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Resource provision for farmland gamebirds: the value of beetle banks

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Summary

Severe declines have occurred in the populations of wild game birds in Britain. This has been attributed to agricultural intensification, leading to the loss of invertebrates vital within chick diets, fewer feeding resources for adults, and inadequate provision of nesting and brood-rearing habitat. This paper explores the potential value of simple sown grass strips – beetle banks – in providing these resources, and compares results with functionally similar conventional field margins. The data indicate that beetle banks can contribute useful, albeit lower, densities of chick-food than conventional margins. These resources are more abundant later in the season, which may have implications for early hatched chicks. Beetle banks provide considerable quantities of nesting cover for adults, although sheltering conditions may never be as satisfactory as in well managed hedgerows. Given the ease and low cost of establishment of beetle banks, we suggest that they may be valuable components within a range of game management techniques on the farm, as a 'spin-off' to their primary role as overwintering habitat for polyphagous predators. They may be important particularly where resources for game birds are impoverished, but clearly cannot substitute for suitably managed field margins.

Key words: Field margin, chick-food invertebrates, nesting cover, biodiversity, agroecosystems, arable

Introduction

Game birds

Grey partridge (*Perdix perdix*) populations have declined drastically over the last few decades. In the 1950s, average densities of around 25 pairs per km^{-2} could be found, whereas fewer than five pairs per km^{-2} were recorded by the mid 1980s (Potts, 1986). Consequently, this species was entered into the UK Red Data Book (Batten *et al.*, 1990). Only large-scale reared bird releases are responsible for maintaining stable populations of red-legged partridge (*Alectoris rufa*), but their wild populations are also in jeopardy (Hill & Robertson, 1988). More recent work, in particular by the British Trust for Ornithology, has revealed further decreases (e.g. Chamberlain & Fuller, 2000; Gregory *et al.*, 2000). Such population declines parallel what is also happening to many other, often less thoroughly studied, birds associated with farmland. In all cases, the reason has been clearly related to loss of biodiversity, attributed to the intensification of farming practices in recent decades (Potts, 1997; Wilson *et al.*, 1999). Increased herbicide usage, the summer use of foliar insecticides, and a loss of under-sowing, have all been implicated in causing increased game chick mortality, by decreasing the available invertebrate food (Rands, 1986, 1988). Grey partridge and pheasant (*Phasianus colchicus*) chicks depend upon a high number of invertebrates in their diet in the first few weeks of life, to provide sufficient protein for survival (Hill, 1985; Green, 1984; Potts, 1986; Wilson *et al.*, 1999). For other species such as the red-legged partridge (*Alectoris rufa*), insects are also important, though to a lesser extent (Green, 1984; Rands, 1988). The presence of weeds in and around crops as hosts for non-pest insects is thus important. Additionally, the amount of plant material eaten increases as chicks mature (Ford *et al.*, 1938), including grass and small dicotyledonous seeds, unripe cereal grains and leaves and flowers (Green, 1984). Adult game birds feed almost exclusively on plant material, with little difference in preference between species (Middleton & Chitty, 1937). Diet items consist of grain, leaves and roots of grasses and dicotyledonous plants.

Later in the season, partridges pair for breeding and establish territories, so that the area of habitat accessible for nesting and brood rearing may constrain maximum population growth (Rands, 1986; Aebischer & Blake, 1994). Breeding success during the spring-summer has been shown to relate to the availability of nesting cover in this spring settling period, as well as the likelihood of nest predation (Potts, 1997). The structural characteristics of hedgerows are important in determining their

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suitability for nesting. Hedge-bottoms, with some elevation for good drainage, and with high proportions of dead grass, litter and other vegetation, have been found to be important, as birds require shelter and material to conceal nests from predators (Rands, 1986). Aebischer & Blake (1994) found that several varieties of field margins and non-crop areas were preferred nesting habitat. Nests were particularly associated with species such as cock'sfoot (*Dactylis glomerata*), nettles (*Urtica dioica*) and hedge-parsley (*Torilis japonica*), i.e. those with tall, more continuous canopy cover. Less preferred vegetation was more open, low and patchy. Beetle banks may also fulfil such habitat requirements. Grassy banks and hedgerows are not such preferred habitats for pheasants, which select field margins specifically adjacent to woodlands. However, these game birds do use this type of vegetation where grass is sufficiently tall and dense (Hill & Robertson, 1988). Vegetation is also important for chicks, as it must provide sufficient cover to conceal them from predators, yet permit movement of the chicks within it (Aebischer & Blake, 1994).

