# The influence of hedgerows on coleopteran distributions: results from a multi-field sampling study

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## Abstract

Understanding the distribution patterns and scale of patchiness of key beneficial species in fields and field margins, and the spatial and temporal stability of these patterns, can provide valuable information on species' ecological requirements. However, previous studies of spatial distribution have focussed on patterns within single fields, although aggregations may extend beyond boundaries and, for some species, may be influenced by them. To investigate this, the distribution of Coleoptera was monitored across 66 ha of arable land encompassing six fields and their boundaries. Sampling was carried out using two pitfall traps at each of 973 locations arranged in a regular grid pattern on four occasions between May and July 2000. The distribution of some Coleoptera was visualised using GIS mapping and analysed using SADIE to identify patches and gaps of significant size. Evidence of aggregation is presented for total carabid species number, *Bembidion lampros*, *Pterostichus madidus* and *Philonthus cognatus*. The highest carabid diversity was found near to field boundaries. For some patches their extent was confined by the field boundaries. The experiment formed part of a new MAFF SAPPIO project "3D Farming – making biodiversity work for the Farmer."

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## Introduction

It is now well recognised that many arthropods exist as discrete patches of local populations that together constitute a metapopulation (Gilpin & Hanski, 1991) and it has been demonstrated for some groups (Den Boer, 1990) that this phenomenon occurs in agricultural landscapes. The size of these local populations within a metapopulation may differ depending on the species and can extend over several hectares (Holland *et al*., 1999). However, most studies of carabids have been conducted within single fields (e.g. Ericson, 1978; Hengeveld, 1979; Holland *et al*., 1999; Thomas *et al*., 2001) and the extent to which linear non-crop features (e.g. field boundaries, tracks, watercourses and roads) influence coleopteran distribution patterns is poorly understood. There is some evidence that the movement of epigeal arthropods is inhibited by such features (Mader *et al*., 1990; Mauremootoo *et al*., 1995; Thomas *et al*. 1998), but the extent to which they impose metapopulation structure on carabid populations by fragmenting them into local populations has not been addressed. There is also little definitive evidence to explain why these patches occur, even though investigating how arthropods are distributed in agricultural landscapes can provide important and useful insights into a species ecology (Taylor, 1986).

Spatial pattern of population distributions has rarely been investigated, partly because of the sampling effort required, but also because the traditional methods of statistical analysis, which examine the relationship between the sample mean, *m*, and the sample variance, $s^2$ (e.g. Taylor, 1961), make no use of information concerning the spatial location of the sample units. A new class of techniques has been developed, termed SADIE (Spatial Analysis by Distance IndicEs), to detect and measure the degree of spatial pattern in spatially-referenced count data (Perry, 1998). The method has the advantage that not only is the size of individual counts considered but also that of their neighbours so enabling clusters and patches of above or below average size respectively to be identified.

