Pedobiologia **44**, 516–526 (2000)

http://www.urbanfischer.de/journals/pedo

Pedo biologia

PROCEEDINGS OF V^TH^ INTERNATIONAL SEMINAR ON APTERYGOTA, CORDOBA 1998

The role of hedgerows in the recolonisation of arable fields by epigeal Collembola

Tania Alvarez, Geoff K. Frampton and Dave Goulson

Biodiversity and Ecology Division, School of Biological Sciences, University of Southampton, Bassett Crescent East, Southampton SO16 7PX, UK

Accepted: 15 November 1999

Summary

The role of hedgerows as reservoirs for beneficial arthropods in agroecosystems has been extensively studied, but their importance as habitats for springtails (Collembola) is largely unknown. Population recovery in arable fields by epigeal Collembola can occur either from population sources in non-crop habitats or in-situ reproduction of field-dwelling species. In this study we investigated the recovery of springtail populations in a spring-sown cereal crop following a physical disturbance due to tillage. To investigate the role of a hedgerow in population recovery, replicated lengths of hedgerow were isolated from the field using exclusion barriers.

Some species of Collembola (e.g. *Isotomurus* spp., *Bourletiella hortensis*) were consistently more abundant next to the hedgerow than within the field. Areas of the field adjacent to barriered sections of hedgerow developed significantly different populations and community structures compared to unbarriered 'controls'. Abundance of several species in the field (e.g. *Isotoma viridis*, *Sminthurinus elegans*, *Sminthurus viridis*) was reduced by hedgerow barriers, providing the first evidence that hedgerows could be important source habitats for the colonisation or recolonisation of arable fields by Collembola.

Key words: Agroecosystems, Field margins, recovery, tillage, refugia

Corresponding author Geoff Frampton, *e-mail:* gkf@soton.ac.uk

0031–4056/00/44/03–04–516 $ 12.00/0

Introduction

The importance of hedgerows for the fauna of arable farmland has been extensively studied (e.g. Pollard 1968a, b; Sotherton 1984, 1985; Burel 1996). It is well known that grass banks and hedgerows are important shelters and sources of recolonisation for predatory arthropods (Dennis 1991; Dennis & Fry 1992) and even for earthworms (Hansen et al. 1989). The presence of source populations is important for recovery following periodic agricultural disturbance including tillage and pesticide applications, both of which have been shown to be detrimental to Collembola (e.g. Heisler 1994; Edwards & Thompson 1973; Hopkin 1997). Pesticides in particular have been found to have long-lasting effects upon epigeal springtail populations (Filser et al. 1995; Frampton 1997). However, the potential of hedgerows as refugia for field-dwelling Collembola has received little attention, although previous work (Alvarez et al. 1997; Reddersen 1997) showed a decrease in species density, diversity and biomass with increasing distance from the hedgerow into the field.

This study aimed to determine whether hedgerows act as source habitats of arable field collembolan populations in the spring. Polythene barriers, which effectively block the movement of Collembola (e.g. Gravesen & Toft 1987; Mebes & Filser 1997), were used to isolate sections of hedgerow from the field to test the hypothesis that Collembola recolonise recently disturbed field habitats from hedgerows. The effects of this habitat manipulation upon subsequent population and community development provided information on the recovery strategies of individual species and the importance of hedgerows as refugia for springtails.

Materials and Methods

Study area and experimental design

The study field had been sown with spring barley on 16 February 1998. It was located on the Leckford Estate in Hampshire, southern England (51°N 1°W). No pesticides were applied during the period of this study. The field had one continuous edge of mature hedgerow (containing *Sambucus nigra*, *Crataegus* sp., *Prunus spinosa*, and a well-developed mixed herbaceous layer) about 2–2.5 m tall and aligned SW-NE. Barriers were erected on the 18 March in the field 50 cm from the base of the hedgerow. The barriers consisted of polythene sheets 1m above ground level and dug 25 cm into the soil, hung on rope and supported by wooden posts. 40 m-lengths of barriers were interspersed with 40 m-lengths of unbarriered hedgerow, and each treatment comparison block was replicated four times (Fig.1).