More non-crop habitat and sympathetic farming practice is needed for the successful survival of wild game species in the arable environment. The UK Ministry of Agriculture, Fisheries and Food (MAFF) is currently piloting an Arable Stewardship Scheme, encouraging farmers to manage their land for wildlife including game, by recommending and monitoring a variety of approaches, such as grass margins, wildlife seed mixtures for margin strips, overwintered stubbles, undersown spring cereals, conservation headlands and also beetle banks (Anon., 1999*a*). The benefits of many such techniques, particularly of the latter, are as yet inadequately quantified.

Beetle banks

Beetle banks are grass-sown ridges, designed to provide additional overwintering sites for beneficial predatory arthropods; and through their location across the centre of fields, reduce the distances these arthropods must disperse to achieve an early homogeneous distribution within arable fields (Thomas *et al.*, 1991). In the UK, the total length of hedgerows has severely decreased (Bannister & Watt, 1994), with many of those remaining either lacking bottom vegetation or overwhelmed by weed species that threaten the crop or are difficult to control, because of poor management (Pollard, 1968; Dunkley, 1997). Beetle banks compensate by providing herbaceous and perennial hedgebottom vegetation in a simple, inexpensive form (Sotherton, 1995). Crop pest predators, such as carabid and staphylinid beetles and spiders, shelter over winter in low vegetation and survive best in dense tussocky grass (Luff, 1965; Asteraki *et al.*, 1992, 1995; Thomas *et al*. 1991, 1992). Tussock-forming species such as cock'sfoot, and Yorkshire fog, *Holcus lanatus*, therefore, are recommended for sowing in beetle banks (Sotherton, 1995; Thomas *et al*., 1991). Previous studies on beetle banks have concentrated primarily on their functional value compared with other types of field boundaries for supporting high densities of overwintering beneficial predators, although none have monitored invertebrates within spring (Thomas *et al.*, 1991; MacLeod, 1994; Collins *et al.*, 1996). Other research to date has shown how beetle banks may provide nesting habitat for harvest mice (Bence *et al.*, 1999) and has indicated successional change in their vegetational composition (Thomas *et al.*, 2000). The Game Conservancy Trust and regional Farming and Wildlife Advisory Groups now propose that beetle banks may be useful for gamebirds, providing additional nesting and feeding sites, if they are retained as permanent landscape features and protected from pesticide and herbicide drift. Application of chemicals within them is restricted to the localised treatment of specific pernicious weeds. The Countryside Stewardship Scheme, along with the pilot Arable Stewardship Scheme, is currently alone in providing financial support for setting up beetle banks on arable farmland (Anon., 1999*a* and *b*).

Aims of study

This study was designed to quantify the resources offered by beetle banks for gamebird chicks and adults. Firstly, it aimed to measure the abundance of chick food invertebrates in beetle banks; and secondly, to quantify their vegetational value for both chicks and adult birds. The latter involved examining cover, used for nesting and brood-rearing, and plants of food value. Relationships between the invertebrates and plant cover could then be assessed. These attributes were compared with those provided in adjacent typical conventional field margins, which are also linear vegetation strips with similar functions in the agricultural landscape.

Materials and Methods

Chick food availability in spring/summer

Sampling took place in beetle banks on farm estates across Hampshire and Wiltshire, UK, all on slightly flinty, calcareous silty clay loam-based soils. Ranging from 200 m - 900 m long and 2.5 m - 5 m wide, the banks had been established between less than 1 and 14 yr previously by autumn-ploughing earth ridges. They were hand-sown with predominately *Dactylis glomerata* and various other grass species. Natural regeneration has taken place within them, although there has been little active management. In all cases, adjacent established grassy hedgerow bottoms or grassy non-shrubby margins were sampled simultaneously to allow comparison with the beetle banks.

In 1998, four beetle banks/margins were sampled in May and five in August, to assess chickfood provision through the main chick-hatching period, on a single Hampshire estate. Fifteen 20 cm × 20 cm areas along each beetle bank or field margin site were randomly selected. Invertebrates on the vegetation and soil surface were removed by a Ryobi RSV3100 vacuum suction-sampler (Stewart & Wright, 1995). Samples were frozen prior to hand sorting to remove invertebrates, which were stored in 70% alcohol before identification. All invertebrate taxa on which game chicks most commonly feed were identified predominantly to family (following Ford *et al.*, 1938; Green, 1984; Moreby & Southway, 1999; Moreby *et al.*, 1999). Mean total numbers of these chickfood invertebrates were compared between beetle banks and field margins, for the two sampling periods, using repeated measures ANOVA, following log (x+1) transformation to increase homogeneity of variance.

