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The contribution of beetle banks to farmland biodiversity

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Summary

The intensification of arable production in recent decades has led to a simplification of the farm landscape, with a resultant loss of many invertebrates, birds and mammals. The provision of herbaceous strips alongside field edges is one way of re-instating non-cropped habitat for many of these organisms. A different design, that of raised grassy strips within field centres, "beetle banks", was devised principally for enhancing predatory invertebrate penetration into fields, and may also support a range of other taxa. This paper outlines experimental work carried out to quantify densities of such predators overwintering in beetle banks, as well as the summer abundance of invertebrates important in the diet of farmland birds. Some of these, Orthoptera and Lepidoptera, rely entirely on non-cropped fragments for continuing survival on farmland. Results suggest that beetle banks, although generally not as valuable as well-managed and long-established, botanically rich field margins such as hedgerows, can contribute a useful habitat resource that is far quicker and easier to instate than a hedgerow.

Key words: Overwintering refuge, farmland diversity, beneficial arthropods, chickfood, grasshopper, butterfly

Introduction

There has been a disturbing decline in farmland biodiversity in the UK over the last few decades, as a consequence of the policy to improve productivity through an intensification of farming. This was achieved by the development of much greater field and farm sizes, plant breeding and pesticides. A more simplified landscape has evolved, in which hedgerows, trees & woodland have been removed, ditches and ponds filled in, and natural grasslands have been 'improved'. Increases in the use of insecticides, fungicides, molluscicides, herbicides and fertilisers, have resulted in both direct and indirect mortalities of 'non-target' organisms, and food or habitat losses (Hill *et al.*, 1995).

It is now realised that remedial action is needed, before such damage becomes irreversible. Farmland diversity depends on high landscape heterogeneity. A return to smaller field sizes; use of rotations and planting of a greater assortment of crops; increased under-sowing; inter-cropping; a reduction and/or more precise targeting of agrochemical inputs, and an expansion in the area of protected non-cropped habitats, are now considered vital for the long-term recovery of farmland biodiversity (McLaughlin & Mineau, 1995). The margins of fields have been shown to be particularly important for providing overwintering shelter, food and reproductive sites for many species (Morris & Webb, 1987; Dennis & Fry, 1992). Providing herbaceous strips along edges or in the centre of fields has been found to be particularly beneficial for invertebrates, game, birds and mammal species (reviewed in Marshall & Moonen, 1998).

Consisting of raised banks on which tussocky grasses are sown, beetle banks were devised to re-instate dense, perennial hedgerow-bottom-type vegetation to where edge to field area ratios have become unacceptably low. They were initially set up to provide temperature-buffered habitat for invertebrates that over-winter in field boundaries, and disperse into fields in spring and consume crop pests. Hence they are best located across the centres of large arable fields (Sotherton, 1995). Farmers may be reluctant to create expensive, permanent hedgerows that need substantial management, but may consider establishing such simple grass banks which can potentially be removed or relocated should farming plans change. Many farmers are establishing beetle banks across the UK for game as well as predator habitat (Thomas, 2000), and their use is now encouraged by MAFF, the Game Conservancy Trust and regional Farming and Wildlife Advisory Groups.

The 'ARABLES' research project was set up to evaluate the contribution that beetle banks may make to farmland biodiversity. This was achieved by comparing the abundance of various important invertebrate groups within these simple planted grass strips to permanently established field margins that usually have a more complex floral composition and structure. This paper summarises some of the key invertebrate findings from the study.