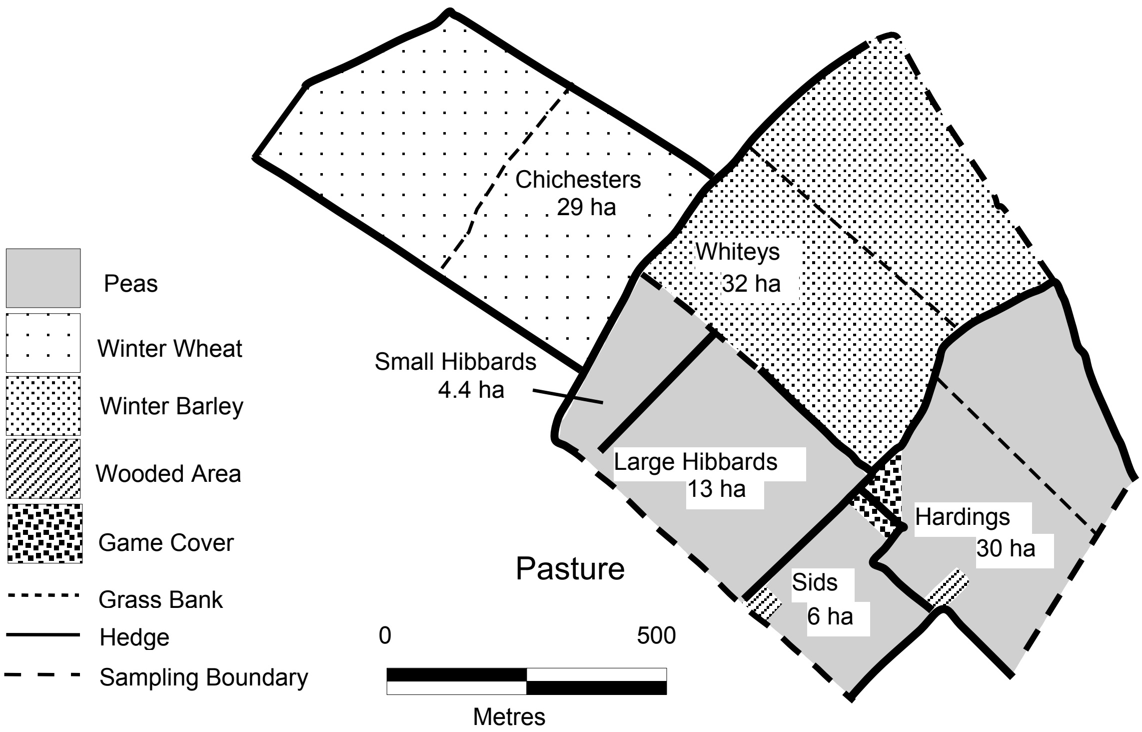
Deciphering which factors are important in controlling arthropod distributions can assist with the development of management practices for conservation or to improve the role of beneficial arthropods in biocontrol. Hedgerows in particular are considered as a valuable source of beneficial insects. In addition, much can be learned about inter- and intra-species competition and predation. The latter may aid the development of integrated pest control as the searching ability and density-dependent response of predators will determine their effectiveness. Previous studies of spatial pattern in agroecosystems have been mainly conducted within fields. In 2000 the "3D Farming Project" was started with the overall aim of increasing biodiversity on farmland and to manipulate beneficial insects so that they provide effective aphid control. One of the main components involves investigating how predatory insects are distributed at the landscape scale and how these are influenced by field boundaries. Some results from the first year of this project are presented here.

## Methods

Ground active arthropods were sampled simultaneously within six arable fields, covering 66 ha, in Dorset, UK using pitfalls traps (Fig. 1). Samples were taken on four occasions (2-9/5/00; 6-13/6/00; 28/6-5/7/00; 12-19/7/00) during 2000. The fields were surrounded by a range of different field boundary types. A grid of pitfall traps arranged in an offset grid pattern with 40 x 20 m spacing was used within each field using two traps at each sampling point. The grid extended across the whole of the three smaller fields, but only half the area of each large field was covered (Fig. 1). Each sample location was surveyed and located using the national grid reference using a differential Global Positioning System. The pitfall traps (6 cm diam.), partly filled with water and detergent, were operated for one week then all arthropods were removed and stored in 70% alcohol. The majority of the catch comprised Carabidae and Staphylinidae, which were identified to species, and Araneae, of which only Lycosidae were identified. Only data for carabid diversity, and a selection of species with contrasting ecology is presented here. These are *Bembidion lampros*, a small carabid beetle which over-winters as an adult in field boundaries; a larger carabid, *Pterostichus madidus* which over-winters mainly as a larva within fields; and *Philonthus cognatus* a large staphylinid beetle which also over-winters as a larva within fields.

For all fields and for individual fields the distribution of insects was analysed using a modified SADIE analysis (Perry *et al.* 1999). This calculates the degree of clustering in the form of 'patches' of large counts, using the overall index $\bar{v}_i$ and its associated probability $P_i$, or of 'gaps' of small counts, using the overall index $\bar{v}_j$ and its associated probability $P_j$ (Perry *et al*., 1999). For a particular set, if all of these indices have values around unity, conformation of the data to the null hypothesis of spatial randomness is indicated; a value of at least one index well above unity indicates spatial non-randomness of some form. Distribution data is presented as two-dimensional contour maps from counts, drawn using the package SURFER (Golden Software Inc, 1997).

