THE DISTRIBUTION OF *EMPIDIDAE* (*DIPTERA*) IN HEDGEROW NETWORK LANDSCAPES

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ABSTRACT

Hedgerows are important uncultivated elements in some agricultural landscapes. They are temporary refuge or constant habitats for different groups of insects. Considering Empididae (Diptera), hedgerows are shelters for adults and development sites for larvae. These uncultivated elements are included in a farming mosaic both defining landscape structure. We are studying how hedgerows structure, hedgerow network and at coarser scale "bocage" landscapes can influence diversity and distribution of Empididae.

INTRODUCTION

Brittany landscapes are characterized by a mosaic of relatively small fields (1 to 5 ha) surrounded by hedgerows: this is the "bocage". Since the 1950's, modification of agricultural practices (helped by subsidies and reallotement programmes) has led to the removal of many hedgerows and dramatic changes in many places. As planning programmes are on a municipality basis, continuous changes across the countryside can be seen.

The ecology of hedgerows and hedgerow networks has been widely studied (Pollard *et al.*, 1974; Forman & Baudry, 1984; Burel & Baudry, 1990 a; 1990 b). These researchs have barely considered the land use mosaic, having focused either on hedgerow structure and species composition or on the role of interconnected hedgerows as a possible route for forest species to move through farmland. This later point, the corridor effect, is one of the major research topics in landscape ecology.

A NEW RESEARCH PROGRAMME ON "BOCAGES"

Our current research has a different perspective: all the landscape components (mosaic and networks) and their spatial relationships are taken into account at a variety of spatial and time scales (Baudry *et al.*, 1993). This programme aims at understanding the factors driving landscape dynamics and how different groups of species "perceive" the landscape. The landscape is no longer seen as a mere framework, but as a place where farming activities and vegetation dynamics continuously change the spatial structure either at short time scale (annual crop production techniques and associated field margin management) or medium scale (hedgerow removal, plantation, enlargement of fields, etc.). The core of this programme is carried out south of the Mont-Saint-Michel Bay, north of Rennes (Brittany). Three study areas of 500 ha each have been chosen because of their differences in landscape structure (hedgerow density and field size).

The *BOCAGE* and *AGRICULTURE* databases

All the hedgerows of the study areas are described individually, recording their structure and type of management. The observations are gathered in various databases (structure, adjacent field use, bank, woody vegetation..) and managed using *BOCAGE* software (Denis *et al.*, unpubl.). The databases are linked to a GIS (raster format) to allow the study of landscape structure and changes in scales (by aggregating cells). As far as time is concerned, we consider that the different variables have different time scales. For example, tree species management (pollarding, shredding..) is a slow variable, constant over 10-20 years, while pruning is intermediate (done every 9 years) and bank mowing is fast (yearly).

AGRICULTURE is a set of databases related to farm structure and farming practices. From an ecological point of view, it allows one to integrate such variables as pesticide inputs or dates of mowing and ploughing as variables driving species presence or abundance.

Therefore, field boudaries (the major component of biodiversity in agricultural landscapes) can be seen as part of both the landscape ecological system and the farming system. This allows a better understanding of the factors regulating biodiversity, and definition of management rules. The later may apply to landscape planning as well as to agricultural practicies or boundaries management. With this perspective, the multiple scale approach of species distribution in landscapes should be profitable.

Insects in bocages

Among insects, forest carabids (i.e. species found mostly in woodland) have been widely studied and exibit a sensitivity to hedgerow vegetation structure as well as to landscape structure, such as hedgerows intersection, connectivity of the network, presence of lanes bordered by parallel hedgerows (Burel, 1991). Studies of the relationships between landscape structure and flying insects are few; this is certainly due to problems in sampling, identification and to their dispersal ability.

STUDY OF EMPIDIDAE

Empids (Diptera) require different sites during their life cycle. Edaphic larvae of the genus *Hilara* develop in the soil of grassland and uncultivated elements such as hedgerows. Adults form two different types of swarms above or close to water: 1. hunting swarms where males search for small prey which are embedded in silk balloons and offered to females prior to copulation and 2. mating swarms, the location of which is different from the former. The environmental conditions of swarm development and location are strictly determined (temperature, hygrometry, wind, sunshine, vegetation structure and pattern)(Tréhen, 1971; Grootaert *et al.*, 1990). Individuals need to find both types of sites within a given radius in the landscape to complete their life cycle (Fig.1). Their flight from the emergence site to the mating site may be facilitated or inhibited by some landscape elements that act as corridor or barriers.

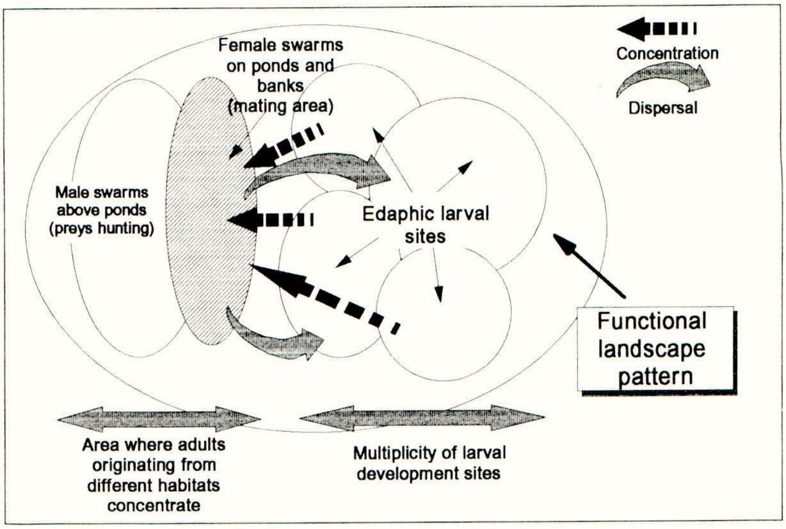

Fig.1. Functional landscape pattern needed for the life-cycle completion of an *Hilara* species.