Materials and Methods

Beetle banks were assessed for overwintering beneficial predatory invertebrates. In both winters of 1997-8 and 1998-9, 15 destructive 0.2 x 0.2 x 0.2m turf samples were removed at random from each of five beetle banks of variable aspect and condition, each being paired with five neighbouring typical, permanently established field margins. Beetle banks were aged 1-2, 5-6, 6-7, 7-8 and 13-14 years old when sampled. Invertebrates within these samples were identified to species. The density per m^{-2} and Shannon-Wiener Diversity Index was calculated. Two-way ANOVAs were performed with year of sampling and habitat type as fixed factors, on both pooled log (x + 1) catch and mean H' diversity of Carabidae, Staphylinidae and Araneae families, which were the predominant taxa. Means were separated using SNK multiple range tests. Relationships between densities and diversities of predators and age of beetle bank were evaluated using linear regression.

In the summer of 1999, 22 beetle banks of different ages, again paired with 22 adjacent field margins, from five farm estates were sampled to evaluate the abundance of invertebrates fed on by game bird chicks. Fifteen sweep-net samples, each of 15 sweeps, were taken within the dense vegetation of each site, sampling close to the ground. The invertebrates were identified to major taxonomic groups known to be important dietary components. To compare between habitats, t-tests were carried out on log (x + 1) transformed data for each taxa.

The above sweep-net samples were also assessed for the presence of Orthoptera. Species richness was compared between beetle banks and field margins by t-test, using means of each site. The number of sites occupied by different species was also examined.

Standard 200m line transect walks (Pollard, 1977) were carried out alongside beetle banks and hedgebanks in June, July and August 1999, recording species richness and relative abundance of Lepidoptera flying along or within the habitat. A total of 82 transects were walked alongside both beetle banks and hedgebanks. Two-way ANOVAs were performed with month and habitat type (beetle bank or hedge) as fixed factors, on log (x + 1) transformed numbers of individuals and of species, and for each of the main families recorded.

Results

Beneficial predatory invertebrates

Overwintering beneficial predator densities ranged from 200 to 700 per m^{-2} (Fig. 1). There was no significant difference in the mean density of Carabidae in beetle banks and field margins, in either sampling year. Staphylinidae density was significantly lower in beetle banks compared to field margins in both years ($F_{1, 296} = 32.9$, $P < 0.001$), and there was a significant interaction between year and habitat ($F_{1, 296} = 6.27$, $P = 0.013$). The year*habitat interaction was also significant for Araneae ($F_{1, 296} = 4.5$, $P = 0.035$), attributable to slightly lower densities in beetle banks in the first sampling year following *a posteriori* tests.

The Shannon-Wiener index gave low diversity values for the predatory groups in both habitats and years (Fig. 2). There was no significant difference in Carabidae diversity between habitats and sampling years. Diversity of Staphylinidae was significantly lower in beetle banks ($F_{1, 296} = 21.7$, $P < 0.001$), although this did not vary between years. Conversely, Araneae diversity was significantly lower in field margins ($F_{1, 296} = 8.02$, $P < 0.01$), and again did not vary between years.

A weak positive relationship between Carabidae density and age of bank was shown ($r^2 = 0.38$, $F_{1, 8} = 4.97$, $P = 0.06$), although not with Staphylinidae nor Araneae. Predator diversities did not indicate any relationships with age of beetle bank.

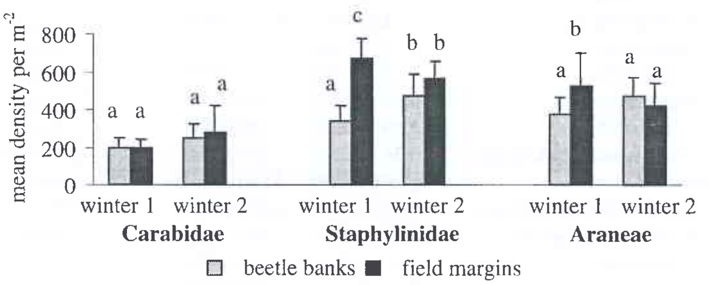

Fig. 1. Mean densities per m^{-2} (+ SE) of predators found overwintering in beetle banks and field margins. Within taxa, columns headed with the same letter are not significantly different between habitats (SNK, $P < 0.05$).