**Figure 1** Layout of 3D Farming Project site in Dorset, UK.




## Results

The SADIE red/blue analysis of number of carabid species revealed significant aggregation on all sample dates when distributions across the whole study site were examined (Table 1). On the whole, the patches with the greatest diversity were located around field boundaries (Fig. 2). Within each field, aggregation was strongest in Large Hibbards on the first two sample occasions but was also present in several fields on the last two occasions.

Individual species exhibited quite discrete distributions within the study area. *Bembidion lampros* was largely associated with the boundaries and especially those surrounding Small Hibbards early in the year. Two patches were present, each extending 200 m along the boundary and reaching 70 m into the field (Fig. 3). The boundaries in these locations were similar in vegetation composition and structure to others in the study site. Penetration of the larger fields occurred later as they became more evenly dispersed across the study site (Table 1). The beetle bank was ineffective because it was only created in the previous autumn and had not been sown with grasses. *Pterostichus madidus* emerged in lower numbers within two fields relatively early, but the greatest aggregation occurred in July within Large Hibbards where a patch covered approximately 6 ha and in Sid's where complete coverage occurred (Fig. 4). The patches appeared to be confined by the boundaries surrounding these fields. Another patch extended along two of the boundaries in Hardings. With *Philonthus cognatus* two main patches were present in May each covering approximately 4 ha, with further patches developing in Small and Large Hibbards on later sampling dates (Fig. 5). These patches also appeared to be confined by the field