In 1999, 22 beetle banks/margins from five estates were assessed, to extend the data set and include farm variation as a factor. Sweep-netting was carried out over June and July to facilitate rapid insect collection from a large number of sites during peak chick hatch. A 50 cm diameter net was swept immediately above the ground within the vegetation, taking approximately 1 s to collect from an area of around 50 cm^2 each sweep. Fifteen sweeps were pooled to form a sample, with 15 samples being taken randomly along each site. Samples were again stored frozen and hand-sorted to remove all invertebrates, which were identified as previously. The relative abundance of invertebrate prey available for chicks to feed on was compared between beetle banks and field margins, and between different farms, by two-way ANOVA following log (x+1) transformation of the data. Site means were again used to avoid pseudoreplication. Additionally, Shannon-Wiener Diversity indices were calculated for each sample of chickfood invertebrates, and used to compare between habitats and farms, by two-way ANOVA. Being normally distributed when calculated from a number of samples, this index does not require data transformation (Magurran, 1988).

Vegetation cover and food plant provision in beetle banks

The vegetation within 20 randomly selected sampling points on nine beetle banks and nine field margins was assessed in July 1998, and in February/ March 1999. This was repeated for 22 beetle banks/ margins in late June/July 1999. Each species present and its percentage cover within a 0.71 m^2 quadrat placed on the ground was recorded. Overall plant cover, the amount of live/dead tussock, and cover of other grasses and dicotyledonous plants, were compared between habitats by two-tailed *t*-tests. Mean values from each site were used, following logit transformation.

Results

Spring and summer chick food availability

In 1998, chickfood invertebrate densities were not significantly different between field margins and beetle banks ($F_{1, 6}$ = 0.02, P = 0.89). There was a significantly higher prey density per m^2 in August compared to May ($F_{1, 6}$ = 7.03, P = 0.04), caused by increased in most taxa, although the interaction between habitat and date was non-significant ($F_{1, 6}$ = 0.00, P = 0.99). In May, mean chickfood densities were 657.50 per m^2 for beetle banks and 564.17 per m^2 for field margins (SED = 232.7). In August, densities were 1547.31 and 1434.23 for banks and margins, respectively (SED = 450.2). Prey densities showed high variability between the fields sampled, on both of the sampling occasions.

Small flies were very frequently caught, and as might be expected, were predominant in the summer catch (Table 1). Small species of staphylinid beetles, bugs and linyphiid spiders were also very abundant. Hymenopteran larvae, regarded as important chick food components (Moreby & Aebischer, 1992) were infrequently caught, and were most numerous in field margins in May. Beetle banks contained more carabid beetle and heteropteran bugs in both seasons, and more coccinellid beetles in spring, when compared with the field margins. Only ants and lepidopteran larvae were consistently more abundant in field margins.

In 1999, sweep capture of mean total chick-food invertebrates was significantly higher in permanent field margins compared with beetle banks ($F_{1, 34}$ = 7.20, P = 0.01). A mean of 46.65 chickfood invertebrates was caught per 15 samples taken in beetle banks, with a mean for field margins of 64.70 (SED = 8.73). Catch did not differ between the farms sampled ($F_{4, 34}$ = 2.30, P = 0.08), and there was no significant interaction between habitat and farm ($F_{4, 634}$ = 0.59, P = 0.67). As in the first sampling year, there was considerable variability between sampling sites.

Small species of diptera, heteropterans and aphids were most numerous in the sweepnet catch (Table 2). Beetles were frequently caught, and did not differ in abundance between habitat type. Field margins contained significantly greater numbers of cantharid beetles, heteropterans, other auchenorrhynchan bugs, flies and some spider families. There was no difference in the abundance of infrequently caught sawfly or lepidopteran larvae between the two

Table 1. Mean chickfood invertebrate densities per m^2 in margin habitats sampled by Ryobi suction sampling in May and August 1998. Results of t*-test on log$_{10}$ (x + 1) transformed data. (*P < 0.05, **P < 0.01, ***P < 0.001)*

