ENVIRONMENTAL INTERESTS OF FIELD MARGINS FOR BIRDS

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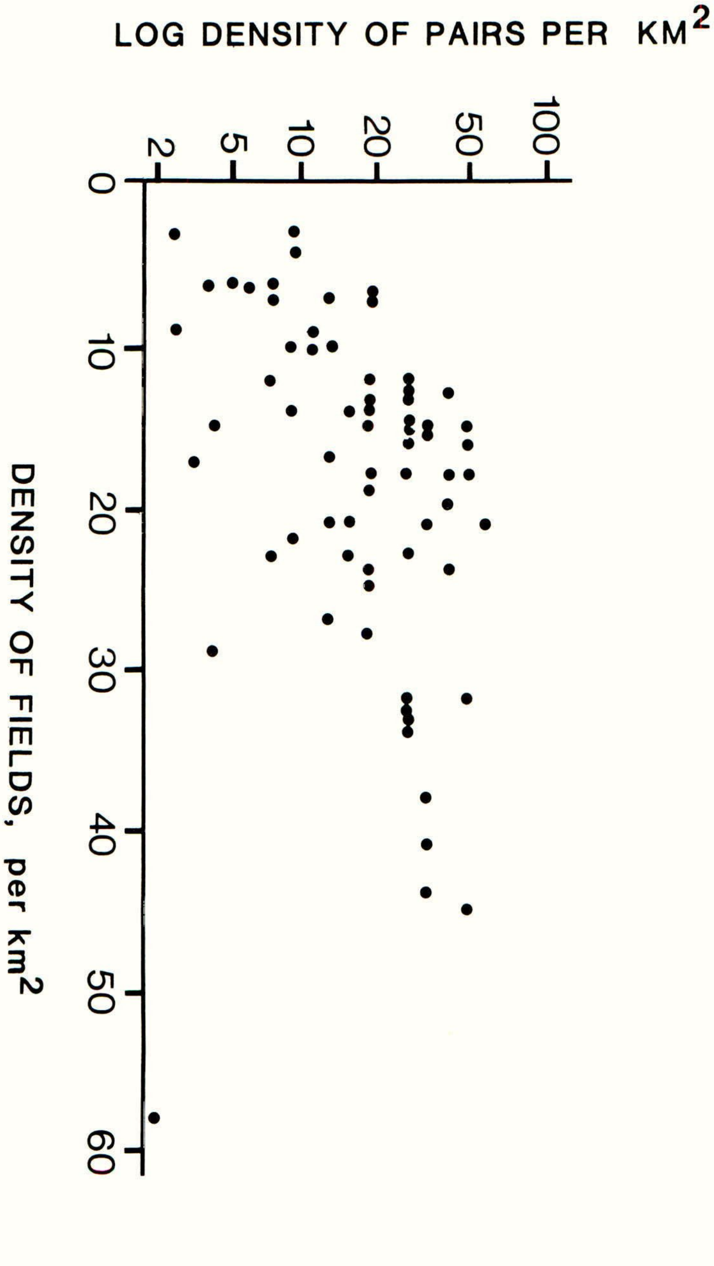
INTRODUCTION

Interest in the value of field margins for birds has historically focussed on hedgerows, an interest particularly stimulated by the high rates of hedgerow losses that occurred on British farmland during the late 1940s and 1950s. The debate on the value of hedgerows has polarised essentially into two camps. On the one hand authors such as Pollard et al (1974) have argued that hedges, together with scrub and woodland copses and spinneys on farmland, provide refuges for the predominantly woodland birds of Britain, permitting them to breed in areas they could not otherwise colonise. The second school of thought has focussed on empirical case studies such as that of Murton and Westwood (1974) and of Bull et al (1976), who reported instances of major removal of hedgerows from farmland resulting in relatively small losses in overall bird populations. This second school was also influenced by the work of Krebs (1971), who showed that hedgerow nesting Great Tits (Parus major) (mostly juvenile birds) would abandon hedgerow territories for vacancies in nearby preferred woodland habitat, suggesting that they resorted to hedgerow only as overflow habitat. Breeding in such secondary habitat is generally poor, so that birds breeding there contribute little to overall population maintenance. In the light of such ideas, conservation interest in hedgerows as bird habitat has, to a degree, declined. Instead, some conservationists have advocated the compensation of hedgerow losses by field corner tree or woodland plantings, on the basis that these offer areas of preferred habitat to birds displaced from more marginal habitat in the lost hedgerows. Much recent research work on hedgerows as bird habitat (Osborne 1982 a, b, 1984, Arnold 1983, O'Connor 1984, O'Connor and Shrubb 1986), however, has tended to support Pollard et al's (1974) position as to the importance of hedgerows. In the present paper I provide a brief review of the current understanding of the significance of field margins for birds, with particular emphasis on the role of hedgerows.

GENERAL IMPORTANCE OF FIELD MARGINS FOR BIRDS

The overwhelming importance of field margins on farmland is to add spatial and structural heterogeneity to the landscape. Bird densities on British farmland are correlated with the numbers of fields (and hence amount of field margin habitat) per unit area, as shown for Dunnocks (Prunella modularis) in Figure 1, with some 24 of 57 species (42%) examined being individually more numerous the more fields were present. Maps showing the location of individual territories on such farms often reveal the location of the field margins, especially so where these are formed by hedges or by lines of trees. The term "prairie farm" applied to the intensive cereal units of East Anglia, Wiltshire, and certain other parts of Britain, tends to be used derogatorily by conservationists but nevertheless reflects a correct perception of the importance of landscape

FIGURE 1 Density of breeding Dunnocks <u>Prunella modularis</u> in relation to the density of fields, on 65 Common Birds Census plots on farmland in Britain.



structure for birds. Figure 2 plots the extent of the bird community on farmland against the extent to which three-dimensional structure is absent from the farm, i.e. against the extent to which the farm approaches prairie conditions. Where all structure is absent, the bird community is depauperate.

The significance of field margins thus reflects the general importance of habitat structural diversity to bird communities (eg MacArthur and MacArthur 1961). Bird species compete for resources such as food and nesting sites, and interspecific differences in preferred foods and habitat features lead to a degree of ecological isolation that segregates one species from another (Lack 1971), thus allowing them to co-exist. Habitat segregation features prominently in avian ecology, particularly amongst the migrant species that are often of most interest for conservation. Lack (1971) provides an extensive review of the extent to which congeners are segregated by food, habitat or other factors and analysis of his data shows that among migrants habitat segregation accounts for some 60% of the congeneric segregations observed. Amongst resident species in Britain habitat segregation is somewhat less pronounced, accounting for just 23% of the cases studied. This largely reflects the highly adaptable, generalist nature of the resident bird species using farmland (O'Connor and Shrubb 1986). Thus field margins may shape the bird communities of farmland by providing the structural diversity needed to permit competing species to breed together.

Although hedgerows are for birds by far the most significant field margins, they are not the most significant habitat on farmland. Scrub and woodland, and copses and spinneys may support larger numbers of birds (da Prato 1985). These habitats rarely form part of the margins themselves; however, when they do occur as field boundaries they may be of considerable importance (Fuller 1984, Cracknell 1986, da Prato 1985). Hedges are the commonest field margin in southern England, though to the north and west they give way to stone walls and banks, features also found in upland elsewhere in Britain (Locke 1962). An associated trend in bird abundance is apparent within Britain, with the greatest densities of many songbirds in southern England (O'Connor and Shrubb 1986).

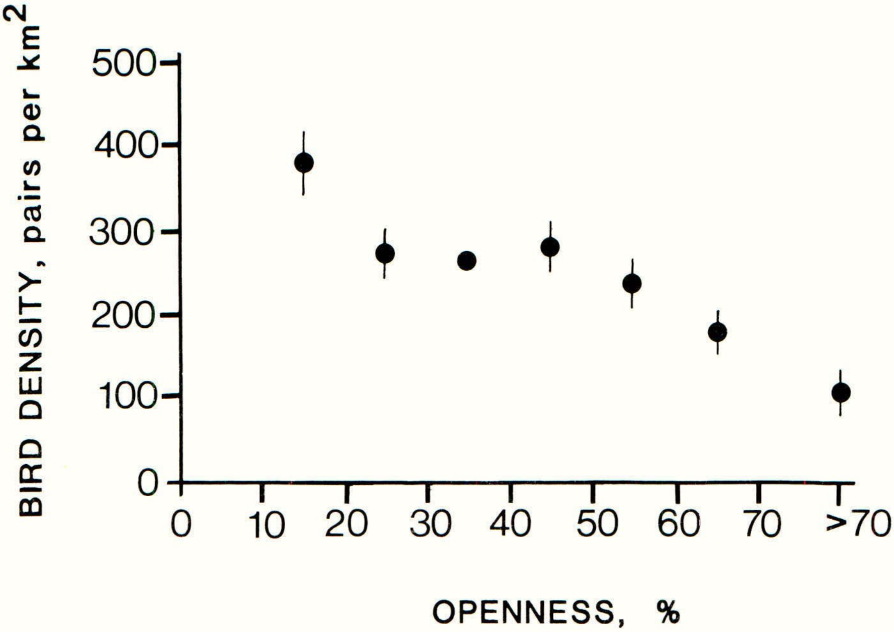
Structural diversity contributes to the variety of ways in which birds may use hedgerows. Hedges may be used as song posts, as nesting places, as feeding areas, as shelter from predators, as shelter for roosts, and as "highways" between patches of other habitats. The most structurally diverse hedges, if sufficiently large, may fill all six roles whilst less diverse hedgerows may be able to fulfil only some of them. Several of these uses relate to the breeding season, and indeed more is known about the use of hedges by birds at that time of year than at any other, though some recent studies have expressly addressed hedgerow use in winter (Arnold 1983, Moles 1975).