Suction samples were taken using a leaf-blower (Ryobi RSV3100) adapted as described in Stewart & Wright (1995). For each sample, a total area of 0.5 m^2 was sampled, comprising five pooled sub-samples of 10-s duration. These were taken randomly within a 1 m^2 area, at each of the six points along a perpendicular transect from the middle of each barriered or control section. Samples were taken at 2 m, 5 m, 10 m, 15 m, 20 m, and 30 m from the hedgerow. Pre-treatment samples were taken before the barriers were erected on 17 March, and post-treatment samples were taken on 24 March, 5 April, and 13 May.

Identification and analysis

Samples were stored in 80 % methylated spirit. Collembola were removed and examined under a binocular microscope; specimens difficult to identify were mounted and examined further

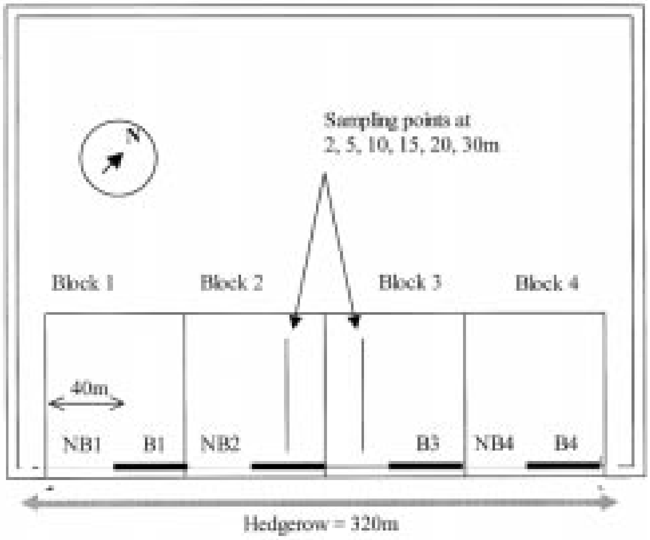


Fig. 1. Experimental set-up in a 17.5 ha field of spring barley. The barriers are labeled B1–B4, the unbarriered areas of open hedgerow are NB1-NB4 (not drawn to scale) within the blocks 1–4

using a compound light microscope. Species were identified with the aid of Christiansen & Bellinger (1998). The entomobryid species *Lepidocyrtus violaceus* Lubbock and *cyaneus* Tullberg and the Isotomid genus *Isotomurus* spp. were not separated; there is continuing debate on the taxonomy of the constituent species within the latter genus (e.g. see Carapelli et al. 1995, 1997; Frati et al. 1995).

The counts of Collembola from the samples were transformed using the square root of the count + 0.5 in order to fulfill the requirements of parametric analysis (Sokal & Rohlf 1995). Three diversity indices were used to investigate community-level effects, since the use of more than one has been recommended to compensate for the dominance-sensitivity versus the abundance-sensitivity of the different calculations (Magurran 1988). Margalef's species richness, Simpson's dominance index, and the Shannon-Wiener diversity index were produced using the program DIVERSE available in PRIMER (Plymouth Routines in Multivariate Ecological Research- Carr, 1997). For each sampling date, species and measure of community composition, a multifactorial analysis of variance (ANOVA) was carried out to test effects of the factors barrier treatment, distance from the hedgerow and block. Where no significant differences were attributable to block, analysis was repeated with this factor excluded. In addition, a repeated measures ANOVA model tested the null hypothesis that there was no change over time in the abundance of each species or measure of community composition.

Results

Effects of the barriers

The most common species encountered were: *Sminthurinus elegans* (Fitch), *Sminthurus viridis* (L.), *Bourletiella hortensis* (Fitch), *Isotoma viridis* Bourlet, *Lepidocyrtus* spp., *Pseudosinella alba* (Packard), *Isotomurus* spp., and *Isotoma notabilis* Schäffer. Significant differences due to the barrier treatments were found in the counts of *I. viridis*, *Lepidocyrtus* spp., *P. alba*, *S. viridis* and *S. elegans* (Table 1). The barriers had no effect upon numbers of *I. notabilis*, *Isotomurus* spp., or *B. hortensis*. Differences in

Table 1. Comparisons of the transformed Collembola counts according to barrier treatment and distance from the hedgerow. 'Date' refers to the number of days before or after the barriers were erected. (Multifactorial ANOVA; 2-way ANOVA when Block was not significant. N.S.= no significant difference, P>0.05; *=P< 0.05; **=P<0.01; *** =P<0.001)