We hypothesize that the "grain" of landscape structure relating the density and arrangement of the different habitats will influence the species assemblage. Agricultural practices,in particular pesticide sprays, influence the survival of individuals. Our second hypothesis is that species assemblages depend on agricultural practices. This study has begun recently, so this paper only presents the general context and describes the methods.

Methods

Empid sampling

The sampling methods have been selected according to previous researchs on different groups of Diptera. Coloured traps may be used for all groups, but their efficiency differs according to the family sampled (Baillot *et al.*, 1976). Empid flies are not trapped when swarming but only when searching for food or egg-laying (Baillot & Tréhen, 1974). Traps are set on hedgerow ground along a transect from a brook (the water source) up to the middle of each study area (Fig.2). Hedgerows have been selected according to the type of landuse on both sides and to their degree of connectivity to other uncultivated elements. Two traps are set at each site and sampled for two days every week from April to August.

A second method of trapping is useful for our approach because of the mating behaviour of adults. Thus, walking along brooks, we have used hand nets to sample the swarms (5 back and forth net sweeps) during the reproduction period.

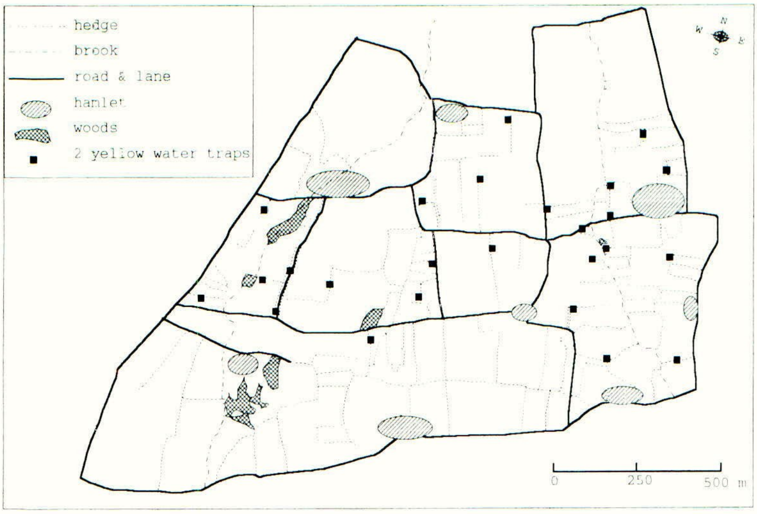

Fig.2. Distribution of traps in a bocage landscape, characterized by a median density of hedgerows.

Landscape data

Landscape structure has been analyzed in order to characterize its grain size and heterogeneity. Based on field work, data on hedgerows have been collected and stored in the BOCAGE database. Only parameters that have been previously suspected to be pertinent for Empididae will be extracted fcr used in the present work. They concern hedgerow structure (height, width, permeability, ...) and hedgerow flora on which many Empid species feed.

The most complex parameter is heterogeneity. The measure of heterogeneity depends not only on diversity of elements in landscape , but also on their spatial arrangement (Baudry, 1985). For Empididae, mosaic and networks must be included in the measure of heterogeneity. Distance between mating sites and emergence sites is important, and these complementary habitats, which can be defined as a functional spatial unit, are scale dependant, in relation to dispersal ability (Delettre *et al.*, 1992) (Fig.1).

Data on landscape pattern are spatially explicit and allow us to compute parameters such as heterogeneity, connectedness, contiguity, mean distance between elements. The measure of heterogeneity considers the spatial arrangement, and the diversity of landscape elements (Baudry, 1985). In our study we must integrate heterogeneity of the hedgerow network as well as heterogeneity of the landscape mosaic. Distance between potential emergence and mating sites is also assessed.

CONCLUSION

At the moment, no more details can be given because this study has just begun. However we hope that the consideration of both agricultural practices and landscape structure will provide a powerful tool to explain Empid species assemblages and conservation guidelines.

ACKNOWLEDGEMENTS

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NEST SITE SELECTION AND TERRITORY DISTRIBUTION OF YELLOWHAMMER (*EMBERIZA CITRINELLA*) AND WHITETHROAT (*SYLVIA COMMUNIS*) IN FIELD MARGINS

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ABSTRACT

Territory maps and nest locations were used to assess habitat selection by breeding yellowhammers and whitethroats in relation to vegetation in field boundaries. Both species selected herbaceous vegetation for nest sites and occurred at higher densities where extensive, perennial, herbaceous vegetation was present in field boundaries.

INTRODUCTION

One of the consequences of agricultural intensification in arable areas has been the loss of perennial, herbaceous vegetation from field boundaries. Grazing, ploughing, spraying and fertilizer drift into the hedge base have resulted in destruction and degredation of the perennial vegetation and its replacement by annual arable weeds (Boatman, 1988). Perennial herbaceous vegetation in field boundaries has been shown to provide a nesting habitat for grey partridges (*Perdix perdix*) (Rands, 1986), hibernating areas for coleopteran aphid predators (Sotherton, 1984) and feeding areas for Lepidoptera (Dover, 1991) and hoverflies (Cowgill *et al*., 1993).

Hedge length and structure are known to influence the abundance of farmland passerines (Morgan & O'Connor, 1980, Arnold, 1983, Lakhani, this volume). In this paper we assess the influence of field boundary vegetation on yellowhammer (*Emberiza citrinella*) and whitethroat (*Sylvia communis*) territory distribution and nest site selection.

