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Use of Cereal Fields by Birds: A Review in Relation to Field Margin Managements

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EXECUTIVE SUMMARY

1. This report uses information from three studies by The British Trust for Ornithology to assess the extent to which different bird species use field margins; a three-year study of bird populations wintering on organic and conventional farms in southern Britain; a two-year study of the spatial use of set-aside fields by birds in summer also on farms in southern Britain and; a two-year survey of cereal headlands under different management treatments on one farm in Hampshire. A review of the literature is used to assess the diet, foraging and nesting behaviour of the farmland bird species identified as most likely to benefit from sympathetic field margin management. This is used, in conjunction with expert knowledge, to determine the potential effects of field margin management practices on plant and invertebrate food resources for birds. The relative value to birds of different field margin management practices is assessed and recommendations are made concerning optimal field margin management practices. The potential wildlife benefits of sympathetic management of field margins are compared with three other approaches to enhancing farmland bird populations; whole field set-aside, organic farming and integrated crop management. Finally, future research needs are identified in relation to maximising the wildlife benefits of field margin management.

2. Field margins are usually defined as the land between the crop and the field boundary, together with the extreme periphery of the crop, but generally extending no more than 12 m into the crop itself. Cereals account for 51% of the total area of arable land in Great Britain with approximately 400,000 km of cereal field edge in the UK. If all such boundaries included a 6 m managed margin, approximately 200,000 ha of land would be available for wildlife benefits in arable areas. Thus, in terms of area alone, the potential wildlife benefits that could be derived from sympathetic management of field margins are considerable.

3. Analyses of the breeding season data from the set-aside and cereal headlands studies suggest that field edges are used, though not necessarily strongly preferred, by a range of bird species in summer and avoided by very few. In summer, overall bird density was significantly higher on field margins compared with field centres. Preferences for foraging in field margins as opposed to field centres were evident among a range of breeding birds including gamebirds (Pheasant and Grey and Red-legged Partridge), thrushes (Blackbird and Song Thrush) and finches (Chaffinch, Goldfinch, Greenfinch and Linnet). All these species made greater use of the area between 5 and 20 m from the boundary with Blackbird, Song Thrush, Dunnock, Yellowhammer and Chaffinch showing a bias towards the outer 5 m while Goldfinch, Greenfinch and Linnet were at higher densities in the 10-20 m zone than elsewhere. Summer densities of Skylarks and a combined group of four wader species (Lapwing, Stone Curlew, Oystercatcher and Snipe) were significantly higher in the field centres (>20 m from the boundary) compared to field edges (0-20 m from the field boundary). No differences in bird densities were observed between sprayed and unsprayed headlands or in relation to hedgerow quality or crop type.

4. The winter use of cereal field margins was examined using data from a comparative study of organic and conventional farms. In winter, preferences for field margins were less evident although, as in summer, there was little evidence of avoidance of margins by any bird species. Only one group of birds, finches (House Sparrow, Yellowhammer, Goldfinch, Greenfinch and Linnet) showed higher than expected numbers in field margins. At the whole farm level, the effects of margin density on bird density were weak but overall bird density did increase with hedgerow density and field margin effects were not independent of hedgerow effects. The absence of any apparent preference for field margins in winter may be related to increased mobility of birds in winter when they are not constrained to remaining close to nests which are

often in the field boundary. Alternatively it may be related to the fact that the winter work focussed on grass field margins whereas the breeding season studies focussed on set-aside (mainly naturally regenerated rotational set-aside) and conservation headlands both of which may offer increased foraging opportunities compared with grass strips (see 19).

5. In general the three above studies suggest that field margins may be used as foraging habitat by a wide range of bird species and avoided by very few. Some species show quite strong preferences for margins. Ones avoiding margins are mainly open field species notably Skylark and Lapwing. Preference for margins may reflect central place foraging (birds may forage near hedgerow nest sites), reduced predation risk (birds can retreat quickly to hedgerow cover) or increased feeding opportunities (increased abundance of seed and/or invertebrate prey in field margins). But data are not available to distinguish between these three potential mechanisms.