IMPORTANCE OF HEDGEROWS IN THE BREEDING SEASON

General features

What features of hedgerows are of greatest interest to birds? Several recent studies have identified the volume of the hedge as being of particular importance to birds (Osborne 1982a, 1982b, Arnold 1983,

FIGURE 2 Breeding bird density in relation to an index of habitat openness for Common Birds Census plots. The openness index used measures the extent to which structures such as hedges, trees, scrub, woodland, farmsteads and other three dimensional objects were present or absent at a matrix of grid points superimposed on each of a sample of Common Birds Census plots spread throughout Britain.

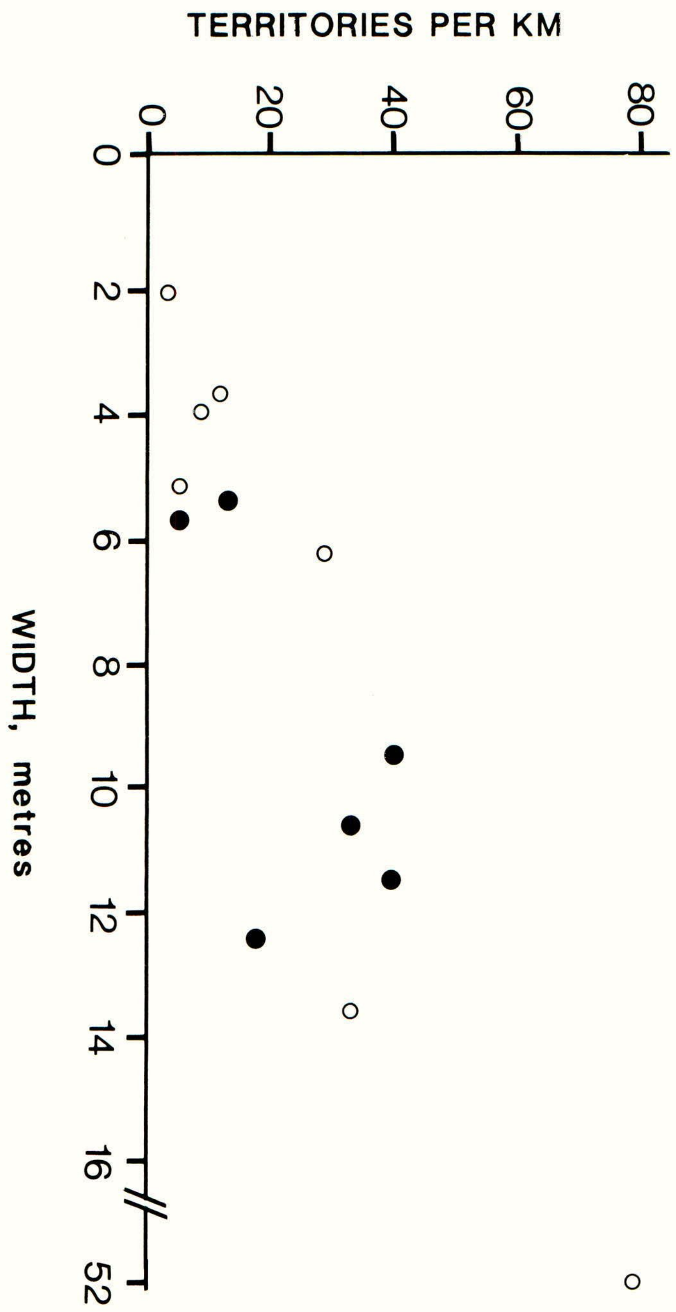


O'Connor 1984 and unpublished, Moles 1975). This appears to be true irrespective (within limits) of the shape of the hedge: a thick hedgerow of moderate height may be as effective as a thinner one of greater height and a large box-shaped hedgerow may be as effective as an A-shaped hedgerow of the same volume. Parslow (1969) has, however, identified a special value in tall hedgerows: he found that those trimmed below 1.2 m supported fewer species and pairs than did taller hedges, and found that the nests in the lower hedgerows produced fewer young. Figure 3 shows how bird densities along field margins in an area of Scottish farmland are strongly correlated with the width of the boundary, despite the great variety of margins considered. da Prato (1985) emphasised the role of individual features of these boundaries -- the presence or absence of a ditch, the extent of trees present, whether the boundary was internal or peripheral on the farmland and so on -- but such effects are merely superimposed on the broader trend with the width of the boundary. The preference by birds for nesting in hedges of large volume may be primarily as a defence against predators: a number of studies have shown that the volume of foliage around the nest site may contribute significantly to reducing nest losses to predation, particularly to avian predators (Best and Stauffer 1980). This idea is supported by the finding that the parts of a hedgerow immediately abutting woodland are less used by birds than are parts further from the woodland, apparently because predators will move out of the woodland into the immediately adjacent hedgerow, but will not penetrate into the more remote sections of the hedge in a search for nests. A particular value of tall hedges and of broad hedges may therefore be in promoting the growth of a ground layer providing protection against predation. Pollard et al (1974) drew attention to this point and Rands (1982) has shown that the amount of dead grass in the base of a hedge has a significant influence on the breeding success of Grey Partridges (Perdix perdix) nesting there, by virtue of the cover provided. Osborne (1982a) similarly found that the number of herbs in a hedgerow base promoted bird species, with some 25% of the variation in the number of species present associated with the species richness of the herb layer and with three of the six bird species studied in detail being more numerous where herbs were more numerous. This point is particularly significant in the light of the recent increase in the practice of spraying-out of hedge bottoms, with an adverse effect on the timing of breeding by species such as Reed Buntings (Emberiza schoeniclus) that previously found nesting cover there (O'Connor and Shrubb 1986). It is, however, possible that large volumes of foliage provide greater foraging area rather than greater protection for birds. Fuller (1984) found that birds in poor quality hedgerow (low, heavily trimmed, little foliage) tended to feed more in adjacent fields than did birds in good quality woodland.

Hedgerow structure

Hedgerow volume is not the sole criterion used by birds in assessing the suitability of a hedgerow for nesting. The detailed structure of the hedge is also of considerable importance. This conclusion is supported by several lines of evidence. First, although the spatial density of hedgerows on a farm has a marked effect on the total density of birds breeding on the farmland, with 51% of the species being more abundant where hedgerows are more plentiful, there is a marked difference in the influence of hedgerows containing trees and of those without trees: the

FIGURE 3 Bird density in relation to the typical width of various types of field margins on agricultural land in Scotland. Open circles indicate field hedges etc. Closed symbols indicate roadside hedges etc. Based on data in da Prato (1985).



former has a positive effect on no less than 72% of all species present, whilst the latter influences only 16%! The influence of lines of trees without an understory is intermediate, influencing some 35% of the species present (O'Connor and Shrubb 1986). Interestingly, the few species that are adversely affected by hedgerow density also react more strongly to the presence of trees in the hedgerow: both Corn Bunting (Emberiza calandra) and Skylark (Alauda arvensis) are significantly less abundant where fields are bounded by hedges with trees. Species particularly affected by hedgerow abundance include Wren (Troglodytes troglodytes), Dunnock, Robin (Erithaculus rubecula), Blackbird (Turdus merula), Lesser Whitethroat (Sylvia curruca), Whitethroat (Sylvia communis), Chiffchaff (Phylloscopus collybita), Marsh Tit (Parus palustris), Blue Tit (Parus caeruleus), Great Tit (Parus major), Magpie (Pica pica), Carrion Crow (Corvus corone), Chaffinch (Fringilla coelebs), Goldfinch (Carduelis carduelis), Linnet (Carduelis cannabina), and Bullfinch (Pyrrhula pyrrhula). Among non-passerines three species - Kestrel (Falco tinnunculus), Cuckoo (Cuculus canorus), and Long-eared Owl (Asio otus) - are similarly affected. Of these species, only the Dunnock responds positively to hedges that lack trees along their length. Thus for almost all species the presence of trees in the local hedgerows greatly increases the attractiveness of farmland for breeding birds.

A second line of evidence as to the relevance of the detailed structure of hedgerows comes from the work of Pollard et al (1974), who found that greater structural diversity in hedges made them more attractive to birds. Overgrown hawthorn (Crataegus spp) hedges with outgrowths proved more attractive than well-trimmed ones and than those kept better trimmed by good management. In an Irish study Moles (1975) also found that neglected hedges supported larger breeding populations than did well-trimmed hedgerows. The benefits of outgrowths may lie in their providing suitable song posts, particularly for species such as Chaffinch that typically sing from taller song posts. Several such species also show high correlations between their breeding densities and the density of trees in the local hedgerows. Alternatively, the benefits may relate to the greater availability of nest sites in these hedges. Osborne (1982 a, b) examined the distribution of birds in hedges of different types on a dairy farm in Dorset, and found that the number of trees present in a given length of hedgerow had a significant effect on the number of species and on the number of individuals present in the hedge. Where trees were selectively removed following Dutch elm disease, bird densities fell, though this was partly, perhaps largely, due to the damage done to the hedges by the removal of diseased trees (Osborne 1985). The influence of trees in hedgerows in part operates by providing a more woodland-like environment for woodland species. Chiffchaffs in Dorset made use of hedgerow trees as a substitute for woodland habitat from which they were excluded by competition, using hedges remote from the preferred woodland only at very high population densities (Osborne 1982a).

A third line of evidence comes from another aspect of Osborne's work, an investigation of the influence of the tree species present. Osborne found nearly as strong an effect on bird species, and on total densities, from the diversity of tree species as from the number of trees. The diversity of the growth form of the trees present had a weaker effect on the breeding bird community, with little effect on number of individuals present. Together, these findings suggest that the variety of trees present may contribute to supporting a variety of species, whilst other aspects of the hedge influence the total number of individuals supported.