METHOD

The study was conducted in 1992 and 1993 at Loddington, Leicestershire, a 300 hectare mixed arable and livestock farm managed by the Allerton Research and Educational Trust. Both hedges with and hedges without vegetated bases are present at Loddington. Where field boundary vegetation has been lost it is mainly due to over-grazing by sheep, while field margins with extensive perennial vegetation are represented by hedgerow ditches. Field boundaries were classified into those with and those without vegetated bases. Double (ie roadside) hedges were not used in the study. Yellowhammer and whitethroat breeding territories were mapped over the entire farm using the method described by Marchant (1983). Territories per kilometre of field margin weighted for hedgerow length were calculated from the territory maps.

Systematic searches combined with observations of territorial birds were used to locate active nests of both species. Nest height was recorded as well as clutch and brood size and the vegetation type selected. Data were collected for Chaffinch (*Fringilla coelebs*) nests (n=26), as well as for Yellowhammer (n=42) and Whitethroat (n=35). Four nest site categories were recognized: herbaceous vegetation in ditch, herbaceous vegetation against hedge, shrubs overhanging ditch and the hedge itself. Nests were visited at two to three day intervals to monitor nest survival as part of a separate study. Calculation of nest survival to fledging was based on an assessment of daily nest survival (Hensler & Nichols, 1981).

RESULTS

Breeding territories of yellowhammers and whitethroats were widely distributed with yellowhammers, in particular, being associated with open unwooded areas of the farm. Ninety seven percent of yellowhammer and 84% of whitethroat nests were in field margins. Both yellowhammer and whitethroat territories were significantly more numerous in hedges with vegetated ditches than in hedges without them (yellowhammer: F= 3.78, df= 9,9, P<0.05, whitethroat: F= 4.50, df= 9,9, P<0.05) (Figure 1).

Nest heights of yellowhammer, whitethroat, and chaffinch were compared. Mean nest heights (± 2SE) of yellowhammer (0.28m ± 0.09) and whitethroat (0.48m ± 0.11) were significantly lower in the hedge than those of chaffinch (1.26m ± 0.20) (yellowhammer: F= 67.85, df 41,25, P< 0.001 , whitethroat: F= 9.92, df=34,25, P<0.001) with yellowhammers often building nests directly on the ground (Figure 2). Whitethroats selected nest sites both in herbs and in brambles (*Rubus fruticosus*) over a ditch while yellowhammer nests were strongly associated with rank perennial grasses and herbs (χ^2_3=13.81, P<0.01).

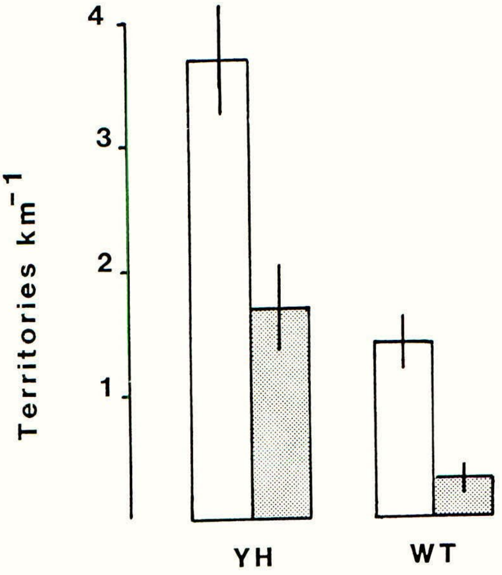

Figure 1. Yellowhammer and whitethroat territory density (means km^{-1}) weighted hedge length in field boundaries with (open) and without (shaded) extensive herbaceous vegetation. Vertical lines represent two standard errors.

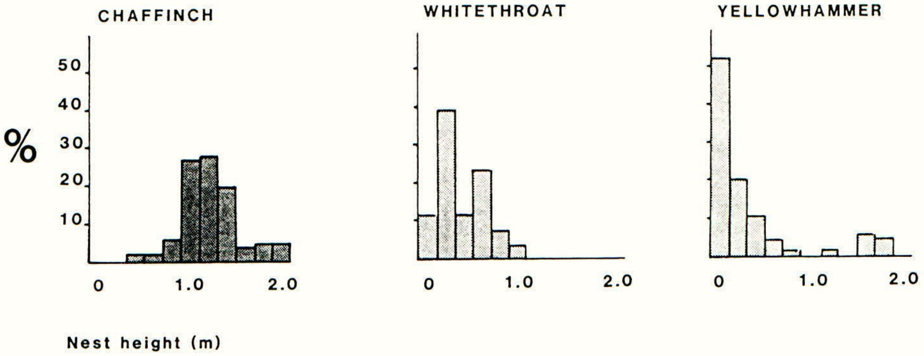

Figure 2. Frequency distribution of chaffinch, whitethroat and yellowhammer nest height.

DISCUSSION

The national yellowhammer population has remained relatively stable while that of whitethroats is at a low level following a considerable decline in 1969 (Marchant *et al.* 1990). Whitethroat nesting success may therefore be expected to be uniformly high because, at low densities, suboptimal territories remain unoccupied. Where there was a significant difference in the variability of clutch size (1992: F=3.96, df=13,22 P<0.01) or fledging success (1993: F= 3.38, df=10,25 P<0.01) yellowhammers were indeed more variable than whitethroats, suggesting that whitethroats occupy fewer suboptimal territories than yellowhammers.