6. Twenty-two bird species were identified as commonly associated with lowland farmland and likely to benefit from sympathetic management of field margins. Information on the diet, foraging and nesting habits of these species was derived from the published literature. A small number of species, such as Grey and Red-legged Partridge and Corn Bunting, may benefit from margin management through improved nesting habitat. Some species may also benefit through improved cover from predators although current understanding of habitat-predation interactions is limited. However, the major benefits of appropriate management of field margins will be through affecting abundance and availability of food rather than providing nesting habitat or influencing predation risk and we therefore focussed on food availability in this review.

7. The major current field margin management treatments designed to benefit wildlife include: grass strips (including grass only strips, grass and wildflower strips and beetle banks); naturally regenerated (rotational) set-aside margins; uncropped wildlife strips; game cover crops and conservation headlands. The potential value of each of these treatments for birds was reviewed.

8. Four important caveats need to be made concerning the validity of comparing the value of field margin management practices for birds. First, the relative value of a number of these margin treatments will vary considerably between different geographic locations in Britain usually reflecting differences in soil type and fertility and/or differences in the existing seed bank. Second, the relative value of a number of these margin treatments will change with time after establishment. This is particularly true in the case of naturally regenerated and, to a lesser extent, sown grass strips. For the purposes of this report we assume 'ideal' conditions and compare treatments in the first one to two years after establishment. Third, margin managements provide different benefits at different times of year making direct comparisons difficult. Fourth, little quantitative data exist on invertebrate abundance and diversity on different field margin management treatments and studies have usually been limited to a small number of sites and carried out over one or two years only. Since invertebrate abundance and diversity varies a great deal between and within years, attempts to assess the relative value of field margin treatments based on such studies are necessarily very preliminary.

9. The focus of this review was on field margins rather than field boundaries but it is important to note that the value of such margins will be heavily influenced by field boundary characteristics. Hedges hold a greater number of breeding birds than any other feature in farmland and can provide food, nest cover and shelter from harsh weather and predation. In general, bird species richness increases with the overall size and shrub/tree species richness of a hedgerow. One consequence of this is that field margins adjacent to relatively large, species rich, hedges are likely to be used by, and so provide benefits for, a larger number of farmland birds.

10. Sown grass strips may fulfil a range of functions. In addition to creating new habitat, they may protect hedges from agricultural operations, prevent annual weed ingress and form access routes round the field. If weed control is the only aim of field margin restoration, grass-only mixtures are the most cost-effective solution since dominant species such as Red Fescue and Smooth Meadow grass form a dense sward base very rapidly. The provision of grass strips can provide food for bird species such as Cardueline finches, Turtle Dove, Tree Sparrow and House Sparrow that feed on grass seeds. Grass swards also provide a valuable habitat for arthropods living at or just below the soil surface such as Carabid and Elaterid beetle adults and larvae and Tipulid larvae (leatherjackets). The latter are particularly important for species like the Grey Partridge when feeding chicks.

11. The incorporation of perennial wildflowers into grass strips provides plants that flower at different times of the year and will provide a more diverse plant food source for birds over a longer period of time. The presence of perennial and biennial wildflowers will also greatly enhance the insect fauna by providing host plants for a range of phytophagous species especially Hemiptera, Hymenoptera and Araneae. Grass and flower strips may be established either by sowing or through natural regeneration. In the latter case, the sward will be dominated in the first year by annual weed species with some biennials. Perennial species usually dominate in the second and subsequent years. The nature of the sward that develops will depend largely on soil type and existing seed bank. In areas where soil fertility is relatively low and the soil seed bank and local flora are good, natural regeneration may be more cost-effective and result in a sward of higher conservation value. Sown swards will develop a cover that contains a relatively high proportion of perennial species in the first few years after establishment. Some consideration should be made of seed provenance when sowing a grass & wildflower strip and where possible local provenance seed should be used. (In this report comparisons between treatments assume that naturally regenerated grass swards resemble naturally regenerated rotational set-aside margins (see 14) in year one and sown grass and flower strips in subsequent years.)

12. The availability of seeds and invertebrates on grass-only and grass and flower strips will be influenced by the cutting management. Such strips typically need to be mown once a year to preventing suckering shrub species, especially Bramble, from colonising. Autumn cutting will leave a short sward over winter which is favoured by birds, such as thrushes, that feed on soil invertebrates. Cutting in mid summer usually has detrimental effects on the invertebrate community and management is better undertaken in spring and autumn but care must be taken to ensure it does not overlap with the breeding season of ground-nesting species such as Skylark (mid April to late June). If swards become very tall and dense, foraging efficiency of birds in these margins will be reduced.