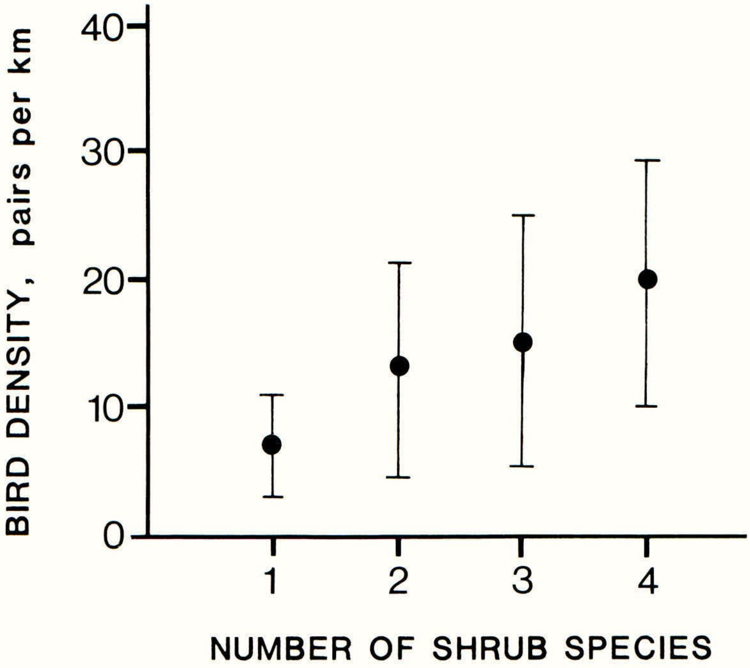
Shrub species composition

The question of the species composition of the hedgerow itself has been rather poorly studied. Figure 4, based on unpublished work by Leo Batten and his colleagues at the British Trust for Ornithology (BTO), shows that the number of shrub species in a hedgerow has a marked influence on the birds breeding there. On the Dorset farm studied by Osborne (1982a), hedges used by Wrens were disproportionately rich in shrub species whilst those left unused were poor in variety of shrubs present. These findings indicate a clear preference by birds for nesting in the shrub-rich hedges, but whether this is a function of the greater structural diversity of these hedges in facilitating nest placement or whether they provide a greater variety of food sources is unknown. Different shrubs come into flower at different times and support a corresponding variation in invertebrate populations (da Prato and da Prato 1977), so a shrub-rich hedge could provide food sources throughout the breeding season in a way that a monospecific hedgerow would not. However, an important element requiring consideration here -- and one which has largely gone unstudied to date — is that shrub-rich hedgerows are often the older, long-established ones (Pollard et al 1974), and this may have implications for food supply quite independent of that of the species composition of the hedge. Southwood (1961) has shown that the older native trees of Britain support richer invertebrate populations than do more recent colonists and one might conceive of analogous effects operating in relation to hedgerows. In the case of the study of Figure 4, the influence of shrub richness was superimposed on to one of volume, thus perhaps making it less likely that the amount of food alone was important. It is of course possible that the volume and the variety of foliage of a species-rich hedgerow are just equivalent ways of increasing overall food supply.

General Countryside relationships

One of the general problems of interpreting the significance of field margins for birds lies in the possibility of cross-correlations between habitat elements on farms. For example, if well-hedged farms are also rich in woodland or scrub cover, such farms might support more birds because of these latter features rather than because of features of the hedgerow. Arnold (1983) found, however, that local habitats were nearly three times as important as were features of the general countryside around the small (5 ha) quadrats of farmland he studied in Cambridgeshire. This applied particularly to hedgerow species, though field species were more influenced by features of the general countryside. Osborne (1982a) similarly examined the influence of nearby (within 250 m) landscape elements, finding that nearby scrub and hedges influenced the composition and abundance of the local bird community, whilst features such as farmsteads, woodland and riparian habitat had little effect. Other analyses by O'Connor (1984) and O'Connor and Shrubb (1986) produced similar findings.

FIGURE 4 Densities of birds of all species recorded in hedgerows on a Hertfordshire farm in relation to the number of shrub species in each.



Specific bird species preferences

One of the most important findings to emerge from recent studies of the importance of hedgerows for birds is that there is no ideal hedgerow for all birds. Each individual species has specific habitat preferences found in some but not in all hedgerows, so that a hedge that may be particularly attractive to Chaffinches may be far less attractive to Whitethroats. Such species-specific preferences are, to an extent, concealed by the analyses so far presented. Although most farmland species individually become more numerous with increase in hedgerow density, they vary species by species in their rates of numerical increases. More importantly, various species do not respond by steadily increasing with yet further increase in hedgerow density but rather peak in abundance at some intermediate density of hedgerow, as shown for the Mistle Thrush (Turdus viscivorus) by O'Connor (1984). A variety of bird species show such modal relationships, different species peaking at different hedge densities. A consequence of this is that a degree of species turnover is apparent along a sequence of farms arranged along a gradient of hedgerow density: on farms with little hedgerow, adding more leads to an increase in the number of species breeding there, but on farms that already have a high spatial density of hedgerow, adding yet further hedges result in a steady decrease in the number of species breeding (O'Connor and Shrubb 1986). These effects go a long way towards explaining the results of Murton and Westwood (1974) and of Bull et al (1976), who found that quite extensive hedgerow removal had little effect on the number of breeding species present and on the overall abundance of breeding pairs in the local bird community. The results showed, nevertheless, that the particular species breeding and the relative abundance of the different species that remained did alter. An understanding of the specific preferences of individual bird species for particular hedgerow densities helps to avoid adopting the excessively simplified conclusion drawn from such studies, that the bird communities concerned can tolerate quite extensive hedgerow removal. Instead, either each species has its own preferred optimum or, if linearly increasing with further increase in hedgerow density, does so at a species specific rate. It follows that one must therefore consider the initial and final densities of hedgerow in evaluating the implications of hedgerow removal, and then consider which species would be affected by such change. In practice, summer visitors, often species of primary conservation interest on farmland, tend to be particularly badly affected by the levels of hedgerow removal actually carried out on farmland. Thus Bull et al (1976) found that summer visitors and hole-nesting species gave way to field species on a Norfolk farm that lost 30% of its hedges over a 4 year period. A knowledge of the optimum hedgerow densities for individual species also allows prediction of the points at which further removal of hedgerows will have a deleterious effect on the total bird community, as evidenced by the study of Evans (1972) on a Common Bird Census site at Ely, Cambridgeshire, where the population of breeding birds was halved following hedgerow removal.

Non-hedge features

Considerably less attention has been paid to the significance of the non-hedge components of field margins. However, even the presence of a simple ditch along a field margin may provide sufficient additional structure to the landscape to accommodate additional bird species. Arnold (1983) found that the presence of a ditch on small plots of arable land in Cambridgeshire significantly increased the number of species breeding on the plots concerned, from an average of just over four species to nearly nine, whilst the density of birds present nearly trebled where ditches were present. When compared against the corresponding effects of a hedge, isolated ditches supported about 80% of the species and about 87% of the individual birds that were drawn on to arable land by the presence of a hedge alone. Skylarks and gamebirds benefitted more from ditches than did other species, whilst of these latter the Yellowhammer (Emberiza citrinella) best maintained its numbers where ditches replaced hedgerows on arable land. Despite these figures for the value of a ditch, a ditch accompanied by a hedge supported twice as many species and one-third more birds as did the ditch alone. In Scotland da Prato (1985) similarly found that the presence of a ditch enhanced the value of existing field margins, in the case of a low hedge by nearly 80% (from 2.8 to 4.9 pairs/km) but in the case of a hedgerow with trees present only by about 13% (from 28.9 to 32.7 pairs/km). Farm boundary hedges benefitted even more from the presence of a ditch, with the bird population increasing from 5.0 to 17.7 pairs/km. These results suggest that the value of a ditch may be not so much intrinsic as in the enhancement it provides to other habitats present at the field margin, with the very richest habitats gaining only slightly because they are already adequate for many birds, and the very poorest benefitting in rather limited ways because of their low initial populations; intermediate quality habitats benefit in a major way, however, because of the additional complexity the ditch affords. The main value of the ditch may lie in the additional foraging opportunities it provides, though a few species do nest in ditches. In Ireland, Moles (1975) found that ditches were particularly significant for birds that fed in soft substrates, such as Song Thrush (Turdus philomelos) and Starling (Sturnus vulgaris).

USE OF HEDGEROWS IN THE NON-BREEDING SEASON

Many of the studies cited above relate to the influence of field margins on breeding communities of birds. Rather few winter censuses of birds have been conducted on farmland and correspondingly less is known about their significance for non-breeding birds. Arnold (1983) used an ordination technique to rank winter bird communities on the basis of their similarity to each other and examined the resulting sequence for evidence of associated gradients in habitat structure. He found that, although the summer communities could be ranked in relation to the gradient from open poorly structured farmland to farmland with complex field boundary structures, this relationship was not present in winter. Despite this, he found significant correlations between the numbers of species present at various sites in winter and in summer. He also found correlations between the winter and summer numbers of resident thrushes, of finches and buntings, of Skylarks and of Dunnocks, Wrens and Robins. Such results imply that birds used the winter habitat in different ways from in summer, with more variable behaviour in winter when birds are no longer tied to a nest site.

The pattern of hedgerow use by birds during the non-breeding season is influenced both by the availability of food and by the risks of predation. In autumn, hedgerow elders (Sambucus nigra) often attract flocks of Starlings, especially of young birds, to feed on the berries, at least until the first winter frosts. In late autumn and early winter hawthorn and rose (Rosa spp) are the main sources of berries. Although the question has not been studied in detail, thicker hedges may reveal fewer rose hips for birds to feed on, due to the hips being hidden by other vegetation. Whether rose hips in the more open hedgerows are then fed upon more frequently by birds because they are more obvious or because they are preferred is unknown. Hawthorn berries are similarly more abundant on straggly hedgerows, particularly along outgrowths, and are particularly attractive to Redwings (Turdus iliacus) and Blackbirds. These species tend to frequent hawthorn hedges for such feeding either until the crop has been depleted or until the hedge is trimmed in early winter, when the crop is lost and the birds are forced to resort to field feeding. At this time of year hedges are primarily important as a refuge from predators, with solitary feeders such as Blackbirds and Song Thrushes usually foraging close to the hedgerow. Species such as buntings, finches and sparrows feed in small flocks further out in the fields but also retreat to the hedges when disturbed. In contrast, species such as Redwings and Fieldfares (Turdus pilaris) feed out in the centres of the fields in large flocks which afford reliable detection of and a degree of protection against predators. Under older agricultural systems more grain was lost in farming operations and finch flocks were larger (O'Connor and Shrubb 1986) and therefore safer against predators. Nowadays finch species depend heavily on field margins for cover, except in stubble fields and in game crop fields where cover is available in the field centre.

