of the lack of replicates for some combinations of adjacent land uses and fencerow types of interest in this landscape. The amount of landscape available (about 1000-ha in our case) is related to the time required for the researchers to cover the sampling stations. This becomes even more restrictive when mark–recapture procedures must be used. These limitations explain why nonmanipulative experimental studies are rare in landscape ecology. If a suitable landscape can be found, however, and replicates carefully chosen, insight into relationships of organisms to landscape structure can be obtained with a minimum of intrusion and simple conclusions may be drawn. For example, our study suggests that we should maintain natural features in the agricultural landscape, and vary the types of these features to increase biodiversity both in the fencerows and matrix elements. Nonmanipulative experiments can also be used to validate findings from studies done at smaller scales.

It is also possible to obtain useful information on the responses of species to landscape pattern by a more phenomenological approach involving large-

scale sampling. Sampling design in such studies is not strictly defined by a priori hypotheses. This approach has some advantages over attempting to impose the experimental paradigm on a natural system that is by definition variable (but see Barrett et al. 1995, Collins and Barrett 1997) and is more likely to reveal unexpected shifts in patterns of landscape use (Henein 1995, Redpath 1995, Wegner 1995). Whereas this method is appropriate for generating hypotheses, however, an experimental approach (manipulative or nonmanipulative) should then be used for testing the hypotheses.

The use of experimental model systems (EMS) has been proposed as a solution to some of the problems associated with studies of species at large scales (Ims et al. 1993, Wiens et al. 1993). This is an indirect approach. In these studies, a process common to two species—one with large and one with small scale use of the landscape—is studied in the species with the small-scale use and extrapolated to the species with the large-scale use. Thus, vole behavior may predict responses of capercaillie grouse to habitat fragmentation (Ims et al. 1993), and chipmunk and white-footed mouse movement patterns in 200 ha of Ontario farmland may simulate the response of panthers and black bears to landscape structure in the State of Florida (Maehr 1990, Henein 1995). Some general responses may be determined using this approach, but the scale and the organisms must be carefully chosen.

There is a need for diversity in approaches to the study of ecosystems and landscapes. Studies done at different scales may complement each other and reveal otherwise unrecognized interscale effects (Wiens 1989). Studies at one scale can generate questions for studies at other scales. Both manipulative and nonmanipulative experimental designs and phenomenological studies can offer insight into ecosystem and landscape function that advances ecological understanding.

Applications for Management at the Landscape Scale

We found a variey of responses of small mammals to fencerow structure and the type of adjacent agricultural matrix. Three species responded to fencerow structure: Two (*Peromyscus leucopus* and *Tamias striatus*) were found more often in fencerows with high structural complexity, and one (*Blarina brevicauda*) was more common in fencerows with low structural complexity. One species (*Sorex cinereus*) responded mainly to the agricultural matrix, and the effect of fencerow structure for one species (*Tamias striatus*) depended on the matrix habitat. Overall, fencerow structure was more important than agricultural matrix in determining small mammal presence in fencerows.

We suggest that, to maintain or increase biodiversity in agricultural landscapes, it is important to maintain or add semi-natural features such as fencerows, and that these landscape elements should be of a variety of types. Morris (1979), Yahner (1983), and Adler (1985) have all suggested that the number of small mammal species coexisting in a habitat is a function of the

diversity of the microhabitats contained therein. These and our findings imply that a farmer can be confident of contributing to conservation of these species by retaining or restoring a variety of these remnant areas, whether the adjacent land is used for crops, pasture, or hay.

It should also be noted that source habitat for small mammal species, such as woods and fields, are important components of any rural landscape if long-term biodiversity is to be maintained. Although some animals may maintain home ranges in fencerows, these elements may not be sufficient to support viable populations in the absence of additional food resources from other landscape elements.

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