Mason (1976) recorded significantly higher nest survival rates in whitethroat nests built within 60cm of the ground than in nests built above this height. There were insufficient data for a similar comparison to be made in the present study but, between species, nest survival rates to fledging (± 2SE) were higher for yellowhammer (0.74 ± 0.03) and whitethroat (0.84 ± 0.04) than for chaffinch (nesting higher in the hedge) (0.24 ± 0.04). However, yellowhammer and whitethroat nests may be more susceptible to predation in territories where low, herbaceous nest sites are not available.

Until now, data on nest site selection in relation to herbaceous field margin vegetation were only available for partridges (*Perdix perdix* and *Alectoris rufa*) (Rands, 1986). Our results strongly suggest that hedges lacking extensive herbaceous vegetation in their bases represent less suitable breeding territories for yellowhammer and whitethroat. Within individual farms management of this field boundary vegetation for game or integrated pest control may therefore improve the breeding habitat for these two species.

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SMALL MAMMAL POPULATIONS IN HEDGEROWS: THE RELATIONSHIP WITH SEED AND BERRY PRODUCTION

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ABSTRACT

This paper presents an analysis of one aspect of a ten-year small mammal trapping program undertaken in twelve sites in England and Wales. It examines the small-scale distribution within hedgerows of small mammal captures. A total of 476 wood mice (*Apodemus sylvaticus*) and 132 bank voles (*Clethrionomys glareolus*) were caught during the autumn of 1990. The distribution of these captures between 696 trap-groups was derived. In addition a survey of the distribution and abundance of berry-bearing species in the hedgerows was also undertaken. Mantel tests were used to i) investigate the spatial component of the distribution of captures, and ii) test the association between captures and the berry abundance. Wood mice were shown to have a very highly significant spatial component to their captures, but also a very strong association with berry abundance. In contrast, bank voles had no detectable spatial component, but also had a very strong association with berries. There is some evidence that this association is largely a result of the captures of adult male voles.

INTRODUCTION

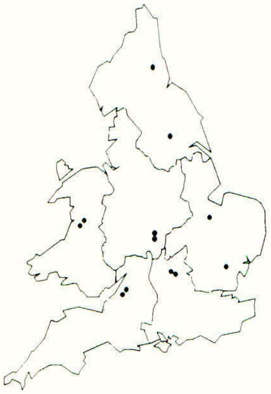
In the spring of 1983, the Agricultural Development and Advisory Service of MAFF began a long-term survey of small mammal populations in hedgerows. Twelve sites, each consisting of a 650m length of hedgerow, were established around the country; their approximate locations are shown in Fig. 1. The work finished in the spring of 1992 with nearly ten years of mammal trapping data. In addition, several surveys were made of the botanical and structural composition of the hedges, the adjacent cropping regimes and the hedgerow management practices.

This paper reports on one aspect of the current survey. During the autumn 1990 trapping session the hedgerows were surveyed for berry and seed production. From the trapping results for this session, the distribution of captures within hedges were derived for two species of small mammal; wood mice (*Apodemus sylvaticus*) and bank voles (*Clethrionomys glareolus*). One problem with data derived from sequential points along a line or transect, is that they do not form an independent sample, and so they violate one of the principle conditions for parametric statistical testing. So the aims of the current analysis are two-fold. Rather than ignore this problem, the first aim is to investigate the spatial component of the capture index. Secondly, having accounted for any spatial effect, the true relationship between the mammal capture rates and berry production can be analysed.

METHODS

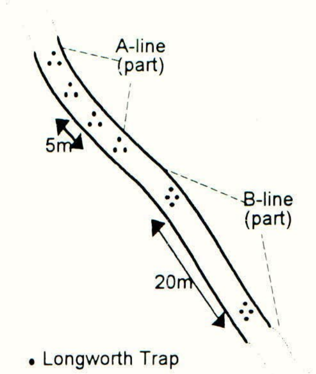
At each site, trapping sessions lasted for four nights during spring and autumn. Longworth live-catch traps were used, provided with bedding and suitable food for mice, voles and shrews. Within each site, 199 traps were laid in 58 trap-groups in two contiguous lines labelled "A" and "B". The A-line consisted of 33 groups of three traps at 5m spacing and the B-line, 25 groups at 20m spacing (see Fig. 2). Polynomial functions were used to equilibrate capture-rates between lines, resulting in a non-integer capture index. Separate indices were derived for i) total captures of each species, ii) adults only, iii) adult males only and iv) adult females only. This gave a total of eight indices.

Fig 1 Location of Hedgerow Sites



NB: Boundaries show MAFF Regions

Fig 2 Arrangement of Traps & Trap-groups



Hedgerows were divided into 5m sections, centred around the trap-groups. Within each section the abundance of seeds and berries (hereafter generically termed "berries") of all shrub and climbing species were recorded on a $\log_{10}$ scale (*e.g.* 1 = 1 to 9, 2 = 10 to 99, *etc.*). Within the B-line, this resulted in three intermediate sections between adjacent trap-groups. To make use of the data recorded in these sections, a weighted rolling average was used throughout to give an index of berry abundance.

RESULTS

A total of 608 mice and voles were caught during the trapping period. Full details of age and sex sub-groups are given in Table 1. Overall, about three times as many mice were caught as voles ($\chi^2_{(1)} = 196$, $P \approx 0$) Approximately half the mice were adults with more males than females ($\chi^2_{(1)} = 9.44$, $P < 0.01$). In contrast, only a third of the voles caught were adults, with more females than males ($\chi^2_{(1)} = 0.364$, $P > 0.05$). A total of 1442 captures were made during this period. The picture for captures was even more pronounced, with over five times the number of captures of mice than voles ($\chi^2_{(1)} = 658$, $P \approx 0$). These differences are shown by the capture ratios in Table 1.