**Figure 2** Distribution of carabid species number in May and early July.

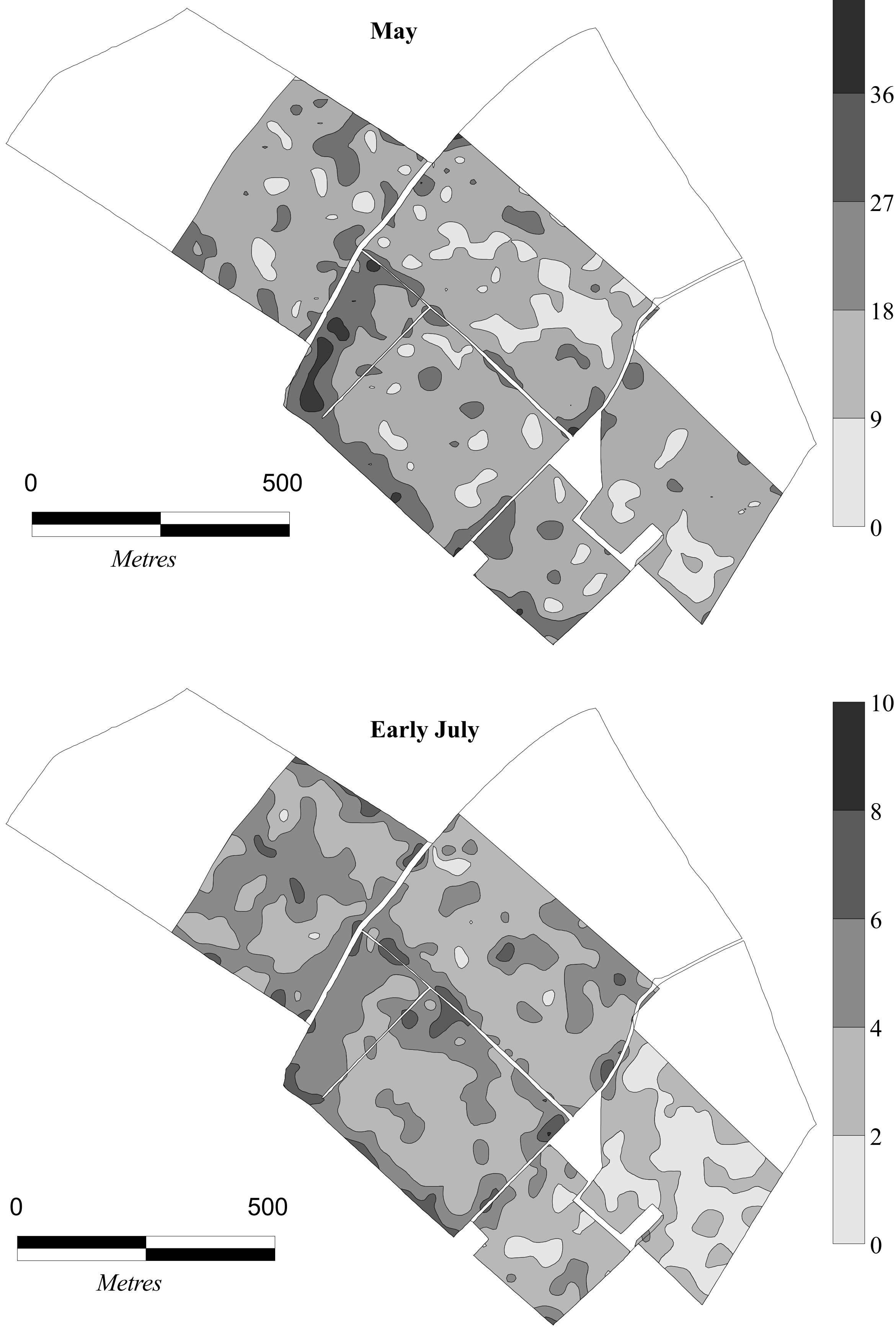