	May mean	(SE)	Aug mean	(SE)	
Carabidae	18.75	(7.01)	29.04	(6.28)	$t_{16} = 2.12$ n.s.
Staphylinidae	81.46	(25.39)	157.69	(37.14)	$t_{16} = 2.12$ n.s.
Chrysomelidae	9.58	(3.28)	25.58	(8.34)	$t_{16} = 2.12$ n.s.
Curcurlionidae	3.75	(1.50)	14.62	(8.47)	$t_{16} = 2.12$ n.s.
Elateridae	2.11	(0.69)	0		$t_{16} = 2.12$ **
Coccinellidae	26.67	(17.80)	3.08	(1.19)	$t_{9} = 2.26$ n.s.
Nitidulidae	0.42	(0.27)	0		$t_{16} = 2.12$ n.s.
Heteroptera	35.83	(17.45)	44.62	(21.93)	$t_{16} = 2.12$ n.s.
Homoptera - Aphidae	15.94	(5.78)	15.38	(8.85)	$t_{16} = 2.12$ n.s.
Delphacidae	84.08	(41.70)	119.04	(22.02)	$t_{9} = 2.26$ n.s.
Cicadellidae	10.20	(3.12)	58.85	(13.35)	$t_{16} = 2.12$ n.s.
Other Auchenorrhyncha	0		1.15	(0.82)	$t_{16} = 2.12$ ***
Small diptera	84.79	(12.07)	670.19	(150.44)	$t_{16} = 2.12$ ***
Hymenopteran larvae	9.38	(7.84)	2.50	(0.81)	$t_{10} = 2.23$ n.s.
Formicidae	34.38	(13.63)	40.19	(10.04)	$t_{16} = 2.12$ n.s.
Lepidopteran larvae	0.49	(0.33)	3.46	(1.18)	$t_{16} = 2.12$ *
Dermaptera	10.01	(7.01)	0.19	(0.19)	$t_{8} = 2.31$ *
Linyphiidae	154.38	(26.09)	251.73	(48.03)	$t_{16} = 2.12$ n.s.
Other araneae	31.04	(8.42)	42.88	(5.81)	$t_{9} = 2.26$ n.s.
Opiliones	4.98	(3.29)	10.58	(2.32)	$t_{16} = 2.12$ *

Table 2. Mean chickfood invertebrate catch, per 100 samples, in beetle banks (bb) and field margins (fm) sampled in June/July 1999, n = 22. Results of t*-test on log$_{10}$ (x + 1) transformed data. (*P < 0.05, **P < 0.01, ***P < 0.001)*

	bb mean (SE)		fm mean (SE)		
Carabidae	0.68	(0.22)	1.22	(0.42)	$t_{35} = 2.03$ n.s.
Staphylinidae	0.59	(0.17)	1.06	(0.30)	$t_{36} = 2.03$ n.s.
Chrysomelidae	13.16	(8.87)	10.36	(4.14)	$t_{42} = 2.02$ n.s.
Curcurlionidae	12.33	(7.36)	7.58	(3.37)	$t_{35} = 2.03$ n.s.
Cantharidae	2.84	(1.26)	6.66	(1.54)	$t_{42} = 2.02$ *
Elateridae	1.65	(0.47)	1.50	(0.41)	$t_{42} = 2.02$ n.s.
Coccinellidae	1.79	(0.47)	1.70	(0.70)	$t_{42} = 2.02$ n.s.
Nitidulidae	19.72	(10.21)	36.41	(12.59)	$t_{42} = 2.02$ n.s.
Heteroptera	78.51	(13.33)	112.05	(12.59)	$t_{37} = 2.03$ *
Homoptera - Aphidae	90.61	(23.41)	77.44	(32.69)	$t_{42} = 2.02$ n.s.
Delphacidae	4.29	(1.39)	7.48	(19.41)	$t_{42} = 2.02$ n.s.
Cicadellidae	10.62	(1.79)	15.24	(3.81)	$t_{42} = 2.02$ n.s.
Other Auchenorrhyncha	2.37	(0.68)	7.95	(1.34)	$t_{36} = 2.03$ ***
Small diptera	57.82	(7.82)	110.85	(13.78)	$t_{42} = 2.02$ *
Hymenopteran larvae	3.52	(0.75)	3.24	(1.21)	$t_{42} = 2.02$ n.s.
Formicidae	0.55	(0.28)	5.82	(2.23)	$t_{24} = 2.06$ *
Lepidopteran larvae	2.49	(1.20)	3.38	(1.21)	$t_{42} = 2.02$ n.s.
Dermaptera	0.65	(0.26)	0.67	(0.48)	$t_{37} = 2.03$ n.s.
Linyphiidae	2.05	(0.88)	3.90	(1.11)	$t_{42} = 2.02$ n.s.
Other araneae	4.37	(0.87)	16.39	(3.01)	$t_{35} = 2.03$ ***
Opiliones	0.38	(0.23)	0.45	(0.16)	$t_{42} = 2.02$ n.s.

habitats (Table 2).