Table 1 also gives a summary of the number of trap-groups containing animals. Mice were recorded in over half of the 696 trap-groups, whilst voles were found in less than 20% of the groups. Clearly, adult male and adult female voles were not widely caught. This table also gives the capture indices, derived from the trapping data, which are used in the subsequent analyses.

TABLE 1. Details of mammal captures by species and sub-groups

	ANIMALS			GROUPS[1]	CAPTURE INDEX[2]	
SPECIES	Individuals	Captures	Ratio		Max	Mean[3]
A. sylvaticus	476	1208	2.54	397	13.0	2.47
- Adult	244	628	2.57	239	12.6	1.42
- Adult male	146	385	2.64	167	8.5	0.71
- Adult female	98	243	2.48	112	8.3	0.51
C. glareolus	132	234	1.77	133	7.5	0.41
- Adult	44	87	1.98	55	5.0	0.16
- Adult male	20	47	2.35	25	5.0	0.04
- Adult female	24	40	1.67	28	3.0	0.07

NB: [1] Numbers of trap-groups containing animals
[2] Captures per trap-group
[3] Total captures / total trap-groups (696)

The results of the berry survey are given in Table 2 showing that 12 species were recorded with berries. In addition an aggregate "Other" category was derived to hold the very scarce species. This category was found in only 55 trap-groups and has been treated as a pseudo-species for the sake of the analysis. The vast majority of seed records consisted of bramble, hawthorn or rose, all three being found in at least ten sites. Oak and spindle were the rarest species, being found in only 31 and 22 sections in two sites respectively. Species richness per site also varied from only two species to ten or more in two sites. Note that this table only summarises presence of species in trap-groups and does not give the abundance of berries used in the subsequent analyses.

The methodology used for the analysis was based on the Mantel test, described in Manly (1986) and partial Mantel tests described in Leduc *et al* (1992). These test for associations between distance matrices. For the purposes of this analysis, Mantel tests have been used in the following way. Firstly, spatial distance matrices were derived from the distances between trap-groups. Berry distance matrices were then calculated using euclidean distances of the berry indices in multi-dimensional space. Finally, capture distance matrices were calculated individually for the eight capture variables. Note that all these matrices have been calculated separately within each of the twelve sites.

TABLE 2. Number of trap-groups and sites containing berries

	Total		Sites											
	Sections	Sites	1	2	3	4	5	6	7	8	9	10	11	12
Ash	25	6	0	0	0	0	12	1	0	2	4	4	0	2
Bramble	347	11	6	21	38	37	45	14	29	51	37	0	45	24
Blackthorn	105	7	0	0	1	0	15	1	42	0	12	3	31	0
Maple	81	4	0	0	0	0	39	0	0	0	39	2	1	0
Hawthorn	569	12	57	53	31	38	48	44	40	58	58	57	55	30
Oak	31	2	0	0	0	0	13	0	18	0	0	0	0	0
Privet	75	4	0	0	27	37	0	0	0	2	9	0	0	0
Rose	361	10	0	21	29	25	58	26	46	14	49	0	44	49
Spindle	22	2	0	0	0	0	20	0	0	0	2	0	0	0
Black bryony	160	7	0	0	30	24	41	47	0	4	5	9	0	0
Ivy	83	6	0	0	0	0	9	0	0	2	45	5	2	20
Clematis	47	3	0	0	17	0	29	1	0	0	0	0	0	0
Other	55	4	0	0	4	0	12	0	33	0	0	0	0	6
No of species.			2	3	8	5	12	7	6	7	10	6	6	6

Tests were carried out independently within sites, and also on an "aggregate matrix". Two test statistics were used. Firstly, the correlation coefficient between a capture matrix and the spatial matrix, and secondly, the partial correlation coefficient between a capture matrix and the berry matrix, holding the spatial matrix constant. 999 randomisations of the capture matrix were made within sites to give approximate one-tailed probability levels for the statistics. The first test statistic describes the spatial component of the capture index; a significant result shows that captures are clustered in space. The second statistic shows whether there is a significant association between the capture index and the berry index, having taken into account any spatial component of captures. The results from this suite of tests are given in Table 3. (Note that these significance levels have not been adjusted for the effects of multiple testing.)

Apodemus sylvaticus

Taking the aggregate data first, it was clear that all the mouse capture indices had a very highly significant spatial component. Capture rates were not constant or randomly varying along the trap lines but were clustered in groups of similar values. However, despite this spatial effect there was also a very significant association between mouse capture indices and berry indices. In other words, capture rates were clustered in some way in "berry space".

The individual site data provides evidence of the generality of the aggregate results. For total mouse captures, eight out of the twelve sites showed a spatial effect, with four of these also showing a highly significant association with the berry indices. In addition, one site revealed no spatial effect but did have a berry association. The most consistent capture index was adult males, where seven sites showed a significant association with the berry index.

Clethrionomys glareolus

The aggregate data here showed a quite different pattern to the mice capture indices. Firstly, for all captures, there was no spatial component to capture rates. Thus vole capture rates were either constant or, more likely, varied randomly between trap-groups. In contrast, there was a very highly significant association with the berry index. The three other capture indices must be interpreted with caution as they are based on a relatively small number of captures. Nevertheless, it is interesting that only male voles showed a spatial component to capture rates, but also a very highly significant association with berry indices. The individual site results were quite consistent, with seven out of eleven sites showing a very highly significant association with berry indices. Adult male and female voles were only caught in half the sites so the other capture indices can provide little evidence of individual site associations.