**Figure 3** Distribution of *Bembidion lampros* in May.

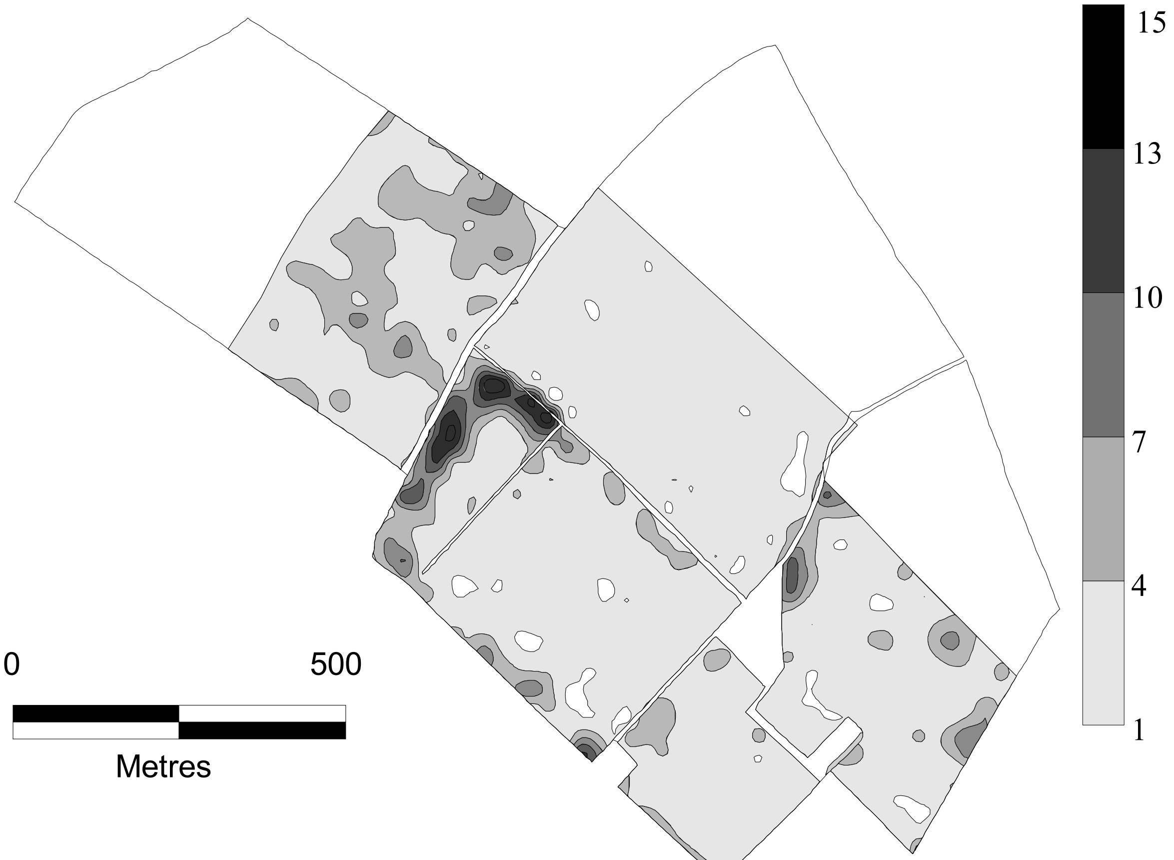



**Figure 4** Distribution