Species	Date	Block	Distance	Barrier
I. viridis	- 1	NS	$F_{5,36}$=3.2*	NS
Isotomurus spp.		NS	$F_{5,36}$=5.1*	NS
I. notabilis		NS	NS	NS
P. alba		$F_{3,33}$=4.0*	NS	NS
S. elegans		NS	$F_{5,36}$=4.2**	NS
S. viridis		NS	NS	NS
B. hortensis		NS	NS	NS
Lepidocyrtus spp.		$F_{3,33}$=20.6***	NS	NS
I. viridis	+ 6	NS	$F_{5,36}$=5.3***	$F_{1,36}$=26.0**
Isotomurus spp.		$F_{3,33}$=4.6**	$F_{5,33}$=7.9***	NS
I. notabilis		$F_{3,33}$=3.2*	NS	NS
P. alba		$F_{3,33}$=4.9**	NS	NS
S. elegans		NS	$F_{5,36}$=13.2***	NS
S. viridis		NS	NS	NS
B. hortensis		$F_{3,33}$=4.9**	NS	NS
Lepidocyrtus spp.		$F_{3,33}$=25.4***	NS	$F_{1,33}$=7.8**
I. viridis	+ 18	NS	NS	$F_{1,36}$=7.7**
Isotomurus spp.		$F_{3,33}$=4.6**	$F_{5,33}$=7.9***	NS
I. notabilis		$F_{3,33}$=3.2*	NS	NS
P. alba		$F_{3,33}$=4.9**	NS	NS
S. elegans		NS	NS	$F_{1,36}$=15.8***
S. viridis		NS	NS	$F_{1,36}$=6.6*
B. hortensis		$F_{3,33}$=4.9**	NS	NS
Lepidocyrtus spp.		$F_{3,33}$=25.4***	NS	$F_{1,33}$=7.8**
I. viridis	+ 56	NS	NS	NS
Isotomurus spp.		$F_{3,33}$=8.4**	$F_{5,33}$=4.5**	NS
I. notabilis		NS	$F_{5,36}$=2.8*	NS
P. alba		$F_{3,33}$=4.9**	NS	NS
S. elegans		$F_{3,33}$=11.7***	$F_{5,33}$=2.6*	NS
S. viridis		NS	$F_{5,36}$=5.1***	NS
B. hortensis		NS	$F_{5,36}$=3.9**	NS
Lepidocyrtus spp.		$F_{3,33}$=12.7***	NS	$F_{1,33}$=10.4**