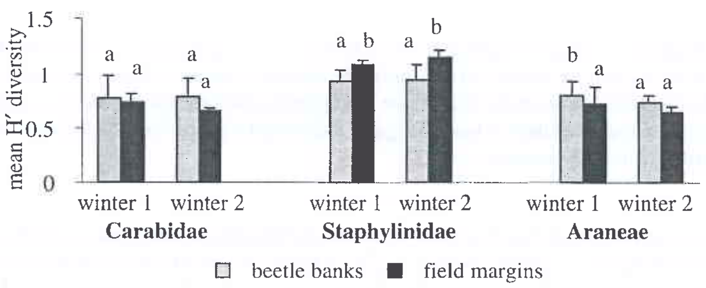

Fig. 2. Mean H′ diversities (+ SE) of predators found overwintering in beetle banks and field margins. Within taxa, columns headed with the same letter are not significantly different between habitats (SNK, $P < 0.05$).

Invertebrates fed on by farmland bird and of conservation interest

Summer sweep-net sampling found that although the overall catch of chickfood invertebrates was significantly less than in other field margins, beetle banks contained a similar abundance of key prey groups (Table 1). In particular, there was no significant difference in total beetle or true bug catch, the two groups that numerically dominated the total catch.

Table1. *Chickfood invertebrate catch in summer sweep-net samples, mean (±SE) of 225 sweeps*
(indicates* P < *0.05, *** P < *0.01, ****P < *0.001)*

	Beetle banks	Field margins	$t_{d.f.}$
Carabidae	0.10 (0.03)	0.18 (0.06)	2.03_{35}
Staphylinidae	0.09 (0.03)	0.16 (0.04)	2.03_{36}
Chrysomelidae	1.97 (1.33)	1.55 (0.62)	2.02_{42}
Curcurlionidae	1.85 (1.10)	1.14 (0.51)	2.03_{35}
Cantharidae	0.43 (0.19)	1.00 (0.23)	2.02_{42} *
Elateridae	0.25 (0.07)	0.23 (0.06)	2.02_{42}
Coccinellidae	0.27 (0.07)	0.26 (0.10)	2.02_{42}
Nitidulidae	2.96 (1.53)	5.46 (1.89)	2.02_{42}
TOTAL BEETLES	**7.91 (2.61)**	**9.97 (2.13)**	2.02_{42}
Heteroptera	11.78 (2.00)	16.81 (1.89)	2.03_{37} *
Homoptera	13.59 (3.51)	11.62 (4.90)	2.02_{42}
Delphacidae	0.64 (0.21)	1.12 (0.21)	2.02_{42}
Cicadellidae	1.59 (0.27)	2.29 (0.57)	2.02_{42}
other Auchenorrhyncha	0.36 (0.10)	1.19 (0.20)	2.03_{36} ***
TOTAL BUGS	**27.96 (4.50)**	**33.02 (5.64)**	2.02_{42}
Tenthredinidae (larvae)	0.53 (0.11)	0.49 (0.18)	2.02_{42}
Lepidoptera (larvae)	0.37 (0.18)	0.51 (0.18)	2.02_{42}
Linyphiidae	0.31 (0.13)	0.58 (0.17)	2.02_{42}
other Araneae	0.66 (0.13)	2.46 (0.45)	2.03_{35} ***
Opiliones	0.06 (0.03)	0.07 (0.02)	2.02_{42}
Diptera (small spp.)	8.67 (1.17)	16.63 (2.07)	2.02_{42} **
Formicidae	0.08 (0.04)	0.87 (0.33)	2.06_{24} *
Dermaptera	0.10 (0.04)	0.10 (0.07)	2.03_{37}
TOTAL CATCH	**46.65 (4.96)**	**64.70 (7.18)**	2.02_{42} *

The Auchenorrhyncha, small Diptera and other Araneae were significantly more abundant in margins, but whilst eaten by chicks, offer limited nutritional reward and are less likely to be encountered being hidden in the plant architecture. Symphytan and lepidopteran larvae, considered highly nutritious and preferred dietary items for game and other farmland bird chicks, were present only in low numbers in both habitats.