of *Pterostichus madidus* in late July.

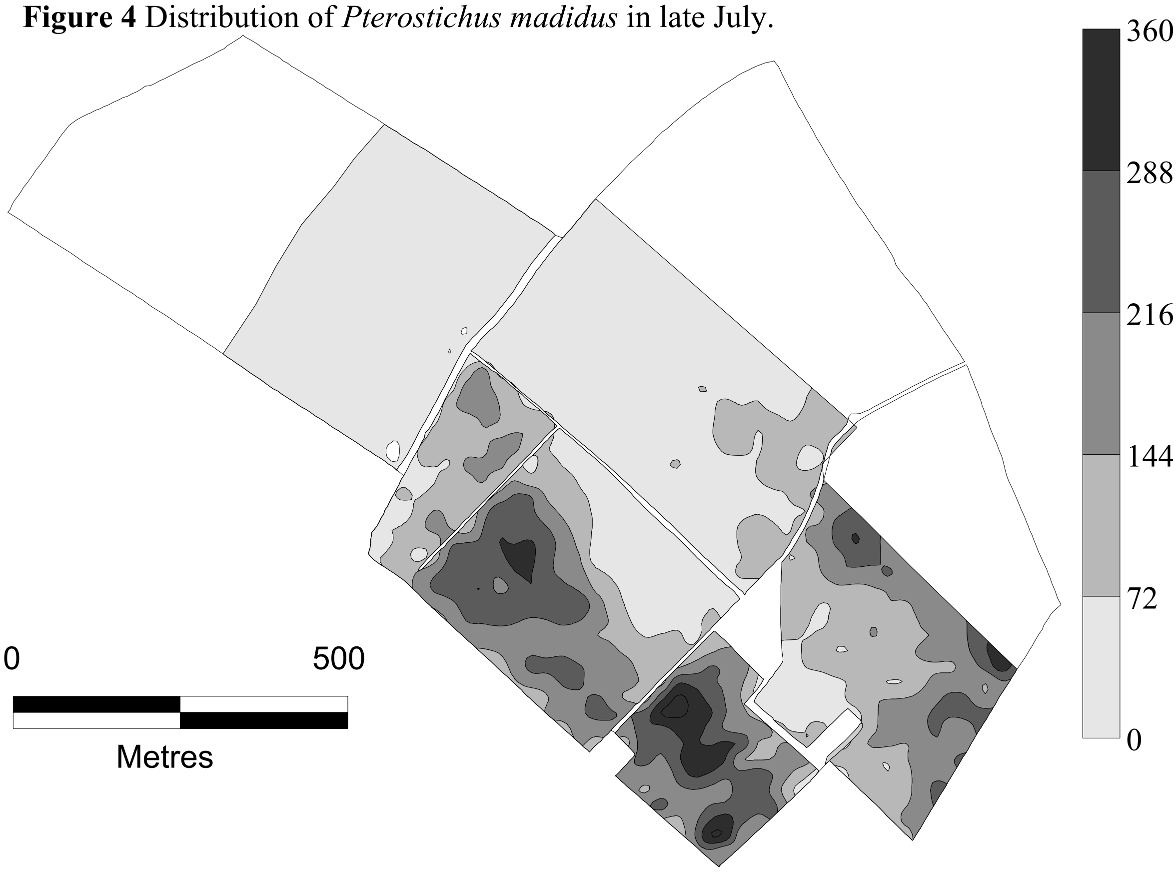
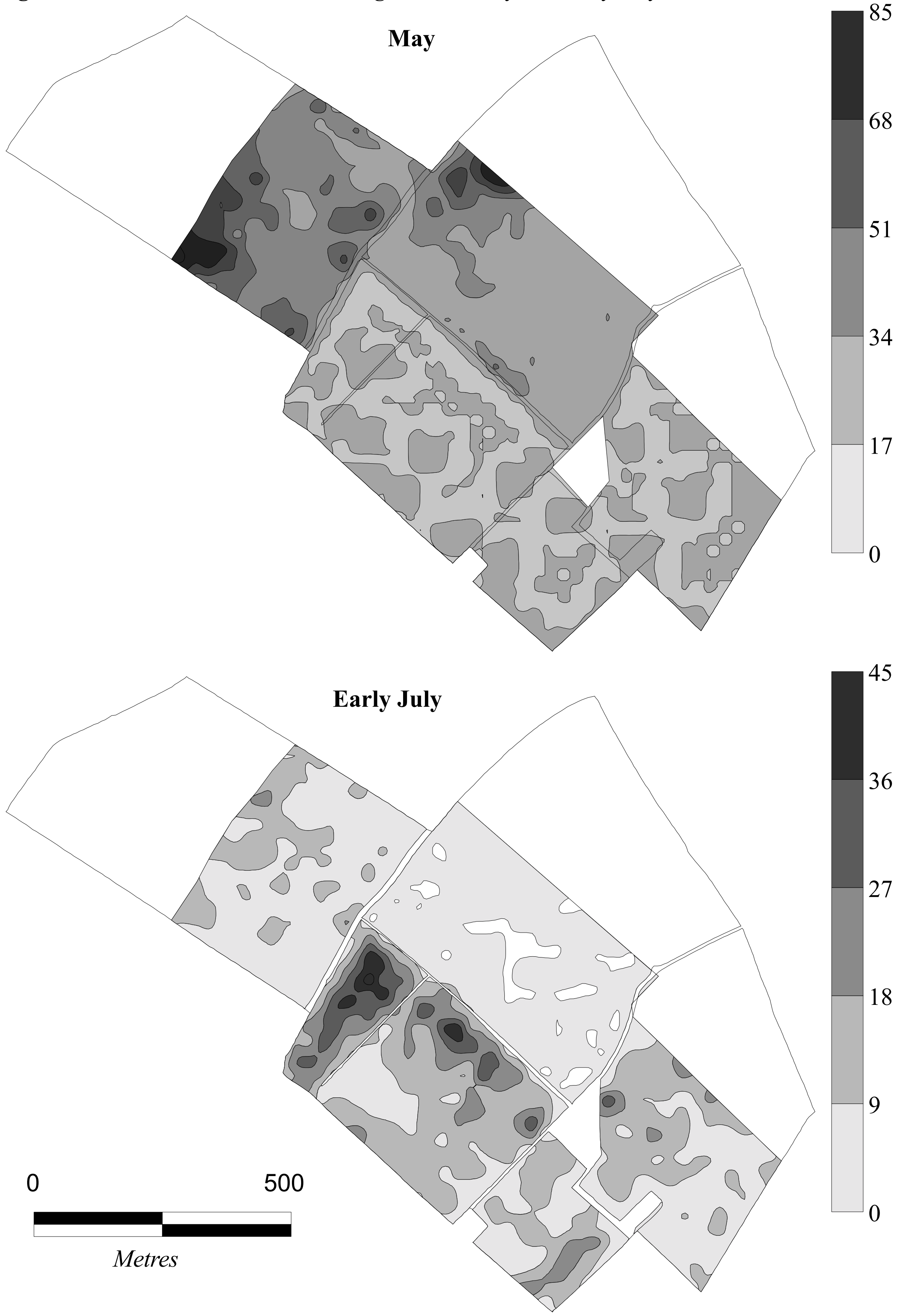