The diversity (H′) of chickfood invertebrates was significantly higher in field margins ($F_{1, 34}$ = 5.20, *P* = 0.03), with a mean index of 1.51 compared with 1.40 in beetle banks (SED = 0.08). However, it did not differ significantly between farms ($F_{4, 34}$ = 0.56, *P* = 0.69), nor was there any significant interaction between these habitat and farm factors ($F_{4, 34}$ = 1.39, *P* = 0.29).

Summer plant provision in beetle banks

1998 sampling revealed that there was more cover in the field margin bases compared to beetle banks (t_{16} = 1.75, *P* = 0.003) (Fig. 1); however, cover provision was high in both kinds of habitat, with no less than 67% cover, and a maximum of 97%. There was no significant difference in the percentage of tussocky-structured grass present in beetle banks and field margin (t_{12} = 1.78, *P* = 0.14). Other grass and herbaceous plant cover, fed on by adult game birds, was not significantly different overall (t_{16} = 1.75, *P* = 0.10, grasses; t_{10} = 1.75, *P* = 0.07, dicots) (Fig. 1). Field margin bases contained small amounts of woody plants, the presence of which was negligible in beetle banks (Fig. 1). There was considerable variation in the abundance of these plant categories between individual fields.

In 1999, there was no significant difference between overall vegetational cover in field margins and beetle banks (t_{37} = 1.69, *P* = 0.10), and levels of both tussocky grass and other grass species were no different either (t_{42} = 1.68, *P* = 0.11, tussock; t_{34} = 1.69, *P* = 0.69, grass). As expected, field margins contained significantly more dicotyledonous and woody plants than beetle banks (t_{26} = 1.71, *P* < 0.001, dicots; t_{42} = 1.68, *P* < 0.001, woody plants; Fig. 2). In the majority of vegetation categories, there was considerable variation between farms.

Winter plant provision in beetle banks

There was no significant difference in total vegetation cover between beetle banks and field margins (t_{16} = 1.75, *P* = 0.33) (Fig. 3). Cover had been maintained with a very similar range to the summer, at between 62% – 97 %. However, when mean percentage of tussocky live and dead grass cover was examined, there was significantly more present in beetle banks than in field margins (t_{16} = 1.75, *P* = 0.01). Mean percentage of other grass growing in the habitat was not different (t_{16} = 1.75, *P* = 0.12), but there was significantly more dicotyledonous plant material in field margins (t_{16} = 1.75, *P* = 0.01), as well as more woody plants (t_8 = 1.86, *P* = 0.02) (Fig. 3).

Plant litter, dead grass and tussock were combined into a single category that was compared between habitats. These vegetation types are important for providing camouflaged nesting material in the spring (Rands, 1988). Beetle banks contained significantly more of this material (t_{16} = 1.75, *P* = 0.01) with a mean of 61% compared to 27%.

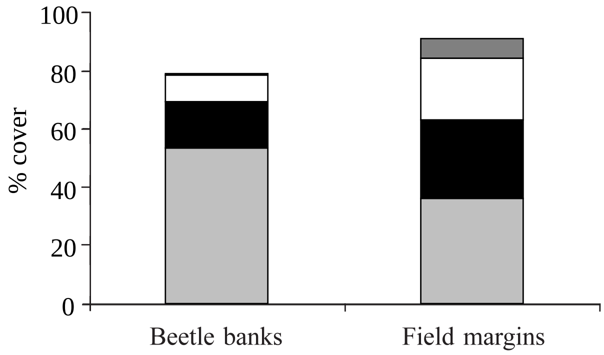

Fig. 1. Mean percentage cover of plant categories in beetle banks and field margins, summer 1998 assessment; n = 18. Light grey shading: tussock grass; Black: other grasses; White: dicotyledonous plants; Dark grey: woody plants.