Orthoptera

Summer sweep-netting found that there was no significant difference in the number of orthopteran species found between the two habitat types (t = 2.02, d.f. = 42, P = 0.29). Although some species of bushcricket were more likely to be found in the more species-rich field margins, grasshopper species and the bushcricket *C. discolor* were more often encountered in the mid-field, less botanically diverse beetle banks (Table 2). A trend for greater numbers of orthoptera in older sites was shown ($r^2 = 0.22$, $F_{1,21} = 5.72$, $P = 0.03$).

Table 2. *Orthoptera captured in summer sweep-net samples*

	Beetle banks	Field margins
Mean number of species found in habitat (± SE)	1.41 (± 0.26)	1.77 (± 0.22)
% sites where spp. found:		
Pholidoptera griseoaptera (Dark bushcricket)	27	64
Leptophyes punctatissima (Speckled bushcricket)	9	77
Conocephalus discolor (Long-winged conehead)	32	9
Chorthippus parallelus (Meadow grasshopper)	55	9
Omocestus viridis (Common green grasshopper)	9	5
Chorthippus brunneus (Field grasshopper)	18	9

Lepidoptera

Although there was a significant difference in the number of lepidopteran individuals recorded in transects by month and by habitat, the interaction between factors was not significant (Table 3). More butterflies were seen alongside hedgebanks than beetle banks, and in both habitats, greater numbers were present later in the season (Fig. 3). Species richness followed similar trends, with a significant difference between months and between habitats (Table 3), with more species recorded along hedgebanks; however, the month*habitat interaction was significant.

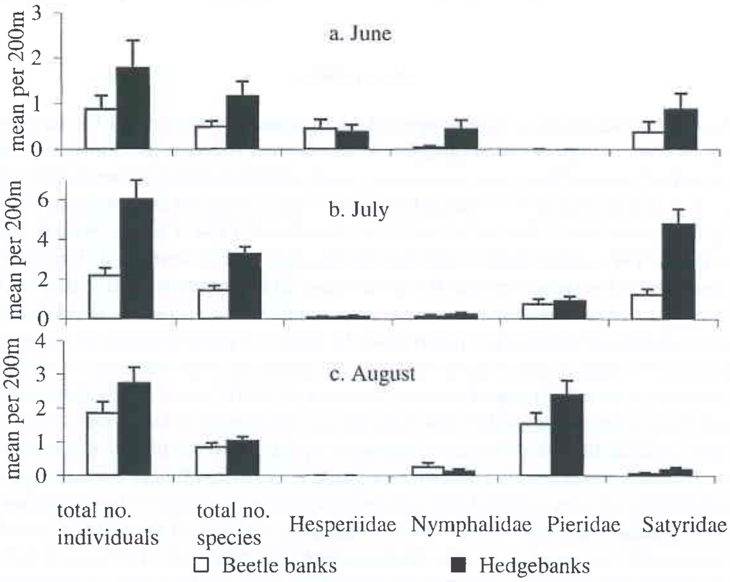

Fig. 3. Lepidoptera recorded by standard transect walks along linear field habitats.