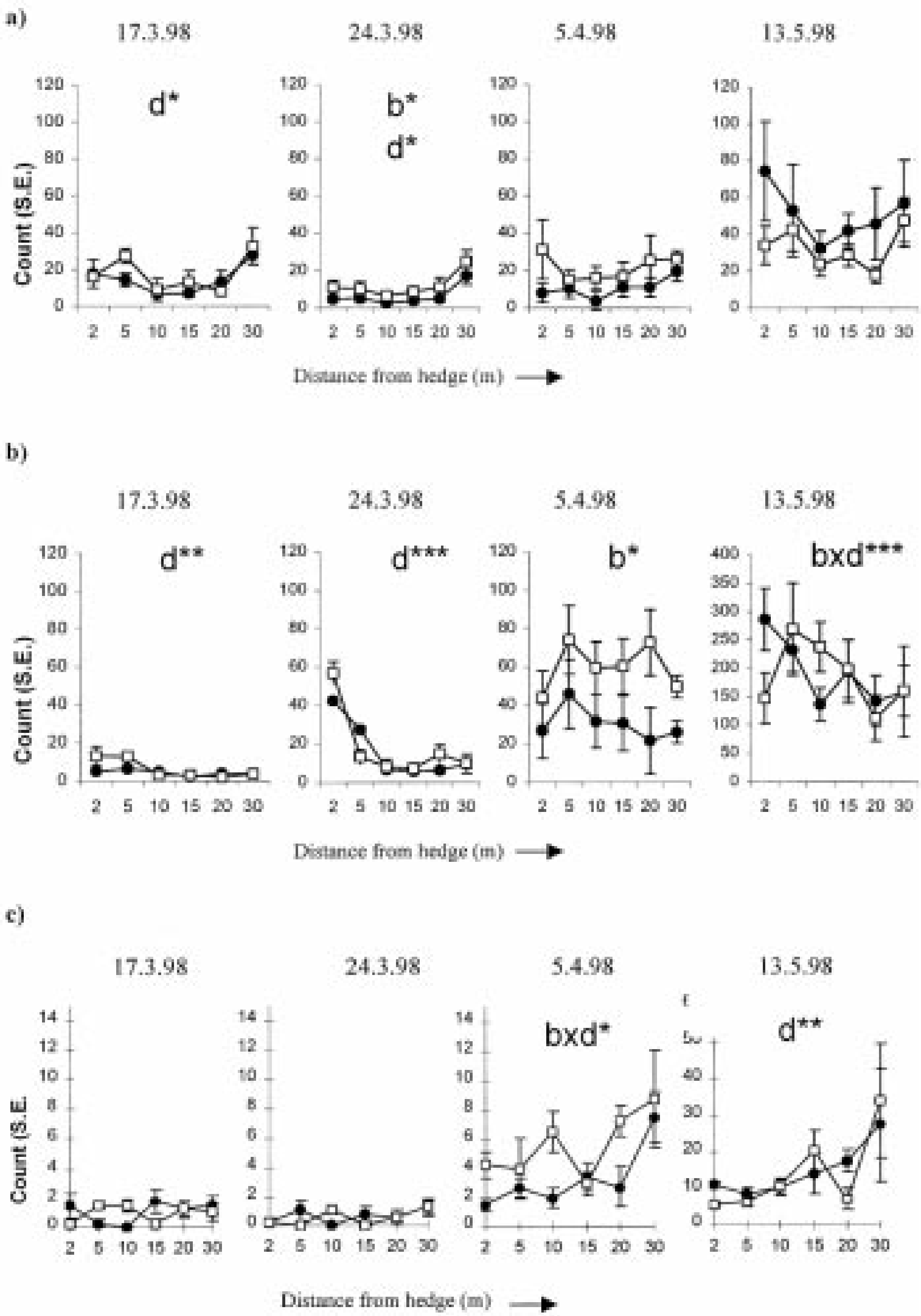


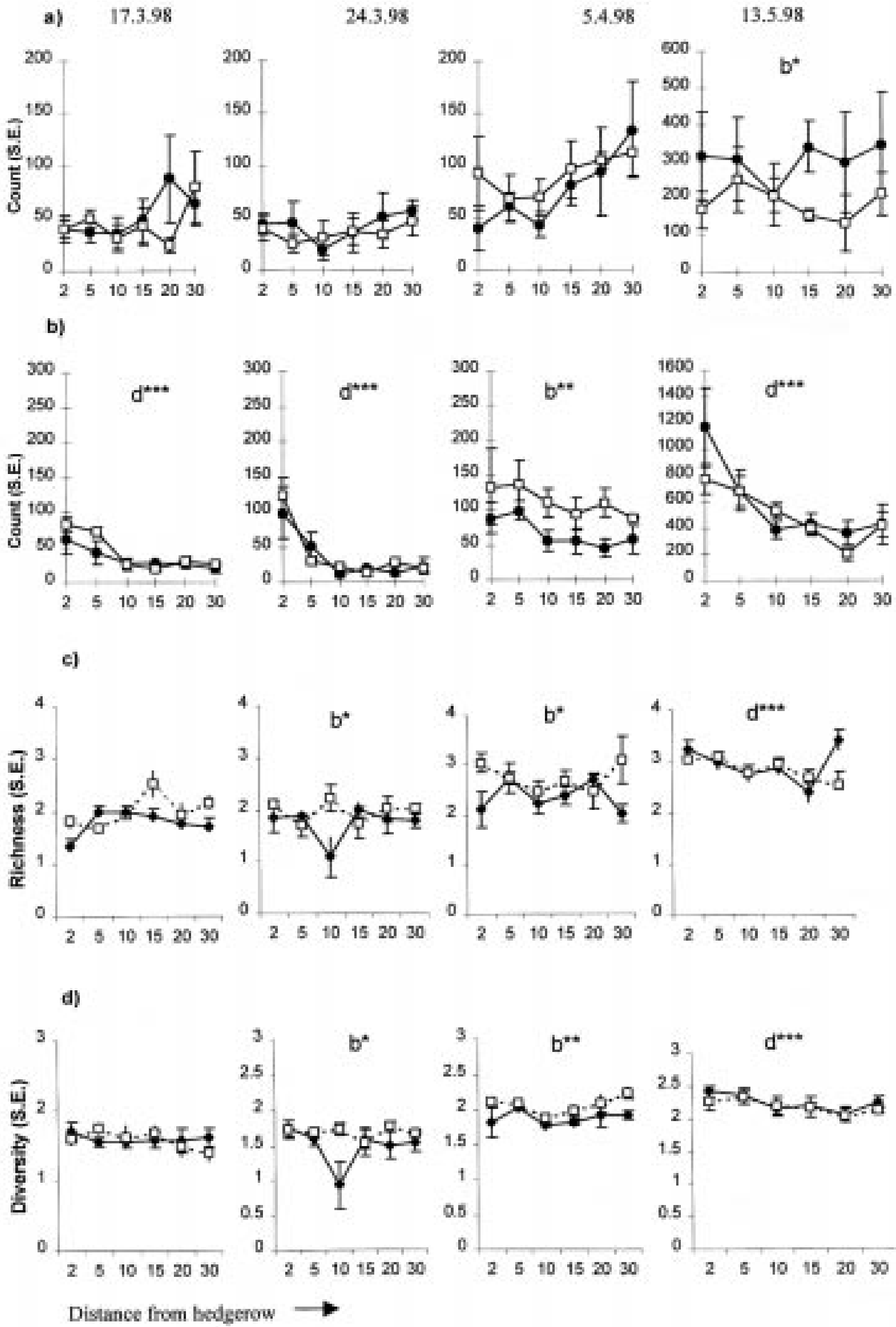
Fig. 2. The catch of Collembola in a field adjacent to barriered (black circles) and unbarriered (white squares) lengths of a hedgerow on four sampling dates and at different distances into the field. a) Data for *I. viridis*; b) Data for *S. elegans*; c) Data for *S. viridis*. Vertical axes give counts (± SE), horizontal axes distance. (*=P<0.05; **=P<0.01, ***=P<0.001)