13. Grass-only strips that are cut on a less than annual basis, such as those of beetle banks, will develop dense tussocky swards and these provide ideal habitat for small mammals such as voles, mice and shrews. Creation of such vegetation, whether as mid-field beetle banks or at field margins, will increase foraging opportunities for birds species that depend on small mammals notably Kestrel, Tawny Owl and Barn Owl.

14. Natural regeneration on set-aside field margins **may be as rotational or non rotational set-aside. The latter is usually planted with Perennial Rye Grass and may be considered a form of grass-only strip. Rotational set-aside favours annual weeds and results in areas of winter**

stubble every year. The diversity of plant food that develops on set-aside land will depend largely on the existing seed bank, soil type and soil fertility. However, whole-field set-aside has been shown to be favoured as a foraging site over arable crops by a range of bird species both in summer and winter and, with the exception of species like the Skylark that avoids field margins, the same benefits are likely to be conferred by set-aside margin strips. The creation of 'stubble strips' is likely to have significant benefits for birds. In recent years, this habitat decreased in area with the decline of spring sowing of cereals and has also declined in quality as a food source for birds. Efficient harvesting has reduced levels of spilt grain and increased herbicide use has reduced diversity and abundance of annual weeds. Stubble fields are used extensively by seed-eating birds such as Corn Bunting and Skylark. Naturally regenerated (rotational) set-aside margins can also provide an important source of invertebrate food for birds but higher numbers of invertebrates may be favoured by leaving set-aside in place for more than a year. This provides better ground cover and avoids cultivation of soil in winter which causes high mortality of insects such as sawfly and Carabids that overwinter in the soil as pupae or larvae respectively. However, the typically open sward structure of rotational set-aside may facilitate foraging by birds regardless of absolute abundance (see 18). Most small mammal species prefer relatively dense cover and numbers tend to be low in rotational set-aside with sparse cover. This option is therefore less likely to benefit raptors and owls within farmland habitats.

15. Uncropped wildlife strips are cultivated approximately annually in the autumn but not sown and are designed to encourage rare annual flora. The application of this margin treatment to date has been localised and restricted to light shallow soils such as those in the Brecklands ESA where it is targeted at the conservation of rare arable weeds. The results of this treatment cannot be readily extrapolated to other soil types. However, where adopted, and if annual plants such as Chenopodiaceae are allowed to flower, the strips will provide good feeding areas for birds. They support large numbers of invertebrates; spiders, Carabid beetles and Heteroptera are all more abundant than in conservation headlands in cereal fields. Uncropped wildlife strips, unlike conservation headlands, are not usually ploughed but are rotovated three out of every four years and only once in the autumn of any one year when it is least likely to affect invertebrate populations. In addition, many plants of disturbed ground such as Knotgrass, Hemp-nettle and Scentless Mayweed support large numbers of phytophagous insects.

16. Game cover strips are usually established using a variety of plants with the commonest cover crops being Maize and Kale. Typically game cover crops are planted as blocks or strips alongside woodlands where gamebirds are released. Seed supplies are usually good on game cover strips provided by the sown crops and also by weeds allowed to establish within the crops. While the strips will not support the variety of insects and other arthropods that occur in more botanically diverse habitats, such as uncropped wildlife strips, some of the crops used can support large numbers of aphids and Lepidoptera larvae which are valuable food for farmland birds. The relative value of different game cover and winter cereal crops is not known and is the subject of an ongoing study by the Game Conservancy Trust and British Trust for Ornithology.

17. Conservation headlands are created by reducing or eliminating agrochemicals in the outside edge of the crops. Broad-leaved annual weeds are allowed to grow and these provide food resources directly, in the form of seeds, and indirectly as host plants for a range of phytophagous insects. Invertebrates, some associated with particular weeds, are also encouraged, such as sawflies and certain Hemiptera that are important for chicks especially of gamebirds. Conservation headlands were developed initially for the conservation of gamebirds within farmland and they have been shown to have significant benefits in terms of brood size and chick survival for Grey and Red-legged Partridge and Pheasant. The wider benefits to non-gamebirds have been less well studied but in general it seems likely that conservation headlands will provide a valuable source of invertebrates and seed for a range of bird species. The diversity and abundance of both food types is likely to be less than that of uncropped strips and may be higher or lower than the very variable levels on naturally regenerated strips. Conservation headlands have also been shown to benefit small mammal populations by increasing food availability for species such as Wood Mice.