A few species such as Wren and Dunnock stay in the hedgerows the year round, finding sufficient food in the hedgerow bottoms and their immediate vicinity. In some cases Wrens may even forage under the snow layer by making entry from the hedge bottom! A few tit flocks also move along hedgerows, particularly tall hedges, in winter but this appears to be primarily a case of moving from one favoured habitat to another under cover.

The importance in winter of field margin elements other than hedgerows are even more poorly understood than in summer. Arnold (1983) found that where a ditch was present as the sole field margin to arable land, rather more species were recorded in winter than if no ditch were present at all, though overall bird density was similar in the two situations. Where the ditch paralleled a hedge, however, substantially more birds were present than in hedgerow alone, and the number of species present nearly doubled (from nine to 17). Arnold also found that bigger ditches supported more individuals of certain species, notably Blackbird, Song Thrush, Wren, Robin and Dunnock. Moles (1975) similarly found that ditches in winter were particularly used by Blackbirds and Song Thrushes, though his Irish site also supported more Reed Buntings and Moorhens (Gallinula chloropus) in the ditches in winter. Ditches can be expected to be particularly significant in winter for probing species such as Snipe (Gallinago gallinago) and Woodcock (Scolopax rusticola), particularly where the ditches contain running water to keep the frost and the snow away (Spencer 1982). There remains considerably scope for further study of the ways in which birds use field margin habitats in winter: their importance in allowing various bird populations to remain on farmland in winter is undoubtedly under-estimated!

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CONSERVATION INTEREST IN PLANTS OF FIELD MARGINS

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Field margins can consist of a significant range of plant habitats: banks, hedges, walls, ditches, streams, headlands, farm tracks, road verges, and the edges of cropped land itself. They exhibit a wide range of environmental conditions; from dry banks and walls to wet ditches or streams and they differ in frequency of disturbance. Although maintained and repaired, hedges at one extreme can continue for centuries, while at the other extreme the adjacent crops in the field may change from year to year. The plants themselves therefore range from long-lived perennial trees and shrubs in the hedgerow, or lichens on a wall, to the annuals and ephemerals of the weed flora in the field.

Conservation interest likewise shows variation. In the sense that plants provide structures or foods for animals a zoologist might express interest in conserving plants of the genus Rosa or the family Rosaceae. A landscape architect might wish to preserve a contrast between the open landscape of the moors and the deep hedged lanes of Devon, or plead for trees on flat plains. A botanist, however, is more likely to concentrate his interest on local populations of particular species.

It is clear that in the context of this meeting I should speak as a botanist, but in declaring an interest in field margins for the perpetuation of local populations of plants, a number of questions are left unanswered.

For example how local is my focus? Am I to consider the plant at a national, regional or parochial level? It may well be that it is a source of sorrow to a Norfolk botanist that a shrub species has gone from his county because of hedgerow removal. For others the question will be whether or not that species is endangered in East Anglia or across the whole of Britain. In turn this brings questions about the rate of hedgerow removal and its geographical distribution. Are hedges being lost fastest in East Anglia? Is the rest of the country static?

For answers to these last questions we do have hard evidence which may put the hypothetical Norfolk botanist's fears in perspective. Hedgerows have been removed at varying rates in different parts of the country for 40 years. From 1946 to 1963 the overall rate for England and Wales was 5,000 miles removed each year, and there is evidence from the Common Bird Census run by the British Trust for Ornithology that the rate was nearer 10,000 miles per year in the latter half of the decade (Pollard et al 1974). For the last 15 years there has been an assumption that the rate of loss fell dramatically after 1970 but until recently there has been no comprehensive evidence of what recent rates have been. Surveys carried out by staff from the Institute of Terrestrial Ecology in 1978 and 1984 show that over this six year period England, Scotland and Wales lost hedges at a rate of just under 3,000 miles a year. Most of this loss (over 2,000 miles per year) took place in England. In England it was the midlands that had the highest loss, closely followed by East Anglia and the southeast: in six years these three regions alone lost over 9,000 miles of hedge. This concentration of loss in the south and east does not mean losses elsewhere were inconsiderable: in the same period the southwest lost over 2,000 miles of hedge and the northern region (Yorkshire, Cumbria, Northumberland and Durham) lost a total of over 4,000 miles. In six years the nation lost nearly 18,000 miles of hedge (Barr et al 1986).

A variety of points can be made about these figures. It is true that the rate of loss has declined from its peak of 20 years ago but it is still going on. It is true that central and western and southern counties have a higher hedgerow density than East Anglia and thus may be able to sustain losses better but the loss is continuing. This fact of continual loss, albeit fluctuating in space and time and small on an average basis of just under 1%, means that two-fifths of Britain's hedges have vanished in 40 years. Hence the conservation interest in plants of hedges must be the question of whether hedgerow species will survive for another 40 years.

In answering such questions we must first ask what plants occur in hedges and what proportion of all their occurrences these hedgerow records represent. Most hedges may have ivy (Hedera helix) or cleavers (Galium aparine) in them but this is less important than the fact that all the barberry (Berberis vulgaris) known in Warwickshire grows in Warwickshire hedges. There are some 20 or 30 species which have three-quarters of their occurrences in hedges and only a quarter or less in other habitats. These I have predicted in the past (Hooper 1970a, Pollard et al 1974) are those most likely to become extinct at a local or regional scale within the time span we are considering. Most at risk are the rarer shrubs and climbers and many are members of the Rosaceae.

In making such a prediction one must consider the alternative sites for these plants. If three-quarters of the records of a species are in hedges and one-quarter are in woods, one must consider the woods too. Unfortunately, as far as I can see, the main alternative for hedgerow plants is deciduous woodland and this too is under heavy pressure. Again a loss rate over 40 years of 1% per annum seems a reasonable estimate (Hooper 1970b).

What of other types of boundary and their flora? The plants of the crop margin itself, in which a conservationist might take an interest, are the annuals and ephemerals, the 'weeds'. Such evidence of them as there is comes from studies of the cropped area itself (Fryer and Chancellor 1970, Chancellor et al 1984). Here there is considerable evidence of major declines in frequency or density. This could worry the zoological conservationist, but the botanist might take heart from the fact that there is not much evidence of local extinctions of these species in recent years. Lack of evidence may be appropriate grounds for acquittal in law but it does not dispel my lingering suspicion that some will soon vanish.

Certainly there are case studies of ditches on Romney Marsh (Mountford and Sheail 1982) which suggest that between one-third and one-half of the species in individual ditches there have disappeared over the last 20 or 30 years. This evidence for ditches coupled with that for the decline in hedges, and the declines in density of weed species, should be enough to worry any botanist interested in the perpetuation of plant species over the next 40 years.

Of course the botanist could be more of an ecologist, and be less interested in species and more in ecosystems. In the early days of conservation, scientific reasons for the preservation of sites were proposed: their echoes linger in the Sites of Special Scientific Interest. There is particular scientific interest in the ecosystems of field margins as they are a complex system of many, closely juxtaposed, differing elements. In a field margin we have these elements occurring in the three basic systems of woodland (the hedge), wetland (the ditch) and grassland (the road verge, hedge bank), all stretched out linearly in space. Moreover these elements function in a time frame imposed by man, which differs from the more usual time frame of woodlands, wetlands and grasslands, and differs between the elements themselves, long in the hedge and short in the crop. Thus in the hedge we have long-lived persistent species, and ephemeral weeds in the field.

From the point of view of interest both in plant species and of ecosystems, therefore, field margins are of distinctive ecological importance.

Not surprisingly perhaps, it is principally for the long-lived persistent woody species, the trees and shrubs of the hedge, that the effects of soil type, management and timescale can be crudely predicted. For some other vegetatively reproducing, long-lived herbaceous plants of the hedge bottom, such as dog's mercury (Mercurialis perennis), the same can be said (Pollard et al 1974). Indeed, for me one of the most remarkable ideas of all is that plants of a herb like dog's mercury can persist for seven hundred years, rivalling the antiquity of specimen trees.

I would say that the longevity of dog's mercury in hedges is of scientific interest and archaeological interest, I do not say that it is of conservation interest. I do not think the species is endangered by hedge removal; it is too frequent elsewhere in woods. But the longevity of this species provides a remarkable contrast to annuals like hedge garlic (Alliaria petiolata) or common chickweed (Stellaria media), and perhaps emphasizes the contrasting effects of management and disturbance as factors controlling the occurrence of one type of plant or the other.

Disturbance makes space available, and success for a weed means occupancy of space. Management maintains existing divisions of space between species, and this perpetuates species and promotes diversity. Ideas such as these, based on the scientific interests of the field margin system give the first important clues to management options.

CONCLUSION

Weeds can be excluded by maintaining a perennial permanent vegetation, but are encouraged when perennial vegetation is killed off, for instance, by spraying hedge bottoms. Only for the maintenance of rare arable weeds would constant disturbance be useful and become 'management'. Hence the core of the matter is recognizing when disturbance becomes management in relation to any objective. A scientific interest is necessary therefore to maintain a conservation interest.

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THE IMPORTANCE OF FIELD MARGINS FOR THE CONSERVATION OF INSECTS

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ABSTRACT

1. The interaction of agriculture with wildlife is briefly described.

2. The insect communities which inhabit arable crops are shown to disperse rapidly and to be characteristic of the early stages of secondary succession.

3. The contribution made by field margins to insect conservation are described under the crop itself, arable weeds, headlands, ditches, walls, fences, and hedgerows.

4. Boundary features are examined for their contribution to the dispersal of species between protected sites. The size, shape, isolation and surroundings of such sites, and of farm fields, are topics for future research.