species abundance were found with distance into the field according to the barrier treatments (Fig. 2). Significantly higher population levels were found in the unbarriered areas for *I. viridis* (Fig. 2a, 24 March and 5 April), *S. elegans* (Fig. 2b, 5 April), and *S. viridis* (Fig. 2c, 5 April). Numbers of *P. alba* and *Lepidocyrtus* spp. were found to differ significantly between blocks in the field throughout the experiment, with significantly higher abundance in blocks 1 and 2. Despite these initial spatial differences, a significant effect due to barriers was encountered for *Lepidocyrtus* spp. in all samples taken after the barriers were erected. Abundance was higher next to the barriers than next to the open hedgerow.

Field areas adjacent to barriers had a different community composition relative to the control areas. Significant differences were found in the counts for total Collembola, Symphypleona, Arthropleona, and in the indices used to estimate species richness, diversity, and dominance (Table 2). These differences occurred mainly three

Table 2. Comparisons of the total collembolan counts and the derived species diversity indices according to barrier treatment and distance from the hedgerow. 'Date' refers to the number of days before or after the barriers were erected. (Multifactorial ANOVA; 2-way ANOVA when Block was not significant. N.S.= no significant difference, P>0.05; *=P<0.05; **=P<0.01; ***=P<0.001)

Group / Index	Date	Block	Distance	Barrier
Total Collembola	- 1	$F_{3,33}$=9.5***	NS	NS
Symphypleona		NS	$F_{5,36}$=10.7***	NS
Arthropleona		$F_{3,33}$=8.3***	NS	NS
Richness		NS	NS	NS
Shannon-Wiener		NS	NS	NS
Simpson		NS	NS	NS
Total Collembola	+ 6	$F_{3,33}$=10.7***	$F_{5,33}$=8.9***	NS
Symphypleona		NS	$F_{5,36}$=13.9***	NS
Arthropleona		$F_{3,33}$=15.5***	NS	NS
Richness		$F_{3,33}$=4.0*	NS	$F_{1,33}$=2.9*
Shannon-Wiener		NS	NS	$F_{1,36}$=5.5*
Simpson		NS	NS	$F_{1,36}$=6.2*
Total Collembola	+ 18	$F_{3,33}$=10.7***	$F_{5,33}$=8.9***	NS
Symphypleona		NS	NS	$F_{1,36}$=11.8**
Arthropleona		$F_{3,33}$=15.5***	NS	NS
Richness		$F_{3,33}$=4.0*	NS	$F_{1,33}$=2.9*
Shannon-Wiener		NS	NS	$F_{1,36}$=10.4**
Simpson		NS	NS	$F_{1,36}$=5.3*
Total Collembola	+ 56	NS	$F_{5,36}$=5.7***	$F_{1,36}$=4.7*
Symphypleona		NS	$F_{5,36}$=12.0***	NS
Arthropleona		$F_{3,33}$=8.6**	NS	$F_{1,33}$=7.1*
Richness		NS	$F_{5,36}$=5.6***	NS
Shannon-Wiener		$F_{3,33}$=4.3*	$F_{5,33}$=2.7*	NS
Simpson		$F_{3,33}$=5.7**	NS	NS