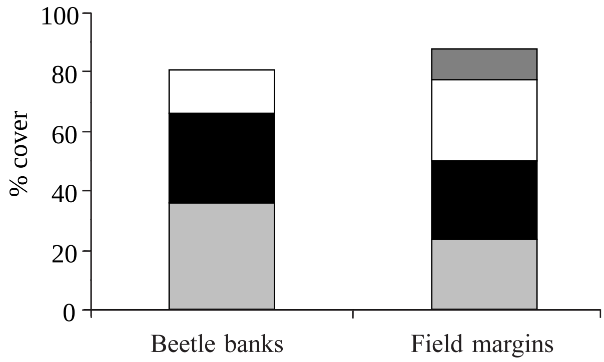

Fig. 2. Mean percentage cover of plant categories in beetle banks and field margins, summer 1999 assessment; n = 44. Light grey shading: tussock grass; Black: other grasses; White: dicotyledonous plants; Dark grey: woody plants.

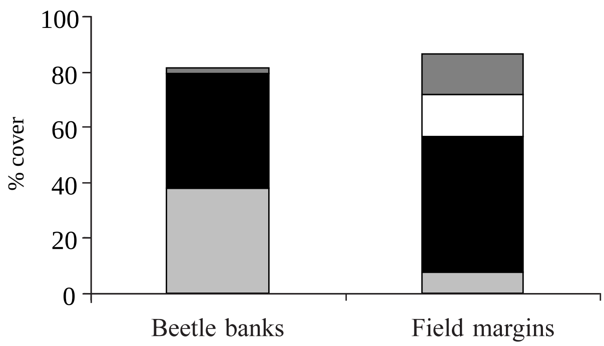

Fig. 3. Mean percentage cover of plant categories in beetle banks and field margins, 1998-99 winter assessment; n = 18. Light grey shading: tussock grass; Black: other grasses; White: dicotyledonous plants; Dark grey: woody plants.

Relationships between plant cover and invertebrates

As the ages of the beetle banks assessed in this study were known, it was possible to assess whether abundance and diversity of chick food invertebrates and plant cover showed age-related changes. Data from the second sampling year was used, which represented a greater sample size of beetle banks. The two newly sown banks were excluded, as being less than a year old, they contained only annual species that had germinated through the ploughing disturbance whilst creating the bank, prior to grass establishment. Regression analysis was performed between age in years and mean invertebrate catch in beetle banks, but no relationship was evident ($r^2 < 0.001$, $F_{1, 18} = 0.015$, $P = 0.905$). However, a regression between age and invertebrate diversity (Shannon-Wiener Index) showed a highly significant positive relationship ($r^2 = 0.335$, $F_{1, 18} = 9.084$, $P = 0.008$). This undoubtedly results from the increasingly complex plant communities that develops in the beetle banks (Thomas *et al.*, 2000). Plant diversity was also calculated, and had a highly significant positive relationship with invertebrate diversity, both in beetle banks ($r^2 = 0.559$, $F_{1, 18} = 22.790$, $P < 0.001$) and in field margins ($r^2 = 0.260$, $F_{1, 18} = 7.027$, $P = 0.015$).

Discussion

The results of this study strongly support the view put forward by Aebischer & Blake (1994), who suggested that grass strips, and in particular beetle banks, may be valuable for game birds as well as properly managed hedgerows. Although beetle banks are simple landscape features, it was found that they could develop high densities of the preferred invertebrate prey of game chicks, approaching equivalent values to those of more complex established hedgerows and other permanent field boundaries. Despite overall chickfood densities being lower in beetle banks, the numbers of many key groups sampled often did not differ significantly. This was particularly so for invertebrates considered nutritionally important, such as sawfly larvae and caterpillars, found by Moreby (1988) to be especially numerous in chick faecal samples. Faecal analysis, although known to under-represent softer-bodied species, also found plant bugs, plant hoppers, ground beetles, leaf beetles, and weevils to be important dietary items. These groups were also similar in relative abundance within beetle banks and the conventional field margins sampled here.

Invertebrate catch from the beetle banks and field margins varied considerably between the different fields, and also between farms. It is likely that previous field management, including differences in cropping and agrochemical inputs over a number of years, influenced catch. Increased replication in the experimental design would be necessary to evaluate such factors, although complications such as the frequent growing of different crops on either side of beetle banks, or the presence of other features such as woods and roads adjacent to margins, would have to be taken into account. In the first sampling year, the farm used had well maintained field margins and hedgerows following a history of environmentally conscious management to encourage game, including the use of conservation headlands around all margins. This may explain why invertebrate densities were similar in the habitats examined. However in the second year, when more farms with different management histories were compared, there was a greater variability in chickfood densities. Barker & Reynolds (1999) also found significant variation between farms when examining chickfood abundance in grass margins.