Table 3. Results of Mantel tests for aggregate data and individually by site

		Aggregate		Sites											
		r^2	P	1	2	3	4	5	6	7	8	9	10	11	12
A. sylvaticus	Spatial	0.102	***	**	-	**	-	-	-	*	***	***	*	***	***
	Berry	0.082	***	-	-	***	-	***	-	-	-	-	***	***	***
-Adult	Spatial	0.058	***	**	-	***	**	-	-	-	***	-	**	***	***
	Berry	0.093	***	-	**	***	-	***	-	-	-	-	***	-	***
-Male	Spatial	0.103	***	***	-	***	*	-	-	-	***	*	-	***	***
	Berry	0.072	***	-	***	***	-	**	-	*	**	-	***	-	***
-Female	Spatial	0.044	***	-	-	*	***	-	-	-	-	***	***	***	*
	Berry	0.069	***	-	-	*	-	***	-	-	-	***	***	*	***
C. glareolus	Spatial	-0.003	-	-	**	-	-	-		-	-	***	-	*	-
	-Berry	0.043	***	-	***	-	***	-		***	***	***	-	***	***
-Adult	Spatial	0.015	-	-		-	***	-				***	-	*	-
	Berry	0.003	-	-		-	-	-				*	-	-	**
-Male	Spatial	0.027	**	***		-		-				-		***	-
	Berry	0.053	***	-		-		-				***		***	**
-Female	Spatial	0.009	-	-		-		-				***		-	-
	Berry	0.003	-	-		-		-				-		-	***

NB: Probability levels: - NS, * < 0.05, ** < 0.01, *** < 0.001 Space = no captures

DISCUSSION

A number of workers have investigated the food preferences of mice and voles, both from field and laboratory studies. A review by Hansson (1985) showed that seeds, fruits and berries form a high proportion (>70% by vol.) of the stomach contents of wood mice. Furthermore, this proportion increases to over 90% in the winter months. In contrast, he showed that these components often constitute less than 40% of the stomach contents of bank voles, leaves and forbs usually formed the largest component. Clearly these food preferences will be reflected in foraging behaviour, but the question still remains whether this can be detected at a population level. In other words, the behaviour patterns of individual animals may be influenced by food availability (see e.g. Tew *et al*; 1992), but is this manifest as a population response?

One strength of this extensive trap-based survey was the large number of animals (and locations) which contributed simultaneously to the data-set; in this case over 600 animals and nearly 1500 captures. The results from this analysis indicated a number of population effects. Firstly, wood mice capture rates were very strongly associated with the abundance (and possibly species) of berries found in hedgerows. This is consistent with the food preferences indicated above. Secondly, a similar , though less pronounced association existed for bank voles, although interestingly it occurred in more of the study sites. This too is consistent with food preferences. These associations may not, of course, reflect any causative relationship between berry abundance and capture rates, or even any linear correlations, but the relationships were very highly significant. Furthermore, the inclusion of a spatial matrix in the analysis allowed for the effects of any other independent variables which may have had a spatial component. In other words, the berry associations were likely to be real and were probably not influenced by the effects of unrecorded variables.

Future analyses will attempt to identify what type of relationships exist between small mammal captures and berry production and with which hedgerow species. In addition, the association of captures with ground flora is currently being analysed, along with the overall species composition and structure of hedgerows and field boundaries. Finally, the influence of adjacent cropping patterns and agricultural inputs on capture rates is being analysed.

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MODIFICATIONS OF FIELD MARGINS AND OTHER HABITATS IN AGRICULTURAL AREAS OF QUÉBEC, CANADA, AND EFFECTS ON PLANTS AND BIRDS

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ABSTRACT

A study was undertaken in southern Québec, Canada, to investigate how wildlife habitat in the vicinity of farmland has been modified in the last 25 years and how this has affected native plants and bird populations. Results show that the landscape has been markedly modified in the last 25 years: many hedgerows and trees have disappeared, and fragmentation has increased due to an increasing number of roads and urban settlements. The herb layer vegetation in wooded habitats is composed of a large number of species typical of the original forested vegetation but many introduced species are also found. Herbicide use has had an adverse effect on the vegetation of field margins. The diversity of native plants and birds is greater in farmlands where some wooded areas remain.

INTRODUCTION

Major change in land use has been occurring in Canada since European settlement started in the 17th century. Large segments of the once dominant deciduous forest have vanished and the forest is still receding due to agriculture, timber production and urbanization. Only 7.5% of the land is under a cropping or pasture regime in Canada (constituting 67.7 million hectares) (Statistics Canada, 1991). While this appears very limited when compared to the UK with 75% agricultural land (Cobham & Rowe, 1986), most Canadian agricultural land is confined to the southern part of the country.

In the last 50 years or so, agriculture has been undergoing dramatic changes in Canada, as in many other countries (Freemark & Boutin, in press). The average farm size gradually increased from about 100 hectares to an average of 200 hectares (Statistics Canada, 1986). Accordingly, field sizes doubled in some parts of the country (Baldwin & Johnston, 1986), and monocultures were favoured with a corresponding reduced variability within and between fields. Woodlots are increasingly managed for wood production or are used as shelter or grazing areas for cattle, and hedgerows and streambanks are sprayed for control of noxious weeds. There is mounting evidence that wildlife (including plants) living in agricultural areas has been adversely affected by these modifications.

Herbicides are the most widely used pesticides in cultivated land of southeastern Canada, and their use has escalated sharply during the last 30 years (Statistics Canada, 1991). Direct acute toxicity to birds and mammals is not a major issue with herbicides; adverse impacts on resources through plants, soil organisms and other invertebrates is the main concern. Use of agricultural herbicides affects not only plants but also organisms at higher trophic levels (e.g. Sotherton *et al.*, 1988). This study was aimed at investigating the relationships between landscape modifications, farming practices, wildlife and wildlife habitats in the farm land of southern Québec.