a)
17.3.98
24.3.98
5.4.98
13.5.98
Count (S.E.)
b*
b)
Count (S.E.)
d***
d***
b**
d***
c)
Richness (S.E.)
b*
b*
d***
d)
Diversity (S.E.)
b*
b**
d***
Distance from hedgerow

weeks after the barriers were erected, although differences in species richness, dominance and diversity were detected after only one week. Highest diversity was found in the unbarriered areas on 24 March and 5 April (Fig. 3d), whilst dominance was accordingly highest near the barriers on these dates.

Distance from the hedgerow

B. hortensis and *Isotomurus* spp. were consistently abundant only in the edge of the field, which followed the same pattern of abundance encountered previously (Alvarez et al. 1997). The counts of *I. viridis*, *Isotomurus* spp. and *S. elegans* differed significantly with distance from the hedgerow before and a week after the barriers were erected. *I. viridis* was more numerous within the field whilst the other two species were more common near the hedgerow. *Isotomurus* spp. remained significantly more common near the hedgerow throughout the study. By the last sampling date most species' spatial distribution showed significant differences due to distance from the hedgerow (Table 1).

Generally the Arthropleona tended to become more numerous with distance into the field, but the difference in abundance with distance was not significant (Table 2; Fig. 3a). The opposite was true for Symphypleona, which tended to dominate the collembolan community in the edge of the field (Fig. 3b). A significant effect of distance from hedgerow on symphypleonid abundance was encountered on all the sampling dates except early April.

Differences over time

For all species, a significant ($P<0.01$) change in abundance between dates was found (repeated measures ANOVA with the factors time, barrier treatment, distance from hedgerow and block). This reflected increases in population numbers from early to late spring. Total counts for Collembola, Arthropleona and Symphypleona, and the Margaleff species richness, Shannon-Wiener diversity and Simpson's dominance indices also showed significant differences between dates ($P < 0.001$; repeated measures ANOVA as above) reflecting concurrent changes in abundance and species numbers over time.

◀

Fig. 3. Collembolan community patterns in a field adjacent to barriered (black circles) and unbarriered (white squares) lengths of a hedgerow on four sampling dates and at different distances into the field. a) Data for total Arthropleona, b) Data for total Symphypleona, c) Data for species richness (Margalef), d) Data for species diversity (Shannon-Wiener). Vertical axes give counts (mean individuals/sample, ± SE), horizontal axes distance (m). (*=P<0.05; **=P<0.01; ***=P<0.001)

Discussion

The species trapped in this experiment consisted largely of those known to be common in agroecosystems in Britain (e.g. Frampton 1989, 1994; Frampton et al. 1992; Alvarez et al. 1997). Certain species were found to be more common near the hedgerow, consistent with previous findings (Alvarez et al. 1997): *B. hortensis* and *I. palustris* were common only near the hedgerow; *S. elegans* and *S. viridis* were found throughout the sampling area in the field. However, we previously found that *I. viridis* was only common in the edges of fields, whilst in this study substantial populations were found within the field itself.

Species richness and diversity were higher in the areas adjoining open hedgerow than next to the barriered areas whilst dominance was highest in the barriered areas, suggesting that the barriers prevented the free movement of species from the hedgerow into the field. The changes in community composition occurred quickly as differences were detected within two weeks of the barrier erection. The influence of barriers upon the field community was transient as few significant differences were found on the last sampling date in May.