INTRODUCTION

Agricultural development has always spelled change for wildlife, including populations of insects. Clearance of the 'wildwood' in prehistoric times meant the replacement of forest insects by those adapted to open conditions. Fluctuations in the acreages of arable, pasture of various kinds, hedgerows and coverts, and in the associated woodlands and wetlands, have influenced the numbers and kinds of insects which inhabit farmland. Present-day intensive agriculture represents the extreme of a range of landscape and ecological changes which have affected wildlife since Man began to exert some control over his own environment. The 'harmony' between Man and nature perceived in less intensive agriculture by romantics in all ages, whilst not entirely illusory, is an almost entirely unconscious by-product of farming in which the balance is strongly tilted towards Man and his material interests.

In the view of many people, intensive agriculture and the conservation of wildlife are incompatible. Efficient exploitation of natural resources demands the channelling of photosynthetic energy into crop production with minimisation of alternative pathways into wildlife production. Whilst the realism of this view has much to recommend it, it may be doubted whether agriculture can ever become so efficient that no wildlife interest remains. The existence of FWAGs might seem to be one manifestation of this.

Wildlife conservation in Britain is dominated by consideration of <u>sites</u> (Ratcliffe 1977, Wildlife and Countryside Act (WCA) 1981). This is appropriate for conservation of climax and plagioclimax communities, but much less so for the conservation of the communities of seres and seral stages. Moreover, conservation of sites has raised questions about their long-term maintenance. For instance, Woodwalton Fen National Nature Reserve now stands well above the surrounding agricultural land and is in danger of drying out in the long-term (Duffey 1970). The size, isolation and surroundings of reserves, and the nature of the interchange of individuals and species between them, has received attention recently (eg Webb et al 1984, Webb 1985).

In this paper, we address three main aspects of the contribution which agricultural field margins make to the conservation of invertebrates: the ecological nature of the communities of arable crops, the variety of marginal biotopes, and the increasing isolation and fragmentation of protected sites which are connected to (or divided by) them.

CHARACTERISTICS OF INSECT COMMUNITIES IN ARABLE CROPS

Special features of insect populations

Except during special phases of dispersal, plants live where their seeds germinate. Animals move, both locally and over long distances. This capacity for movement characterises the type of organism which inhabits arable crops. Many vertebrates take the same kind of food throughout their lives, though this is often modified by parental care in early life. In contrast, insects in the endopterygote group (which are predominant) often have very different food requirements in the larval, as opposed to the adult, stage. This is particularly true of parasitic (strictly, parasitoid) insects, which are very numerous in species though less well studied than other groups. The dependence of insect populations on several features of the environment, or habitat, is a notable aspect of their ecology. In studies of such insects, it is clearly important to examine the requirements of the eggs, larvae and pupae as well as adults. In most cases, the study of one stage alone, especially mobile adults, is not sufficient and can lead to profound errors being made. For instance, insects such as butterflies, bees and hoverflies may take nectar hundreds of metres away from sites suitable for breeding.

Unlike most vertebrates, nearly all insects have a high 'natural rate of increase'. Sometimes this is spectacular, as with many aphids. Consequently, large fluctuations in abundance are commonplace in insects. It is often difficult to distinguish real trends in the decline or increase of a species from the 'noise' produced by annual variation in numbers caused by weather, predation and other causes. From a practical viewpoint, this means that the abundance of species cannot be judged from just a few samples or from data taken in one season, but must be assessed over longer periods of time. Moreover, sampling of adults and larvae may need very different methods, involving exact timing because of the short duration of some stages of their life histories.

Insects are small animals, and the effects of scale are more complex and subtle than is often realised (Price 1984). It is often assumed that an insect population can be supported in a smaller space, or area of 'habitat', than is required by a population of large vetebrates. Whilst this is broadly true, the judgement as to what constitutes 'habitat' is not that of the ecologist but of the insect population itself. Species are often 'unaccountably' absent from areas which appear to be suitable for them. Recent work has established why areas which seem suitable to support butterflies, particularly some of the more local species, actually do not do so. Although many insects are phytophagous and feed on only one or a few species of plant, the condition of that foodplant, not its mere presence, can be very important in determining the presence or absence of particular species. The presence of the foodplant is often assumed to be the all-important factor determining the occurrence of a species, but although the foodplant is necessary, it is not always sufficient. Other factors of the habitat, such as the structure of either foodplant or other vegetation or both, may determine presence or absence. Often these factors are are not well understood.

The main features of the dynamics of insect populations cannot easily be summarised in a few words. Their study can be complicated, though essential for understanding how to conserve species of particular interest. Modern work has, however, laid increasing emphasis on the natural exctinction of species on a local scale, with recolonisation as a corollary under normal conditions. 'Normality' needs to be stressed because the history of conservation in Great Britain over the last 50 years has shown that conditions, as stated in the introduction to this paper, have been changing rapidly.

Characteristics of agricultural insects

Few areas with even vestiges of a claim to be considered 'natural' occur in Britain. The exceptions are mostly areas of 'new land', eg sand dunes, or regions with a very harsh climate, such as mountain tops. The natural vegetation of lowland England, the 'wildwood', has long since been cleared away. Its characteristic insects included the so-called 'Urwaldtiere', a group characterised by very narrow habitat requirements, sedentary populations, and poor colonising ability. Agriculture, whether pastoral or arable, has selected insects with opposite characteristics.

Opportunistic species have been particularly encouraged by agriculture. Insects which disperse readily and rapidly, which have several generations a year, and which have short development periods are especially characteristic. A good example is the leafhopper Macrosteles laevis, characteristic of all kinds of 'disturbed' grasslands (Andrzejewska 1962) and a ready flier and coloniser (Waloff 1973). Communities of agricultural insects are largely made up of species with these characteristics, and their predators. The phytophagous insect fauna is naturally dominated by those species feeding on the crops themselves, the weeds associated with them, or other features of the agricultural landscape, such as hedges and the herbaceous plants growing in them.

On arable land, especially, the insect communities are characteristic of the early stages of secondary succession. This point again emphasises the opportunistic nature and colonising ability of the constituent species. As arable fields are usually ploughed each year, the community has little time to change and develop, but is continually renewed and maintained in a state of immaturity. Ley grassland may be a little longer-lived, but not much, and its characteristic insect fauna is equally a pioneer one. A usual feature of such communities, particularly in the absence of a rich flora of agricultural 'weeds', is that they are species-poor and characterised by high populations of one or two very abundant species.

Although the insect communities of arable land are, in general, little valued by conservationists, they do have features which are seldom present in nature reserves or other protected areas. Wildlife conservationists in Britain have scarcely considered the communities developed in early secondary succession. Some traditional arable weeds have become particularly rare and so, naturally, have any insect communities associated with them. Elsewhere, these communities are found mostly in association with road construction or widening of carriageways. Few conservation bodies maintain examples of early secondary succession.

Pesticide use clearly has had a profound influence on the biotic communities of arable and pastoral farmland. Direct effects of insecticides, and indirect ones of herbicides, may be equally damaging to specific insect populations. While the general case of pesticide use, through drift, having a serious effect on wildlife off the farm has been over-stated (except for the persistent organochlorines), there can be little doubt that populations of wildlife, particularly insects, have been greatly affected on farmland itself. It follows that the greatest diversity and value of the early successional communities occurs when use of pesticides is low.

FIELD MARGINS AND THEIR VALUE FOR INSECT CONSERVATION

The crop

Although they are not usually thought of as constituting a natural habitat, crops do support a variety of insects. Most of these are common and abundant species, and many are numerous or damaging enough to be pests. Some crops, either because they are unusual or because they are relatively novel, support species which are generally regarded as uncommon and scarce. A topical example is the Rape winter stem weevil (*Ceutorhynchus picitarsis*) which has become a pest of oilseed rape, though usually thought of as a rarity. It has either spread throughout East Anglia with the increase in the rape crop, or is now much more frequently recorded (John and Holliday 1984).

Arable weeds

Many of the traditional weeds of arable crops support varied and interesting insect faunas. As arable weeds are becoming scarce under modern farming management, and because ruderal habitats are not regarded highly by conservationists, some of these faunas may be under considerable threat.

Nowadays, many of the early stages of secondary succession are to be found mainly in association with roadworks and more rarely on agricultural land. Such weeds as *Fumaria*, *Polygonum* and *Galeopsis* spp, together with various Cruciferae, scentless mayweed (Tripleurospermum maritimum), common poppy (Papaver rhoeas) and many other plants, support a wide range of phytophagous Hemiptera, Coleoptera, Lepidoptera and other insects. The flowers of these plants are also used by species feeding on nectar and pollen. Most of these plants survive, often for long periods, in soil seed banks (Fenner 1985). Although associated insects may be highly mobile, with an efficient dispersal phase, continuity of habitat in time must be problematical, though little studied. In some cases it is known that a small proportion of pupae may overwinter for a second time, so spreading the risk of becoming locally extinct. An example is the Mullein moth (Cucullia verbasci), which feeds on species of Verbascum and Scrophularia.

Many of the most recalcitrant weeds of present-day agriculture are grasses, which, being taxonomically and structurally related to cereal crops, tend to be more difficult to control than broad-leaved weeds (Chancellor et al 1984). The weed grasses of arable land are of little significance to insects, though the range of grasses attacked by different species is imperfectly known.

Although neither crops nor the weeds associated with them are exclusively marginal features, they are particularly important in the field margin area. The edge of a crop tends to be more expendable than the centre, and is more easily sampled for insect life. Weeds are more abundant at crop margins and gateways, and edges are the most likely places to find most weeds.

Headlands

Headlands are the semi-permanent or temporary grassy or herbaceous strips of land left around fields, traditionally the places where the plough and its teams turned at the end of each furrow. Headlands have been reduced in size and number because of the ease with which obstructions can be removed by modern machinery (Southwood 1971), but they have also had their faunas changed as a result of spraying with pesticides, particularly herbicides. Under such treatments the insect fauna inevitably becomes impoverished.