**Figure 5** Distribution of *Philonthus cognatus* in May and early July.



boundaries. The results from the SADIE analysis correlated well with the presented contours.

## Discussion

The distribution of arthropods can be influenced by many factors (Holland & Luff, 2000), although scant evidence exists at the field or landscape scale to identify the most important factors. In this study the highest number of carabid species were found near to the field boundaries compared to the mid-field, leading to greater diversity across the smallest field. The majority of boundaries were comprised of a hedge with a herbaceous/grass bank, although in many places the dominant species were *Anisantha sterilis* and *Urtica dioica* which are unlikely to support as high a density of overwintering Coleoptera as the tussocky grasses. In future years these will be improved and the impact on Coleopteran distributions monitored. Holland *et al*. (1999) also found greater numbers of carabids within 60 m of the field boundary. This was expected because the boundaries are used for over-wintering, harbouring high densities of Coleoptera (Sotherton, 1984) which then disperse into the crop during spring (Wallin, 1985; Coombes & Sotherton, 1986), as seen here with *B. lampros*. The margins also provide a different habitat to that of the crop and so support additional species, some of which may also move into the crop. In addition, the field edges are weedier (Wilson & Aebischer, 1995), providing better foraging resources. Indeed, practical ways of encouraging predatory arthropods for pest control through the provision of additional non-crop habitat have been developed and tested, although the benefits for pest control remain to be demonstrated. These techniques include the reintroduction of hedges (Fournier & Loreau, 1999), "beetle banks" (Thomas *et al*., 1991), weedy strips (Nentwig, 1989) and wildflower margins (Marshall, 1988) and various headland management schemes (Hawthorne *et al*., 1997). Landscape evaluations have revealed that invertebrate reproduction and diversity can be higher in areas with greater complexity and a larger proportion of non-crop areas (Bommarco, 1999; Holland & Fahrig, 2000).

The patches of *P. madidus*, remained relatively static over the monitoring period and appeared to be confined by the field boundaries, as found by Brown (2000) for this species in winter beans. Patches of *P. melanarius, Poecilus cupreus* and other species also remained relatively static in winter barley through the summer with few individuals moving greater than 55 m (Thomas *et al*., 1998; Thomas *et al*., 2001), even though *P. melanarius* is capable of moving up to 73 m day$^{-1}$ (Lys and Nentwig, 1992). Providing food and environmental conditions are satisfactory, there may be no incentive for a species to move large distances and these conditions need to be measured in conjunction with the collection of distribution data if credible explanations for spatial pattern are to be found. The field boundaries may, however, have also been acting as an impenetrable barrier thereby restricting movement to within the field. Mark/release-recapture (MRR) experiments (to be reported elsewhere) using *P. madidus*, *P. melanarius* and *P. cupreus* confirmed that few beetles moved through the hedgerows. Similarly, using MRR relatively few *P. melanarius* and *Nebria brevicollis* moved through a hedgerow (Thomas *et al*., 1998; Joyce *et al*., 1999; Fernández García *et al*., 2000). Greater movement through hedgerows were also found when marked beetles were released within areas of hedgerow surrounded by barriers, but the creation of the barriers and confinement of the beetles may have encouraged penetration (Mauremootoo *et al*., 1995). *B. lampros* and *P. cognatus* did not appear to be restricted by the hedgerows, but because they were present in most fields initial aggregations may have dispersed within each field, masking any confinement.

The capture rate of pitfall traps is influenced by many factors but especially activity levels and beetle activity is known to be influenced by hunger levels and vegetation structure (Adis, 1979). The higher capture of *P. madidus* in the pea fields compared to the cereal fields may have been because at ground level the crop structure in peas is less of a physical impediment to movement than dense cereal tillers. Prey availability may also have been different, causing the higher capture. However, additional MRR experiments conducted within the same fields confirmed that it was the emergence of tenerals which was creating the patches.

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**Table 1** Degree of clustering into 'patches' using overall index $\bar{v}_i$ and associated probability $P_i$, or of 'gaps' using overall index $\bar{v}_j$ and associated probability $P_j$ across all fields and within each field. (*=$P$<0.05, **= $P$<0.01, ***= $P$<0.001)