The higher populations of *I. viridis* and *S. elegans* in the unbarriered areas suggest that movement from the hedge was interrupted by the barriers. However, *I. viridis, S. elegans* and *S. viridis* all had population sources at 30 m into the field even at the start of the experiment. These could have been present from populations permanently resident within the field, or from recolonisation previous to barrier erection as the disturbance caused by sowing the crop had occurred a month before sampling began. Both *S. viridis* (Wallace 1968) and *S. elegans* (Alvarez et al. 1997) are known to survive certain disturbance events as diapausing eggs, although the use of this survival strategy in an arable field context requires further investigation. Overall, the higher abundance of Symphypleona in the unbarriered areas suggests that this group moved largely from the hedgerow into the field, and the barriers blocked this colonisation. *Lepidocyrtus* spp. were the only group to have consistently higher populations in the barriered areas, suggesting that recovery sources were present within the field and that the hedgerow was not an important source of field populations.

No effects of the barriers were found for *B. hortensis, I. notabilis* or the *Isotomurus* spp., which suggests that these species may be more mobile, or the barriers may simply not have provided an obstacle. Individuals could have climbed the barrier itself, or have dropped from the vegetation above the barrier level: the climbing of trees for potential dispersal has been described for several species (e.g. Bowden et al. 1976; Farrow & Greenslade 1992). In future studies the isolation of hedgerow sections could be improved by erecting higher barriers or completely covering the hedgerow vegetation.

The extent to which early spring recolonisation determines the successive population structure in the field would require a longer term investigation. In particular the differences in dispersal strategies used by different species for recolonisation, and the roles of predator and competitor exclusion in determining the collembolan community composition, should be investigated. Within-field recovery of Collembola has been previously reported and attributed to predator exclusion (Duffield & Aebischer 1994), although individual species were not studied.

Many studies have demonstrated that Collembola are sensitive to pesticide applications and previous studies on beetles have shown that the sources of population recruitment affect the ability of different species to recover from pesticide effects in the field (Burn 1992). Seasonal movements are well-known for various beneficial arthropods, and have been described as specific adaptations to cyclical disturbance patterns in arable landscapes (Wissinger 1997). Equivalent information on the seasonal distribution of different collembolan species would be useful for understanding the recovery patterns of epigeal field Collembola. This study has shown that hedgerows are important sources of population recovery for the Collembola of arable fields, but more information is required on species' phenologies and dispersal strategies in order to understand the dynamics of collembolan populations and communities following disturbance events in arable fields.

Acknowledgements

We thank Phil Gould for help in setting up the barriers and Ben Gibbons for allowing us to work on the Leckford Estate. This work was part of Tania Alvarez' Ph.D. studies funded by MAFF. We also thank those who gave constructive comments, including K. Hyder, Henrik and S. Thomas.

References

Alvarez, T., Frampton, G. K., Goulson, D. (1997) Population dynamics of epigeic Collembola in arable fields: the importance of hedgerow proximity and crop type. Pedobiologia 41, 110–114.

Bowden, J., Haines, I. H., Mercer, D. (1976) Climbing Collembola. Pedobiologia 16, 298–312.

Burel, F. (1996) Hedgerows and their role in agricultural landscapes. Critical Reviews in Plant Sciences 15, 169–190.

Burn, A. J. (1992) Interactions between cereal pests and their predators and parasites. In: Greig-Smith, P. W., Frampton, G. K., Hardy, A. R. (eds) Pesticides, cereal farming and the environment. HMSO, London pp. 110–131.

Carapelli, A., Fanciulli, P. P., Frati, F., Dallai, R. (1995) The use of genetic markers for the diagnosis of sibling species in the genus *Isotomurus* (Insecta, Collembola). Bollettino di Zoologia 1, 71–76.

Carapelli, A., Frati, F., Fanciulli, P. P., Dallai, R. (1997) Estimating levels of gene flow between natural populations in the genus *Isotomurus* (Collembola, Isotomidae). Pedobiologia 41, 19–25.

Carr, M. R. (1997) PRIMER user manual. Plymouth Marine Laboratory, Plymouth, UK.

Christiansen, K., Bellinger, P. (1998) The Collembola of North America North of the Rio Grande. 2nd ed. Grinell College, Iowa.

Dennis, P. (1991) The temporal and spatial distribution of arthropod predators of the aphids *Rhopalosiphum padi* W. and *Sitobion avenae* F. in cereals next to field margins. Norwegian Journal of Agricultural Science 5, 79–88.