A comparison of the butterflies recorded on field edges which have been left unsprayed with sprayed ones showed that 13 of 17 species were significantly more numerous on the unsprayed margins (Rands and Sotherton 1986). It now needs to be established that butterflies and other species breed on unsprayed headlands, and that they can survive other agricultural treatments, for instance ploughing at the end of the growing season. Grassland insects are very sensitive to management (eg Morris 1979, Morris and Plant 1983). Even quite moderate trampling greatly reduces the invertebrates in grassland litter (Duffey 1975); extensive pressure on headlands by machinery is likely to reduce diversity.

Ditches

Though many ditches have been destroyed on farmland, others remain as characteristic marginal features of fields, particularly of permanent grass in low-lying districts. The function of most ditches is to drain the land through which they run and so many ditches lack permanant water, being full only in winter and during wet weather at other times. Such impermanent bodies of water probably do not support diverse and important faunas of aquatic insects. In some regions, such as the East Anglian fens, the Somerset Levels, Romney Marsh and other areas, the ditch fauna may be rich and include nationally rare species. Naturally, such ditches are normally permanent bodies of water.

Their management by roding, or clearing out of the floating and emergent vegetation, is usually essential, but eutrophication through fertiliser run-off and deterioration of the fauna indirectly through the use of herbicides, are thought to be deleterious. Changes in the way in which drainage of agricultural land is achieved have recently been analysed by Mountford and Sheail (1984). Although their study has considered only the effects of agricultural drainage on natural vegetation, it is clear that there is a 'knock on' effect on insects, most directly on phytophagous species. Four plants which are being intensively studied for their response to water depth are the hosts of a wide range of insect species: lesser water-parsnip (Berula erecta), greater water-parsnip (Sium latifolium), flowering-rush (Butomus umbellatus) and branched bur-reed (Sparganium erectum).

Even those ditches which lack any permanent water may be important in diversifying the insect life of agricultural land. Ditches normally provide a damper and more sheltered environment than is present in open fields. In this they may be similar to hedge bottoms, and the two features (ditch and hedge) are often combined on one site. The damp microclimate may allow the presence of marsh plants (eg great willow herb (Epilobium hirsutum)), each with its complement of phytophagous insects. Such plants may contribute pollen and nectar to foraging insects such as bees and wasps.

Walls

Walls, particularly dry walls, are characteristic marginal features of agricultural land in many areas, particularly upland ones, but also in lowland places where stone is readily available. Walls vary in their construction but although all provide shelter for wildlife (as well as stock), it is the traditional dry-built stone wall, with plenty of spaces for insects to conceal themselves, which is richest entomologically. Walls which are traditionally turfed and planted with shrubs, as in parts of Devon and Cornwall, provide particularly diverse habitats for insects. Vegetation associated with walls is of particular importance, turning a temporary shelter into a permanent habitat for many insect species.

Many plant species are characteristic of dry walls, either at the foot, on the sides or on the top of the structures, and these plants are often absent from, or much rarer in, the agricultural fields the walls surround. Particularly in areas of high rainfall, the well-drained wall may support species which occur only sporadically elsewhere. The plants support the usual complement of phytophagous species.

Predaceous insects are also particularly associated with dry walls. Shelter is provided for many species, particularly the large, nocturnal predators. A usual feature of walls in unpolluted areas is their covering of lichens. These not only provide food for a rather limited number of lichen-feeding insects, but provide a background on which many cryptic insects, particularly moths, can rest. This may be important in areas where trees are scarce, though there is no information on the effect a suitable substrate or its absence has on the populations of such species.

Fences

In contrast to walls, the usual post-and-wire fence is a poor habitat for insects on agricutural land. Posts may give some shelter but are not usually colonised by plants, whether epiphytic or rooted. Fence posts are often attacked by wood-boring insects and may be of limited significance in unwooded areas. Although the wire fence itself is of little significance to insects, sheep wool caught in barbed wire may be of minor importance to those insects which feed on discarded wool, fur and hair, particularly when incorporated into the nests of birds (Morris 1969).

Hedgerows

Hedges are the agricultural boundary feature which has attracted most attention from conservationists (Pollard *et al* 1974). There are many reasons for this. One is that hedgerows are undoubtedly rich biotopes for all kinds of wildlife, including vascular plants (Hooper 1970) and songbirds (O'Connor 1984) as well as insects. The popularity of birds ensures that hedgerows are valued by conservationists in a way that cannot be matched by headlands, except of course for gamebirds such as the partridge. The obvious and well-documented destruction of hedges, particularly in eastern England, has greatly influenced public opinion and hedges are now regarded highly. Another influence is the importance of hedges in local history, both as boundaries to parishes and other areas and as datable features. The principle of 'one woody species per 30 m per hundred years' has been well-publicised and has the appeal of being very simple to understand.

Hedgerows are complex structures, often including trees and always shrubs, both of which have themselves a complex and involved architecture. This structural complexity, together with the biochemical diversity produced by the various species of woody plants in hedgerows, makes for a very varied and important insect fauna. As well as a range of phytophagous species (suckers, chewers and miners), feeding on or in foliage buds, fruits and seeds, and including galls, there is an important component of feeders in dead wood and inhabitants of bark. The phytophagous fauna of mites and insects associated with hawthorn (*Crataegus spp*), a very common hedge shrub, is as great as 230 spp. (Duffey *et al* 1974). Other shrubs, such as hazel (*Corylus avellana*) and rose (*Rosa spp.*), have abundant phytophagous faunas (107 species in each case), while shrubs such as spindle (*Euonymus europaeus*) (19) and elder (*Sambucus nigra*) (19) have much smaller faunas (Duffey *et al* 1974). There is a similar variation of faunas between hedgerow trees such as oak (*Quercus spp*), with a particularly abundant one, and sycamore (*Acer pseudoplatanus*), which has only a small fauna. Even so, there are about 90 species which have been recorded as feeding on sycamore (L. K. Ward, pers comm); many of these are not regular or frequent exploiters of the tree; some examples of the exploitation of structural features of oak by insects are given by Morris (1974). Naturally, mixed hedges with a variety of shrubs and associated trees are likely to support a particularly diverse range of insect species (Pollard et al 1974).

However, hedgerows contain more plants than just trees and shrubs. The associated herbaceous vegetation is an important feature of those hedges which are richest in insect wildlife. A considerable range of phytophagous species is associated with hedgerows, though each herb species supports, on average, fewer insect species than the architecturally more complex woody plants. Also important is the large ground-living fauna which derives cover and an equable microclimate from the ground vegetation. Many groups of invertebrates are predominantly ground-living, though many have arboreal representatives. Spiders and Carabidae (ground beetles) are two such groups. The Carabidae of a hawthorn hedge include species associated with the hedge, but not restricted to it, and others confined to the hedge. Some species overwinter in the hedge bottom and clearance of the ground flora impoverishes the fauna (Pollard 1968).

Some hedges have been clearly planted, but others have originated by preservation of the boundaries of woods which have been clear-felled or altered in other ways. Insects associated with the latter type of hedge may include woodland species, either because there are relict members of the woodland fauna or because they feed on woodland plants (eg dog's mercury (Mercurialis perennis)) which survive in the hedge.

The size of a hedge is an important factor in its value for conservation. Very low, and recently laid, hedges usually have an impoverished fauna, although very tall and 'leggy' hedges, which have been neglected, may also be relatively poor in insect species. Of equal or greater importance than height is the width of a hedge. Although the concept of 'linear habitats' has achieved some currency, few insects are likely to inhabit a one-dimensional hedge. Width, height and density are all important factors in producing an abundant and diverse insect fauna in a hedge.

These features are produced, and changed, by hedgerow management. The tendency in recent agricultural management has been on the one hand to produce a thin, low hedge of minimal importance to wildlife but occupying a small area of valuable land, and on the other to use machinery in place of more labour-intensive methods of management. The first trend is clearly deleterious to the insect life of the hedgerow, but the latter, though everywhere condemned and deplored by conservationists, has not been comprehensively studied, as far as its effects on insects are concerned. Traditional hedge management seems to produce the right kind of structures for some insects, for instance the weevils Anthonomus bituberculatus and A chevrolati, which feed as larvae in hawthorn buds (Morris 1962), but such evidence is purely anecdotal. Certainly, traditional cutting can have considerable importance in maintaining blackthorn (Prunus spinosa) in a suitable condition for the Brown Hairstreak butterfly (Thecula betulae), but also, depending on the exact intensity of cutting, removes and destroys a high proportion of the eggs. Prescriptions for the management of blackthorn hedges with populations of this butterfly can be made, but are rarely compatible with modern, efficient, management practices (Thomas 1974).

Unfortunately, different conservation interests are sometimes in conflict, as well as the broader interest of conservation and intensive agriculture. Some conservationists wish material cut from hedges to be removed and burnt, because this gives the hedge a tidy appearance. Others point to the insect life that is destroyed in this way, and prefer to see the cut material left on or near the hedge so that some, at least, of its insects can move onto the living hedge.

The conversion of hedges to the 'A' type by mechanical cutting, which reduces their width, and the thinning of the hedge bottom which is inevitable if hedges are not plashed ('laid') in the traditional way, are both thought to be deleterious to insect life. The entomological effects of these processes have not been quantified.

Some attention has been given to the question of whether hedges are 'primary' or 'secondary' habitats (eg O'Connor 1984). Although this is relevant to insect conservation in hedges, a more important question is whether marginal features of all kinds include the permanent, total, habitats of insects, or provide only components of habitats, either in space or in time. This was briefly discussed earlier with reference to butterflies on sprayed and unsprayed headlands. In many cases, hedges (and other field margins) do indeed seem to provide a complete habitat for many species. The small size of most insects of course means that a boundary feature represents a much larger area of potential habitat than may be the case for a bird or mammal.

Dispersal

It has been stated that a characteristic feature of insects in agricultural biotopes is their mobility and ready colonising ability. Dispersal is most important in those biotopes which are destroyed and re-created most rapidly; most obviously these are agricultural crops themselves. That pest problems are serious even when cultural, as well as chemical, control is practised is evidence of the dispersive power of insects. In the more permanent boundary features such as hedges, dispersal may not be as important as it is for headlands, for example, which may be ploughed each year.