Suctioning has been described as an inefficient sampling method (Green, 1984), as chrysomelid beetles, sawfly and lepidopteran larvae, highly preferred dietary choices, may be scarce in suction samples though common in sweep net samples. More recently, sweep-netting has been preferentially selected technique for chickfood capture (Barker & Reynolds, 1999; Itamies *et al.*, 1996). Beetle banks are established to enhance ground-active fauna (Thomas *et al.*, 1991, 1992), for which suction-sampling may be a more appropriate assessment method.

Peak partridge chick hatch occurs in late June to early July, coinciding with high insect abundance, although it may be any time from April to September (Green, 1984; Anon., 1995). Although there was a lower catch of chickfood in beetle banks, the difference between the habitats was consistent and small in both May and August, i.e. food availability may remain adequate for chick survival throughout the hatching season. Chicks may fare better later in the season, when there is greater food abundance, with conventional field margins providing improved food resources. However, the addition of beetle banks to a monoculture of cereals may enhance game chick survival, especially considering the increasing invertebrate diversity that appears to develop within the maturing habitat structure. Once established, beetle banks have a dense grassy structure, and are probably at least as good as many other marginal habitats for provision of camouflaged shelter for both adult game birds and their chicks, though may never be equivalent to that provided by well managed hedgerows. Plant cover was high throughout all sites, and beetle banks were found to be valuable for the supply of nesting material, in late winter and early spring. Many field margins are observed to have exposed bases, with little material of value for either forming a nest or allowing shelter from harsh weather and predators, and so any additional resources in fields may be important. The farms used in this study tended to manage margins sympathetically for wildlife and thus usually had fairly well maintained hedgebases, inevitably linked to the desire to also create beetle banks.

Foraging gamebirds tend to avoid vegetation that is difficult to penetrate (P Thompson, personal communication). It may be that some of the sites developed cover that actually became too impenetrable as the season progressed, a factor that may merely inconvenience adult birds, yet jeopardise the survival of chicks. Where plants are too densely spaced, chicks may become so wet from the vegetation that unless they can dry off quickly they may chill and die. Barker & Reynolds (1999) considered that many planted grassy margins, including beetle banks, could be less than ideal habitat for birds, although they reported that some farmers had experimentally cut channels within such habitats for birds to move around and dry out following rain. The provision of a sterile strip alongside field boundaries and features such as beetle banks has been suggested as useful for game chicks, as it provides an open area for drying out (Bond, 1987). Such solutions may be essential where vegetation has become especially dense. We observed that where tussocky cover had developed patchily, often because many beetle banks are hand sown (Thomas, 2000), not only did this allow some other plants to develop, but it allowed some degree of permeability for the benefit of game. There is a clear trade-off between managing beetle banks for the dense tussock cover to enhance maximum predatory invertebrate survival, their primary aim, and allowing some patchy alternative plant cover for the benefit of game species.

Herbaceous and grass species that may be fed on by adult birds were only present at low levels in beetle banks, although this has been found to increase through time following establishment (Thomas *et al.*, 2000). Many seed-producing dicotyledons known to be preferred specifically by game birds are more usually found within the field itself, rather than in boundary habitats. However, with the development of more efficient herbicides and low tolerance of weeds within fields by farmers, weed seed availability may be low, and thus any extra food resources within the habitat in which adult birds may be nesting can only be seen as beneficial.

Game birds with chicks were observed within banks during the course of the study, indicating that the habitat was being utilised. Overall, we suggest that beetle banks make a valuable contribution to game habitat on farmland, with their low cost and ease of construction adding further positive points. They may be especially invaluable when combined with spring brood-rearing and winter cover crops within set-aside strips, such as recommended by Boatman & Bence (2000), a methodology shown to significantly increase wild pheasant populations, as well as the nationally declining skylark, on conventionally managed farmland on UK lowland. Although beetle banks may add chickfood invertebrates and nesting shelter to arable fields, and may be useful where such resources are lacking, appropriate good management of conventional field margins may be much more important for the continuing survival of game bird species on farmland.

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