Dennis, P., Fry, G. L. A. (1992) Field margins: can they enhance natural enemy population densities and general arthropod diversity on farmland? Agriculture, Ecosystems and Environment 40, 95–115.

Edwards, C. A., Thompson, A. R. (1973) Pesticides and the soil fauna. Residue Reviews 45, 1–79.

Farrow, R. A., Greenslade, P. (1992) A vertical migration of Collembola. The Entomologist 111, 38–45.

Filser, J., Fromm, H., Nagel, R. F., Winter, K. (1995) Effects of previous intensive agricultural management on microorganisms and the biodiversity of soil fauna. Plant and Soil 170, 123–129.

Frampton, G. K. (1989) Effects of some commonly-used foliar fungicides on springtails (Collembola) in winter cereals. PhD Thesis, University of Southampton.

Frampton, G. K. (1994) Sampling to detect effects of pesticides on epigeal Collembola (springtails). Aspects of Applied Biology 37, 121–130.

Frampton, G. K. (1997) Species spectrum, severity and persistence of pesticide side-effects on U.K. arable springtail populations. ANPP – IVth International Conference on Pests in Agriculture – Montpellier 6–8 January 1997, 129–136.

Frampton, G. K., Langton, S. D., Greig-Smith, P. W., Hardy, A. R. (1992) Changes in the soil fauna at Boxworth. In: Greig-Smith, P. W., Frampton, G. K., Hardy, A. R. (eds) Pesticides, cereal farming and the environment – the Boxworth Project. HMSO, London. pp. 132–143.

Frati, F., Carapelli, A., Fanciulli, P. P., Dallai, R. (1995) The genus *Isotomurus*: where molecular markers help to evaluate the importance of morphological characters for the diagnosis of species. Bulletin Entomologique de Pologne 64, 41–51.

Gravesen, E., Toft, S. (1987) Grass fields as reservoirs for polyphagous predators (Arthropoda) of aphids (Homopt., Aphididae). Journal of Applied Entomology 104, 461–473.

Hansen, B., Holmstrup, M., Nielsen, A., Ostergaard, I. (1989) Soil macrofauna of arable land and surrounding hedges. Flora Fauna 95, 27–31.

Heisler, C. (1994) Effects of soil compaction on soil mesofauna (Collembola and Gamasina)-a 3-year field study. Pedobiologia 38, 566–576.

Hopkin, S. P. (1997) Biology of the Springtails (Insecta: Collembola). Oxford University Press, Oxford.

Magurran, A. E. (1988) Ecological diversity and its measurement. Chapman and Hall, London.

Mebes, K. H., Filser, J. (1997) A method for estimating the significance of surface dispersal for population fluctuations of Collembola in arable land. Pedobiologia 41, 115–122.

Pollard, E. (1968) Hedges II. The effect of removal of the bottom flora of a hawthorn hedgerow on the fauna of the hawthorn. Journal of Applied Ecology 5, 109–123.

Pollard, E. (1968) Hedges III. The effect of removal of the bottom flora of a hawthorn hedgerow on the Carabidae of the hedge bottom. Journal of Applied Ecology 5, 125–139.

Reddersen, J. (1997) The arthropod fauna of organic versus conventional cereal fields in Denmark. Biological Agriculture & Horticulture 15, 61–71.

Sokal, R. R., Rohlf, F. J. (1995) Biometry. The principles and practice of statistics in biological research. W.H. Freeman and Co., New York.

Sotherton, N. W. (1984) The distribution and abundance of predatory arthropods overwintering on farmland. Annals of Applied Biology 105, 423–429.

Sotherton, N. W. (1985) The distribution and abundance of predatory Coleoptera overwintering in field boundaries. Annals of Applied Biology 106, 17–21.

Stewart, A. J. A., Wright, A. F. (1995) A new inexpensive suction apparatus for sampling arthropods in grassland. Ecological Entomology 20, 98–102.

Wallace, M. M. H. (1968) The ecology of *Sminthurus viridis* (Collembola). II. Diapause in the aestivating egg. Australian Journal of Zoology 16, 871–883.

Wissinger, S. A. (1997) Cyclic colonization in predictably ephemeral habitats: a template for biological control in annual crop systems. Biological Control 10, 4–15.