Most insects disperse independently of directional features, such as hedgelines, although the vagile butterflies and some other species may disperse along hedges which provide shelter from the wind. In general, however, the idea that boundary features provide 'corridors' for insects to disperse along does not seem to accord with the facts. However, boundary features may provide a chain of permanent habitats which may be important in the dispersal of species.

APPLIED BIOGEOGRAPHY

Considerable attention has been given recently to the application of biogeographical theory to the choice, design and performance of nature reserves (eg Margules and Usher 1981, Margules et al 1982). Questions of the size, shape, nature of the surroundings and isolation of areas set aside for wildlife can equally well be asked of agricultural land in the context of field margins and wildlife conservation. However, there are few answers to many of these questions.

The question as to whether boundary features link, in any substantial way, populations of insects on protected sites seems to depend on the insects. For many of the rarer and more threatened species, the answer seems to be generally 'no'. Many butterflies, and probably other insects, exist in discrete populations with little dispersal between them. Most field margins are too much altered to provide the habitats for the insects whose presence is valued on protected sites. Current views are that the isolation and fragmentation of 'natural' sites is not compensated for by field margins and that re-establishment, after appropriate management has recommenced, rather than waiting for natural recolonisation, is the correct strategy to deal with species which become extinct locally (Anon 1986, Morris and Thomas in press). Experience with the Adonis Blue butterfly (Lysandra bellargus), for instance, suggests that field boundaries are ineffective in linking colonies of the butterfly on chalk downland (Thomas 1983).

Little information is available about the effects of field size and shape on the insect faunas of boundary features of any type, or indeed if there are any effects. It would be interesting to see whether large fields dilute, or concentrate, the faunas of hedges (or other features) which surround them. The field pattern which would most assist in aiding dispersal remains to be determined.

Almost equally uncertain are the effects of the size of individual agricultural holdings and the intensification of agricultural use over large areas of land, eg the 'prairie' fields' of East Anglia. In such a landscape, the faunas of those hedges or other features which survive may well become progressively impoverished as the species which disperse less well or less far are progressively eliminated. Some work on these problems is currently being done (S. Wratten, pers comm).

One idea which has been current for some time is that hedges are essentially linear woodlands, or substitutes for them. Because the avifauna of hedges is largely woodland in origin, this idea has been particularly advanced by ornithologists. It raises the question of how boundary features interact with other forms of land use, particularly forestry, urbanisation and the 'site safeguard' aspects of wildlife conservation. In particular, the interactions with modern transport systems, primarily roads but including railways and even airfields, could be important since several authors have demonstrated that roads are a barrier to the dispersal of some insects, at least ground-living ones (eg Mader 1981).

Traditionally, agricultural land has been regarded as providing the 'background conservation' of wildlife in Britain. With a shift away from permanent grass to arable, and increasing intensification, this view has been under attack recently. We need to know whether the contribution of arable land to wildlife conservation can be quantified, either in terms of species representation or in the reservoir of relatively common species which it represents. In such an assessment, the contribution of field margins is likely to be important.

Whatever the future brings for the conservation of insects in Britain, field margins will continue to support a wide range of species and to provide habitats, or habitat components, for them. Perhaps the most crucial question which needs to be asked is whether this contribution is significant, in terms of populations of common as of well as of rare species, in the context of protected sites where wildlife conservation is either a primary or secondary objective of management, and in the context of conservation at local, regional and national levels.

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THE ENVIRONMENTAL INTEREST OF FIELD MARGINS TO GAME AND OTHER WILDLIFE: A GAME CONSERVANCY VIEW

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ABSTRACT

In this paper we summarise the research which has shown the importance of field boundaries and the outermost edge of field crops to gamebirds and other wildlife. Permanent field boundaries make up the majority of nesting habitat for grey and red-legged partridges in Britain. Their value to these species can be greatly enhanced by retaining or creating an earth bank at the base of the field boundary and by increasing the amount of dead grass in the hedge bottom. These habitat features also benefit overwintering polyphagous predatory insects of crop pests.

The outer edge of crops (field headlands) are the major chick-rearing areas for grey and red-legged partridges. The chicks feed on arthropods and weed seeds which are significantly more abundant in the field headlands than elsewhere.

There are two essential components of the field margin that are known to be important to gamebirds. First, the hedgerow or field boundary which is used by the grey partridge (*Perdix perdix*), the red-legged partridge (*Alectoris rufa*) and the pheasant (*Phasianus colchicus*) as nesting cover. It has been estimated that up to 90% of Britain's partridge population breeds in this field boundary system and possibly 50% of the pheasant population. The second component of the field margin is the outermost edge of the crop. This is the area, in cereal fields at least, in which newly hatched gamebird chicks feed.

The loss of hedges resulting from increased mechanisation and intensification in modern farming has been given as one of the causes for the widespread and dramatic decline of wild partridges in Britain (Potts 1980). The importance of field boundaries to partridges has been demonstrated by three further studies. Church (1980) showed that individually marked grey partridges in east-central Wisconsin, USA, spent the majority of their time after pairing in close proximity to nesting cover. A similarly intensive study of red-legged partridges in north-west Norfolk in Britain showed that the proportion of males remaining to breed in an area reflected the distribution of suitable field boundaries (Green 1983). A more extensive study of 17 farms throughout Britain (Rands 1982) showed that the number of yearling partridges of both species remaining to breed in an area (an index of which is known as recruitment efficiency - see Rands 1982 for details) was related to the amount of nesting habitat available. Figures 1 and 2 show the relationship between the amount of permanent field boundary available and the recruitment efficiency of grey and red-legged partridges respectively. For grey partridges it is clear that beyond 8 km of field boundary per km^2 there is little benefit of additional nesting cover, a conclusion supported by Potts (1980).

For ten farms for which breeding densities were accurately obtained in 1981 (Rands 1982), the within-farm correlation between the amount of nesting habitat available and breeding density for both species of partridge are given in Table 1. The detail of these relationships has been given elsewhere (Rands 1986) but it is clear that the breeding density of both species rises with the amount of nesting cover.

TABLE 1

Correlation coefficients between the breeding density of grey and red-legged partridges and the amount of hedgerow available as nesting habitat for ten study farms.

Farm	Grey partridge			Red-legged partridge		
	n	r	p	n	r	p
A	5	0.90	0.03		None present	
B	6	0.84	0.03	6	0.87	0.02
C	6	0.62	0.19	6	0.10	0.89
D	6	0.83	0.04	6	0.93	< 0.01
E	6	0.82	0.05	6	0.90	< 0.01
F	5	0.90	0.02	5	0.87	0.03
G	5	0.86	0.05	5	0.79	0.05
H	5	0.12	0.78	5	0.17	0.78
I	6	0.88	0.02		None present	
J		None present		5	0.88	0.02

Where 'n' is the sample size (blocks of farmland per farm); 'r' is the correlation coefficient; 'p' is the level of statistical probability.

Variation in hedgerow quality (physical structure and vegetation characteristics) has also been shown to influence the suitability of hedges for nesting. Blank et al (1967) suggested from a survey of partridge nests in seven field boundary types (woodland strip, thick hedge, trimmed hedge, incomplete hedge, grass track, grass strip, wire fence) that incomplete hedges were the most favoured of these, a result they attributed to the vegetation characteristics of such hedgerows. In the hedgerow complex of Saskatchewan, Hunt (1974) showed that grey partridges nested in association with gaps in the hedges which he found contained more suitable ground vegetation.

The first study to quantify these variations in nesting cover quality (Rands 1982) showed that two features of hedgerows were of overriding importance to grey partridges; the amount of residual dead grass in the

FIGURE 1 The relationship between the amount of permanent field boundary available and the recruitment efficiency of grey partridges.