MATERIAL AND METHODS

The present study is part of a broader project undertaken using Breeding Bird Survey (BBS) data obtained from 1966 to 1992 to assess trends of bird populations associated with agriculture (Jobin *et al.* 1994). The BBS data, gathered all over North America during the breeding season, consist of a series of routes, 40 km long, with a stop (0.5 km^2) every 800 m for a total of 50 stops per route (Falardeau & DesGranges, 1991). Our choice of sites was confined to the BBS routes situated in the St. Lawrence Valley. Originally 172 stops were selected within ten BBS routes; only stops having at least 50% or more of their area cultivated in the 1980s were selected for landscape inventory and bird census. Ninety-five of these stops were retained for a detailed study of vegetation, farming practices, and bird utilization. For 20 minutes in June 1992 birds seen and/or heard were recorded. Trends in birds using the BBS data are presented in Jobin *et al.* (1994). Change in farming areas and noncultivated habitats were determined for the 172 stops using interpretation of aerial photographs (1:15000) taken from 1959 to 1966 and 1981 to 1989. Variables measured were: 1) average crop area (cash crops, vegetables, forage crops, pastures could not be differentiated) and noncrop areas including old fields, forested, urban and aquatic areas, and other noncultivated habitats, 2) linear features such as hedgerows and length of woodland edges, and 3) features which could be counted such as woodlots, trees and buildings. The floristic composition and structure of 66 wooded hedgerows (minimum 5 m wide), 35 woodlots (less than two hectares), 57 woodland edges (woodland greater than two hectares with edges adjacent to cropfields), 50 old fields, and 47 ditches were described. At each stop habitats were selected so as to survey at least one habitat type present per stop. The point-intercept method (Bonham, 1989) was used for the ground vegetation; 3 X 10 m transects were used, 20 points per transect, except for woodlots where transects were 20 m long. For edge habitats the 10 m transects were positioned 5 m inside the noncrop area and 5 m outside into the crop. Only the 5 m transects inside the noncrop habitat are presented. For the woody vegetation, the line-intercept method was used. Information on farming practices and pesticide use was gathered by means of a questionnaire and interviews with farmers who owned the land at the stops. Responses were obtained from 183 farmers with land on the 95 stops.

RESULTS

Table 1 shows the trend in land use as interpreted from the aerial photographs. Cultivated areas have decreased between the 1960s and 1980s as have aquatic areas (mainly lentic systems) which were reduced by 12 ha. Forested areas (+83 ha), old fields (+52 ha) and urban settlements (+53 ha) have increased. In rural Québec many family farms have been abandoned hence the reduction of total cultivated areas which were gradually replaced by old fields and forested areas such as woodlots. In the remaining farmed land, features such as hedgerows, and trees have been removed and are thus present in a lower number of stops in the 1980s than in the 1960s (Table 1). Concomitant with an increase in urban areas, more roads and buildings are also present.

TABLE 1. Changes in the habitat types between 1960s and 1980s in the 172 stops

	Areas (ha)		n of stops		
	1960s	1980s	1960s	1980s	Prob.[a]
Total	8600	8600			
Cultivated[b]	7650	7468	172	172	.0001
Forested	509	592	94	96	.0052
Old field	229	281	72	68	.5012
Aquatic[c]	191	179	40	40	.0494
Urban	22	75	6	17	.0016
Others	0	5	0	2	-
Linear features (average m /stop)					
Hedgerows	247	218	109	96	.0272
Edges					
agri-forest	402	447	94	96	.3887
agri-urban	18	67	6	17	.0003
Roads	961	988	172	172	.0117
Element features (average # /stop)					
Woodlots	0.19	0.34	27	42	.0001
Trees	13	10	165	157	.0001
Buildings	11	17	160	163	.0001

[a] Wilcoxon signed rank test on change in area

[b] includes cash crops, forage crops, pastures, vegetables, summerfallow

[c] includes streams, lakes, ponds, wetlands

TABLE 2. Characteristics of the herb layer vegetation (%)

	Woodlot	Woodland edge	Hedgerow	Old field	Ditch
Status					
Native species	71.7	56.1	51.2	51.9	39.4
Introduced	11.1	24.2	31.5	30.1	46.7
Unknown	17.2	19.7	17.4	18,1	13.9
Lifespan					
Annual	2.9	2.2	5.4	4.6	16.7
Biannual	4.5	0.5	3.9	4.5	3.9
Perennial	76.1	80.2	73.6	73.8	65.9
Unknown	16.5	17.1	17.1	17.0	13.4
Habitat					
Shaded	45.1	16.5	5.1	1.4	0.7
Open	13.3	25.0	36.0	38.4	44.9
Ubiquitous	12.0	13.7	18.7	15.2	5.9
Wet	8.5	16.0	11.9	18.7	24.0
Crop	3.9	8.9	10.9	8.0	10.6
Unknown	17.2	19.9	17.4	18.3	13.9

Characteristics of the vegetation inventoried in the different uncultivated habitats are presented in Table 2. The vegetation of the herb layer was composed of a large number of introduced species; e.g. 47% of the vegetation in ditches. A large proportion of the species in the ditches were annuals typical of open areas. In contrast, woodland edges and small woodlots contained the highest percentage of perennial species typical of shaded areas. Crop species have penetrated the different habitats to comprise between 8 to 11% of the species in most habitats except woodlots. The shrub/tree layers of the different habitats were represented mostly by native species (not shown).