With the exception of two *Polyommatis icaris* (Lycaenidae) seen in hedges, only four families were recorded. Small skippers (*Thymelicus sylvestris*) and Large skippers (*Ochlodes venata*) were recorded on beetle banks, with additionally Essex Skippers (*T. lineola*) on hedgebanks (Hesperiidae). Small tortoiseshells (*Aglais urticae*), Red admirals (*Vanessa atalanta*) and Painted ladies (*V. cardui*) were recorded on banks, with also Peacocks (*Inachis io*) and Commas (*Polygonia c-album*) on hedgerows (Nymphalidae). Small (*Pieris rapae*), Large (*P. brassicae*) and Green-veined whites (*P. napi*) were recorded on beetle banks, with Brimstones (*Gonepteryx rhamni*) also on hedges (Pieridae). Meadow browns (*Maniola jurticea*), Marbled whites (*Melanargia galathea*), Ringlets (*Aphantopus hyperantus*) and Gatekeepers (*Pyronia tithonus*) were recorded on beetle banks, with Speckled woods (*Parage aegeria*) and Small heaths (*Coenonympha pamphilus*) additionally on hedges (Satyridae). Seasonal variation was evident in the occurrence of these families (Fig. 3). The Hesperiidae declined in abundance from June to August, whereas Pieridae exhibited the opposite trend. The Satyridae were most abundant in the July sampling period, but the Nymphalidae were present at similar levels throughout sampling, and were the only family not to show a strong significant difference by month (Table 3). The overall difference between habitats could be attributed mostly to the Satyridae, with a month*habitat interaction also resulting in this family.

Table 3. *Summary of ANOVA results for 200m standard butterfly transect walks (* indicates* $P < 0.05$, ** $P < 0.01$, ***$P < 0.001$)

Factor	**Month**	**Habitat**	**Interaction**
Total no. individuals	$F_{1, 143} = 15.63$ ***	$F_{1, 143} = 13.85$ ***	$F_{1, 143} = 2.79$
No. species	$F_{1, 143} = 23.04$ ***	$F_{1, 143} = 18.82$ ***	$F_{1, 143} = 3.42$ *
Hesperiidae	$F_{1, 143} = 11.15$ ***	$F_{1, 143} = 0.05$	$F_{1, 143} = 0.04$
Nymphalidae	$F_{1, 143} = 1.04$	$F_{1, 143} = 4.81$ *	$F_{1, 143} = 3.00$
Pieridae	$F_{1, 143} = 36.14$ ***	$F_{1, 143} = 2.28$	$F_{1, 143} = 0.58$
Satyridae	$F_{1, 143} = 53.97$ ***	$F_{1, 143} = 28.27$ ***	$F_{1, 143} = 9.13$ ***

Discussion

Beetle banks were designed to provide optimal microclimatic conditions for the survival of high densities of overwintering beneficial predatory invertebrates; although previously only relatively newly established sites had been examined. Densities of predators found in the present study were equivalent to or higher than those obtained by similar work carried out in previous years (Thomas, Wratten & Sotherton, 1992; Dennis & Fry, 1992; MacLeod, 1994; Collins, Wilcox, Chaney & Boatman, 1996). The current study found that for most taxa there were no differences in either predator densities or diversities between the beetle banks and conventional field margins. The field margins selected for assessment contained dense and well-established vegetational cover, representing exceptional field margin quality. Had the study compared predator densities with other field edge habitats, such as where farm tracks immediately adjoined the crop, or had evaluated predator densities on poorly managed margins, the value of beetle banks may well have been more pronounced. Low diversity may reflect that many species overwinter as larvae rather than as adults, but may also indicate that only a limited number of species were available for potential spring biocontrol. Thus it is important that overwintering conditions are sufficient to encourage survival.

The small number of sites sampled for overwintering invertebrates doubtless restricted distinct indications of predator densities and diversities changing with age of beetle bank. Beetle banks appear to be rapidly colonised soon after establishment (Thomas *et al.*, 1992), with the predator populations found overwintering within them depending more on the cropping and management history of the surrounding area than subtle successional differences in vegetational structure resulting from age. The other studies mentioned involved the sampling of a single site for a few years following establishment, with again only patchy evidence for increasing numbers of predators as they aged. This study has shown, however, that older banks may continue to be good quality sites, and thus should not be removed on grounds of age alone. Only if dense cover has become degraded should re-seeding or replacement be considered.