| Field | Number of carabid species | | | | | | | | *Bembidion lampros* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May | | June | | Early July | | Late July | | May | | June | | Early July | | Late July | |
| | $\bar{v}_j$ | $\bar{v}_i$ | $\bar{v}_j$ | $\bar{v}_I$ | $\bar{v}_j$ | $\bar{v}_i$ | $\bar{v}_j$ | $\bar{v}_i$ | $\bar{v}_j$ | $\bar{v}_i$ | $\bar{v}_j$ | $\bar{v}_i$ | $\bar{v}_j$ | $\bar{v}_i$ | $\bar{v}_j$ | $\bar{v}_i$ |
| All | -2.54 *** | 2.67 *** | -4.87 *** | 5.13 *** | -4.68 *** | 5.42 *** | -5.62 *** | 5.74 *** | -3.04 *** | 3.19 *** | -2.38 *** | 2.43 *** | -1.98 *** | 2.05 *** | -1.66 ** | 1.69 * |
| Chichesters | -0.94 | 1.00 | -2.14 *** | 2.29 *** | -1.00 | 0.98 | -1.50 ** | 1.32 * | -1.44 * | 1.44 * | -2.45 *** | 2.38 *** | -1.47 * | 1.29 | -1.69 ** | 1.66 ** |
| Small Hibbards | -1.24 | 1.34 | -1.60 * | 1.81 ** | -1.48 * | 1.63 * | -0.81 | 0.78 | -1.55 * | 1.48 * | -1.55 * | 1.87 ** | -1.55 * | 1.64 * | -1.57 * | 1.50 * |
| Large Hibbards | -1.82 *** | 1.64 ** | -2.47 *** | 2.48 *** | -1.53 ** | 1.44 ** | -3.86 *** | 4.08 *** | -1.39 | 1.41 ** | -1.30 * | 1.16 | -1.14 | 1.08 | -1.12 | 1.12 |
| Sids | -1.49 * | 1.47 ** | -1.21 | 1.35 * | -1.50 * | 1.30 * | -1.43 ** | 1.35 * | -1.53 ** | 1.59 ** | -1.11 | 0.99 | -1.36 * | 1.41 * | -1.04 | 0.90 |
| Hardings | -0.98 | 1.00 | -1.44 * | 1.43 * | -1.20 | 1.07 | -2.82 *** | 2.96 *** | -1.53 ** | 1.37 * | -2.07 *** | 2.09 *** | -1.14 | 1.08 | -1.14 | 1.16 |
| Whiteys | -1.40 * | 1.31 * | -1.25 | 1.26 | -1.42 * | 1.41 * | -5.16 *** | 5.13 *** | -1.39 * | 1.64 * | -2.41 *** | 2.55 *** | -2.24 *** | 2.36 *** | -2.35 *** | 2.51 *** |
| | *Pterostichus madidus* | | | | | | | | *Philonthus cognatus* | | | | | | | |
| All | -2.84 *** | 2.76 *** | -3.93 *** | 3.82 *** | -5.25 *** | 5.03 *** | -6.29 *** | 6.35 *** | -8.61 *** | 9.24 *** | -7.43 *** | 7.95 *** | -2.56 *** | 2.54 *** | -2.52 *** | 2.68 *** |
| Chichesters | 2.30 *** | 2.09 *** | -1.69 ** | 1.57 ** | -2.07 *** | 2.03 *** | -1.34 * | 1.30 * | -3.07 *** | 2.78 *** | -0.96 | 0.88 | -2.04 *** | 2.00 *** | -1.89 *** | 1.91 *** |
| Small Hibbards | -1.39 | 1.50 * | -1.43 | 1.22 | -1.08 | 1.11 | -1.83 ** | 1.60 * | -1.54 * | 1.69 * | -1.63 * | 1.56 * | -1.11 | 0.95 | -0.90 | 1.00 |
| Large Hibbards | -1.27 | 1.31 * | -2.57 *** | 2.18 *** | -3.78 *** | 3.78 *** | -3.39 *** | 3.48 *** | -1.27 | 1.23 | -2.79 *** | 2.61 *** | -1.90 *** | 1.84 *** | -2.15 *** | 2.10 *** |
| Sids | -1.20 | 1.22 | -2.22 *** | 2.05 *** | -1.66 ** | 1.75 ** | -1.44 * | 1.31 | -1.05 | 1.03 | -2.44 *** | 2.25 *** | -1.24 | 1.20 | -1.36 * | 1.46 * |
| Hardings | -1.21 | 1.16 | -2.10 *** | 1.77 ** | -2.68 *** | 2.77 *** | -2.75 *** | 3.03 *** | -1.01 | 0.95 | -1.35 * | 1.15 | -2.05 *** | 1.84 *** | -1.56 ** | 1.51 * |
| Whiteys | -3.14 *** | 3.11 *** | -2.66 *** | 2.81 *** | -4.64 *** | 4.79 *** | -5.33 *** | 5.43 *** | -3.53 *** | 3.06 *** | -3.22 *** | 2.78 *** | -2.05 *** | 2.00 *** | -2.27 *** | 2.11 *** |