TABLE 3. Effects of herbicide use on vegetation in margins (probability values (ANOVA) for difference between unsprayed and sprayed with herbicide)

Variables	Hedgerow	Woodland edge	Ditch
# species	0.10 (↓)	0.12 (↓)	0.48 (NS)
Shannon index	0.01 (↓)	0.08 (↓)	0.69 (NS)
Cover	0.04 (↓)	0.69 (NS)	0.02 (↑)
Height	0.22 (NS)	0.82 (NS)	0.01 (↑)

TABLE 4. Importance of different farmland habitats for bird and plants

a) Plants (herb layer)

Habitats	Number surveyed	Total # of species	# of unique species	# (%) of typical spp.[a] MH	MBY
Woodlots	35	102	20	14 (35)	34 (69)
Woodland edges	57	99	13	10 (25)	24 (49)
Hedgerows	66	110	10	7 (18)	17 (35)
Old fields	50	120	25	5 (13)	13 (27)
Ditches	47	144	38	4 (10)	9 (18)

b) Birds

Stops with:	n	Cumulative # of bird species
1- Cropland only or with old fields, no wooded areas	10	38
2- 1 + wooded hedgerows, no wooded areas	13	39
3- 1 & 2 + woodlots <2 ha, <10% forested areas	16	45 (41.5)[b]
4- 1 & 2 & 3 + woodland >2 ha, <10% forest	25	56 (49.75)
5- As 4, >10% forested areas	31	64 (52.25)

[a] From Grantner (1966), 2 types of vegetation associations: in 3 routes, MH = sugar maple (*Acer saccharum*/) hickory (*Carya cordiformis*) +40 herb spp; in 6 routes, MBY = sugar maple/basswood (*Tilia americana*) /yellow birch (*Betula lutea*) +49 herb spp.

[b] Numbers within brackets refer to the average # of species counted when 13 stops were randomly selected 4 times in order to test for the effect of different sample size.

To assess the effect of herbicide use on the vegetation of hedgerows, woodland edges and ditches, stops where herbicide had been used (n =79) were compared to stops where no herbicide had been sprayed (n =16) for at least 6 years (Table 3). There were significant reductions in species diversity and cover where herbicide had been used in hedgerows and woodland edges. In contrast, for vegetation in ditches, cover and plant height was enhanced where herbicides had been used. Ditches are highly managed and subjected to agricultural runoff containing both nutrients and pesticides.

The importance of different farmland habitats for plant and bird diversity was assessed (Table 4). The number of unique species relates to species recorded in one habitat but not found in any other habitats inventoried during the study. Ditches have the highest number of distinct plant species, mostly introduced or typical of wet areas (Tables 2 & 4a). Two slightly different vegetation associations are found in the studied area both dominated by sugar maple (see Table 4a). The associations differ in the proportion of the main species present and in the composition of secondary species (Grantner, 1966). We compared these different recognised associations to the inventory performed during the study. Results indicated that woodlots harbour more plants that are representative of their traditional associations (Table 4a). The number of bird species was notably higher in stops with wooded habitats (Table 4b). Stops with large forested habitats (5 in Table 4b) provided shelter for a number of warblers and thrushes, among others, that were not present in stops with only old fields, hedgerows and small wooded areas.

DISCUSSION

The aerial photographs revealed a great diversity of habitats. As expected, however, some habitat features such as hedgerows were reduced and trees have been removed. Hedgerows are important habitats in agricultural landscape especially if they are connected with forests, woodlots or old fields (Wegner & Merriam, 1979). In the present study, although the total number of bird species did not increase with the presence of hedgerows, species such as the Great Crested flycatcher (*Myiarchus crinitus*) and Eastern Phoebe (*Sayornis phoebe*) were not seen in areas devoid of trees. In order to increase the area under cultivation or to facilitate the passage of farm equipment, wooded and vegetative margins are frequently reduced or eliminated. More recently, however, the establishment of shelterbelts has been advocated to replace vanished hedgerows to prevent soil erosion and to enhance soil moisture. Unfortunately, the recommendation given to farmers promotes the establishment of a few rows of trees together with eradication of the herb layer to prevent the intrusion of noxious weeds into the crop (Baldwin & Johnston, 1986). The width and structural diversity of hedgerow habitats are crucial in supporting a diversity of wildlife and protecting it against predation (Best *et al.*, 1990). Thus a simple shift in the management of shelterbelt/hedgerow features could enhance and protect biological diversity in agriculture.

The area under cultivation has slightly declined in the past 25 years in the study sites while old fields and forested areas have progressively expanded. Forested areas, primarily in small woodlots (< 2 ha), have increased mainly due to regrowth of trees in abandoned fields. Buildings have been erected and the road system has extended contributing to the sectioning of the land. Clearly, the regrowth of forest due to abandonment of farms can only be beneficial to some bird species if fundamental requirements are satisfied, and, in some cases, these can only be met in large wooded areas (e.g. low predation and parasitism, food and nesting requirements, minimal disturbance). In the present study eight bird species were counted exclusively in stops with large forested areas, including three thrush species, three warblers and other forest species (Table 4b).

Uncultivated habitats, especially woodlots, appear to be important refuges for remnant plant species typical of the once dominant vegetation of southeastern Canada (Tables 2 & 4a). In addition three species rare for Québec (Bouchard *et al.*, 1983) were found - *Aster ontarionis* in a ditch, *Viola affinis* in a woodlot and *Waldsteinia fragarioides* in a hedgerow and a woodlot - illustrating the conservation value of such habitats associated with agriculture. In this context the effect of herbicides on plants situated at the margins of croplands (Table 3) is of concern. The occurrence of small amounts of herbicide drifting into field margins and affecting plants has been documented (Marrs *et al.*, 1989). The establishment of an unsprayed buffer zone at the margin of cropfields would reduce the drift of herbicide into wildlife habitats. However before this can be implemented properly in Canada more research on the agronomic impact and cost to farmers is needed.

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