In summary, beetle banks clearly add to the amount of overwintering refuge available to predators of crop pests, especially where other field margins are lacking or have poorly managed bottom flora because of close ploughing, herbicide drift or misplacement of fertiliser.

Many farmland birds, especially game species, have suffered huge population declines, attributed to the loss of invertebrate food available for young chicks (Potts, 1997). Beetle banks may increase the availability of such resources in cereal fields, by adding to that provided by well-managed field margins. Penetrability may be limited where the grass is too tall and dense, with chick survival jeopardised if they become too frequently wetted in such vegetation (Aebischer, Blake & Boatman, 1994), but sterile strips either side of beetle banks can enhance accessibility and provide open pathways in which chicks can dry. Game birds with chicks were observed within beetle banks during the course of experimental work, and many banks had such strips on each side. Unlike similar work by Barker & Reynolds (1999), chickfood catch did not show any relationship with the age of the beetle banks from which samples were taken. However, in this study a smaller number of farms was examined within a reduced geographic area, and only mid-field beetle banks were sampled. In contrast, Barker & Reynolds pooled a variety of differently sized grass strips, planted with a range of seed mixtures, leading to differences in suitability for invertebrates.

Once abundant on arable land, the Orthoptera have almost entirely disappeared from cereal fields, with excessive insecticide use accountable for the decline. On intensively managed land, marginal habitats are suggested as increasingly important sources of grasshoppers, and other invertebrates, considered especially important in the diet of birds (Wilson *et al.*, 1999). Whether viewed as food for birds or deserving conservation in their own right, the provision of beetle banks clearly has value for orthopteran survival. Mid-field grass strips may be favourable areas for grasshoppers because the high grass in summer can provide adequate shelter for nymphs and adults, whereas field margin vegetation, though better for egg hatching, may be too low and open. The protection of exposed beetle banks from accidental agrochemical drift would appear essential to protect such Orthoptera.

Arable farmland is accepted as having an impoverished Lepidoptera fauna, but butterflies can be considered as indicators of farmland biodiversity (Dover, 1999). Aside from hedgerows and reduced-spray headlands, many parts of the farm have received limited attention as potential resources for Lepidoptera. Many species are reported as being reliant on a landscape mosaic, with corridors and links between habitat patches (Sparks & Parish, 1995), thus even simple linear features may be of some importance in limiting isolation. In this simple study, we found only low species richness even in hedgebanks, although the species seen corresponded with those from other reports (e.g. Sparks & Parish, 1995; Dover, 1999). Differences between beetle banks and hedgebanks undoubtedly related to abiotic factors such as shelter, sward structure, shading, and the abundance of key nectar-producing flowers, a major determinant of adult abundance (Feber, Smith & Macdonald, 1996). Beetle banks are also usually sown initially with only one or two grass species. Because plant species richness increases with beetle bank age (Thomas, Goulson & Holland, 2000), they may increase in value for butterflies. Where selectively sprayed headlands are managed alongside beetle banks, as well as other field margins, there will be enhanced benefit to butterflies. Overall, beetle banks may contribute value as dispersal corridors in the farm landscape, even if they have a lesser role in providing breeding habitat because of their unsheltered location.

Although initially simple grassy strips, these investigations have shown that beetle banks can support a faunal diversity that approaches levels found in good quality established field margins. In terms of both densities of beneficial arthropods and overall farmland diversity, farmers will benefit by leaving beetle banks undisturbed and protected from agro-chemical damage and close-ploughing, and establishing more of them in large arable fields. For example, organisms such as butterflies are highly vulnerable to the impact of spray drift, if present in such exposed mid-field features; thus beetle banks deserve as much care and protection as other margins. Beetle banks add to the mosaic of uncropped habitat on arable farmland, and so may assist in supporting or even increasing the abundance and diversity of beneficial invertebrates and other organisms, and facilitate their dispersal to more favourable habitats.

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