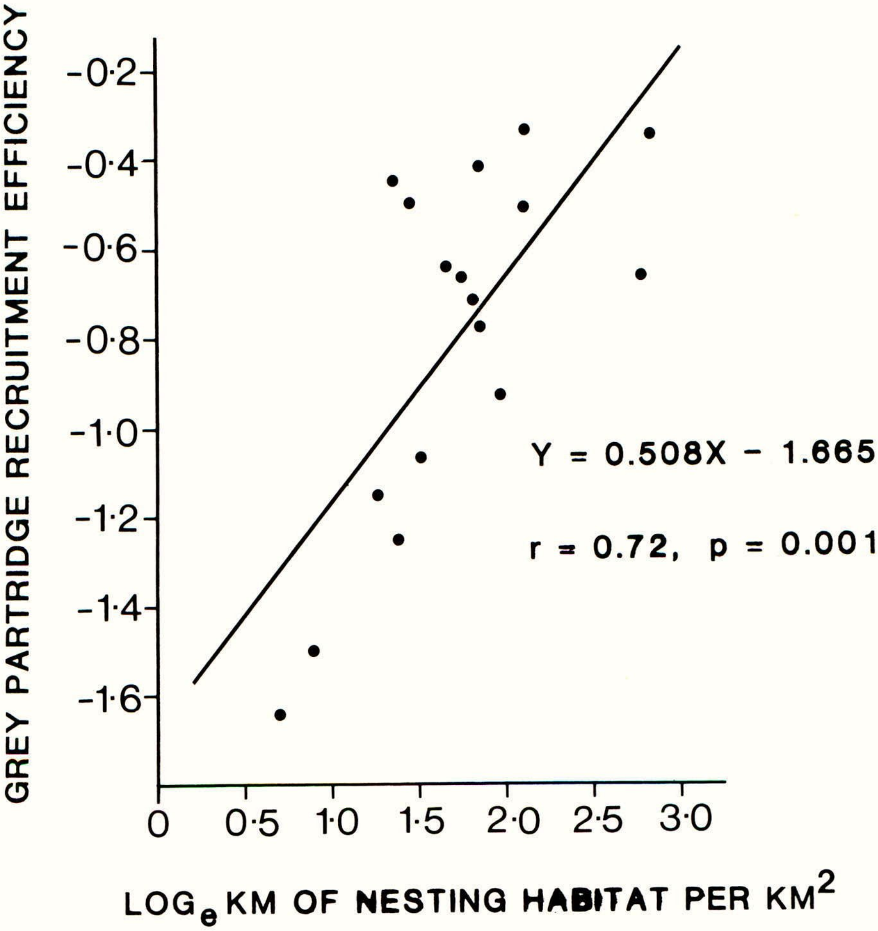
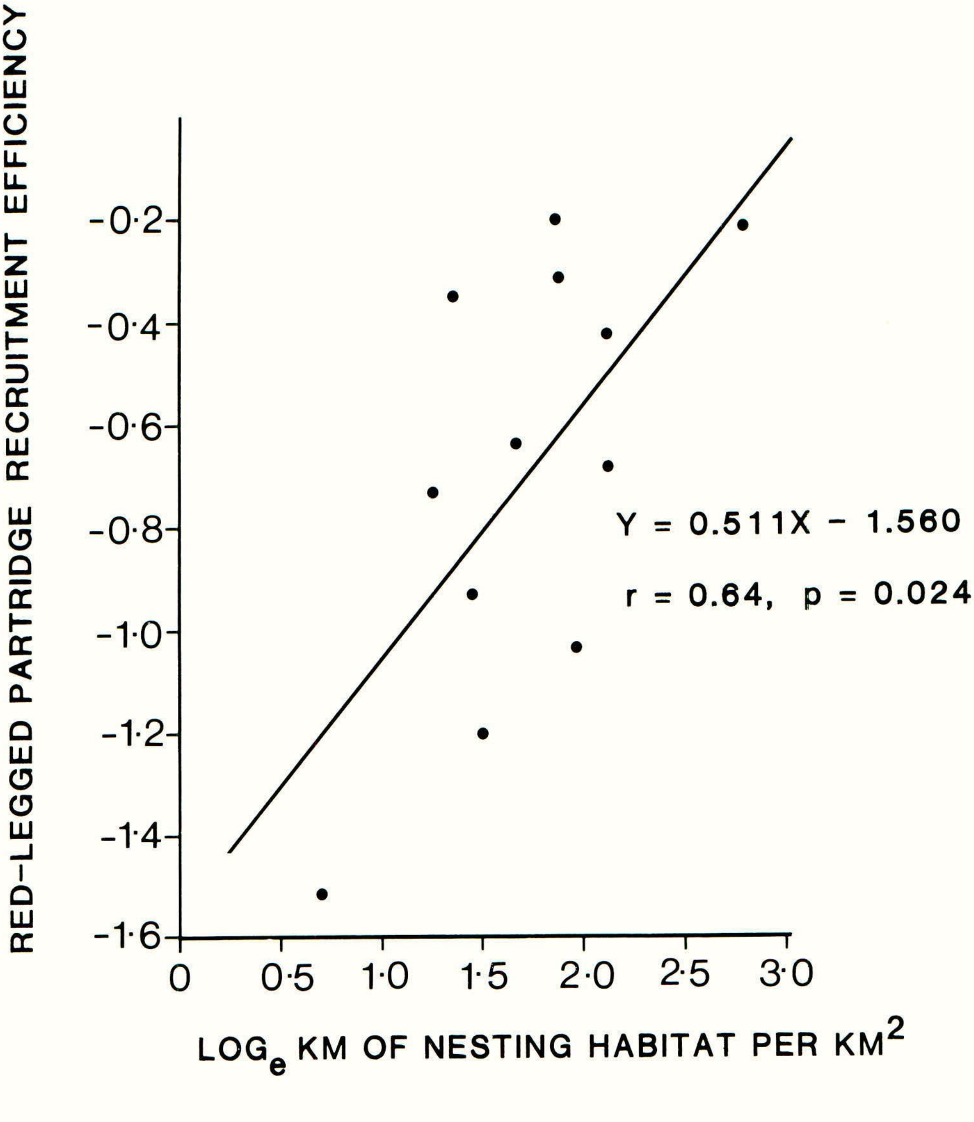


FIGURE 2 The relationship between the amount of permanent field boundary available and the recruitment efficiency of red-legged partridges.



hedge bottom and the presence of an earth bank at the base of the hedge. For red-legged partridges the amount of nettle (Urtica dioica) in the hedge bottom was the most influential aspect of habitat quality. All these factors were found to influence recruitment efficiency, breeding density and nest-site selection (Rands 1982, 1986).

While the hedgerow is vital as a nesting habitat, as soon as eggs hatch the brood of chicks is moved into the adjacent crops, and hedges are never used as a foraging area for the chicks of either species of partridge or the pheasant (Green 1984, Hill 1985, Rands 1986). The diet of grey partridge chicks has been widely investigated and it has been shown that they feed almost exclusively on four or five insect groups for the first ten to fifteen days of life (Ford et al 1938, Southwood and Cross 1969, Potts 1970, 1980, Green 1984). These insects are found in cereal fields and are significantly more abundant close to field boundaries than out in the middle of fields (Green 1984). Red-legged partridge chicks feed on insects and grass seeds in both cereals and root crops and again their food supply is more frequent in the field margin (Green 1984). Consequently, broods of both species of partridge choose to feed in the edges of fields where their arthropod and weed-seed food supplies are most abundant (Green 1984, Rands 1986).

The direct contribution of the field boundary and outermost edge of the crop to the biology of gamebirds is clear. However, the presence of a field boundary that has its own distinct structural and vegetational characteristics also has possible indirect benefits to game production as well as potential benefits for farmland wildlife other than game.

The increasing intensification of modern farming, especially the increased use of pesticides has been implicated in the decline of wild gamebird populations in Britain via a reduction in the numbers of insects vital in the diets of chicks (Potts 1980, Hill 1985). Therefore, methods of cereal production that encourage lower pesticide inputs, or the use of more selective agrochemicals such as in those systems that incorporate an integrated approach to pest management, would be of indirect benefit to gamebird chick survival.

The role of the natural enemies of pests has received much attention in these integrated systems, and research has recently focused on the role of farmland habitat in the biology of these natural enemies, especially the polyphagous predators of cereal aphids (Sotherton 1984, 1985).

Extensive surveys of crop and non-crop habitat on farmland in the winter has shown the importance of the field boundary as the overwintering sites of many important species of polyphagous predators. Table 2 shows the proportion of the total numbers of six species of polyphagous predators of cereal aphids captured on farmland that were found overwintering in field boundaries. These six species were those that when listed in order of their importance as cereal aphid predators, according to the criteria of Sunderland and Vickerman (1980), came out most highly ranked. Non-crop habitats provided overwintering sites for over 60% of the total numbers of these species, field boundaries being the most important of these non-crop habitats.

TABLE 2

The percentage of the total numbers of six species of highly ranked polyphagous predators of cereal aphids found overwintering in six types of farmland habitat, Hampshire 1981 - 1983.

	Field boundaries	Woodland	Cereal stubbles	Autumn sown cereals	Stubble turnips	Grassland
Carabidae						
<u>Agonum dorsale</u>	87.0	12.2	-	-	-	0.8
<u>Bembidion lampros</u>	55.9	11.2	1.4	-	-	31.5
<u>Demetrias atricapillus</u>	88.4	2.5	1.5	-	-	7.6
Staphylinidae:						
<u>Tachyporus chrysomelinus</u>	42.6	21.4	4.4	15.1	1.5	15.0
<u>Tachyporus hypnorum</u>	42.9	20.5	3.2	14.1	2.6	16.7
Dermaptera:						
<u>Forficula auricularia</u>	37.8	33.4	11.4	-	-	17.4

Examination of the types of field boundary most used by each species showed that a grass strip, usually beneath post and wire fences, was in most cases providing overwintering sites for the lowest proportion of predator species (Table 3). The clipped thin hedgerow growing on a raised grass bank (hedge bank) was an important site for the Carabidae especially Demetrias atricapillus, whereas shelterbelts of deciduous trees were found to provide overwintering sites for the greatest proportion of staphylinid beetles of the genus Tachyporus (Table 3).

TABLE 3

The percentage of the total numbers of five species of highly ranked polyphagous predators of cereal aphids found to overwinter in field boundaries in four different types of boundary found in Hampshire, 1981-1983.

	Boundary type*			
	Grass bank	Hedge bank	Grass Strip	Shelterbelt
Carabidae:				
Agonum dorsale	32.4	30.0	12.3	25.3
Bembidion lampros	22.9	31.5	23.5	22.1
Demetrias atricapillus	19.4	59.8	7.3	13.5
Staphylinidae:				
Tachyporus chrysomelinus	24.4	26.9	8.7	40.0
Tachyporus hypnorum	19.5	24.8	18.2	37.5

* (full descriptions in Sotherton 1985)

The implications of field boundary quality, and the ratio of the area of boundary to the areas of enclosed crop (i.e. field size), in relation to the effectiveness of overwintering predators as natural enemies of cereal aphids have been less well researched. Certainly we know that for D. atricapillus, mid-field, mid-summer densities are significantly positively correlated with their overwintering density in surrounding field boundaries the previous winter. Also, that higher numbers of this beetle are to be found in fields surrounded by hedgerows compared to fields surrounded by grassy boundaries (Coombes and Sotherton 1986). However, much more research is needed to assess the effectiveness of these predators with increasing field size and decreasing habitat quality, as well as to discovering the best methods of creating new field boundaries or improving existing ones.

Management of field margins for game must not be viewed in isolation. Alterations to the cutting regimes of the hedges, grass banks or ditches (timing, frequency, severity), to the presence or otherwise of a sterile strip of land between the field boundary and the crop itself, and finally to the use of pesticides on the outermost areas of the crop (the outermost 6 metres of the headland), are also of potential benefit to other forms of farmland wildlife beyond gamebird species. For example, as details of the ecology of some species of butterflies found on farmland are discovered, we can determine how these species interact with both crop margin and field boundary habitats, and thus how alterations to the habitat management of these areas could be affecting them (Dover 1986).

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