18. It is important to asses the accessibility of food under different margin management schemes and the extent to which birds are able to utilise enhanced food supplies. Insect and seed abundance do not necessarily equate to availability for birds since the structure of the vegetation will influence foraging behaviour. Current understanding of the detailed foraging behaviour of most farmland birds and the way in which food availability is modified by vegetation structure is limited. In general, however, open patchy swards generated by naturally regenerated vegetation are thought to be more suitable as foraging habitat than dense swards. The encouragement of a diverse insect fauna will not automatically address the food requirements of all farmland birds which depend upon invertebrates as either adults or nestlings. Much more information is needed on key food items required for particular bird species so that management schemes can be tailored to their needs. Management of margins to increase certain key insect groups, rather than just encouraging general arthropod diversity, may be more profitable for some individual bird species.

19. In general the best winter food supplies (mainly seeds) will be provided by options that create stubble strips in winter. The best summer food supplies (invertebrates and seeds) will be provided by a diverse sward. Stubble will be provided by game cover crops and naturally regenerated rotational set-aside strips. In summer plant food (seeds, fruits and green material) will be highest on those options that are botanically most diverse. Grass and wild flower strips, and uncropped wildlife strips (in certain geographic regions) and are likely to offer the highest food availability in summer, followed by [naturally regenerated (rotational) set-aside field margins] conservation headlands. The inclusion of a form of winter stubble is, in our view, highly desirable in maintaining winter food resources for farmland birds. The inclusion of an area of permanent cover, such as a grass or grass and flower strip, will promote invertebrate and small mammal populations. By maximising the diversity of habitat structures present at the field edge the opportunities for birds should be further enhanced. Thus the presence of a well-managed hedge with hedgerow trees, together with a tussocky grass hedge bottom, will enhance the wildlife value of most of the management treatments of the margin itself.

20. The least valuable margin management, in terms of its potential value to birds as a source of plant and invertebrate food, is a grass-only strip. Although these are cheap and easy to establish and hence frequently adopted, they have very low wildlife interest compared with other treatments considered here.

21. There is little detailed information on the optimal width of field margins but many advisory publications recommend 6-12 m and studies of herbicide drift from adjacent crops suggest a buffer strip of at least 6 m is required to protect field margin flora. In the absence of evidence to the contrary we would not wish to contradict this and recommend margins of widths of 6-12 m.

22. Timing of management, e.g. cutting of grass strips to prevent scrub encroachment, must be selected with care. Cutting should be avoided during the summer breeding season of ground nesting birds such as Skylark (early/mid April to mid/late June) and where Corn Buntings are nesting later in the season (mid May to late July) . Cultivation of soil during the winter causes high mortality of insects such as Sawfly that overwinter as pupae in the soil but provided land is not cultivated until adult emergence is complete in spring (early May is peak emergence) the habitat will provide a key overwintering site.

23. The location of field margins with respect to hedgerows and woodland can significantly enhance their value. If margins are to be managed on only a proportion of fields then, where possible, these should be adjacent to well maintained hedges or woods that provide good nesting habitat for birds.

24. Field margin management at the whole farm scale is potentially very advantageous for birds; most species will use field margins; few avoid them and the abundance of invertebrate and plant prey is likely to decrease with distance from the field edge. Other approaches to enhancing bird density are compared with field margins below. It should be noted that such comparisons are extremely difficult to make due to the high variability within whole farm approaches. For example, the nature of the cover that develops on rotational set-aside is highly variable and dependent on the existing soil bank as well as soil fertility and type and there is also much variation within organic farms and little is known about Integrated Crop Management.

25. Many of the benefits of whole field set-aside could be gained from set-aside field margins at least in summer. Few species, with the exception of Skylark and Lapwing, avoided field margins in the summer and a number of species occurred more frequently in the margins than the field centres. The value of rotational set-aside for birds is likely to derive from increased food availability as a result of reduced pesticide inputs, an open patchy sward that facilitates foraging in summer and stubble in winter. On an area for area basis, most of these benefits will also be gained from one of more of the field margin treatments.

26. Organic farming may provide significant benefits for birds since, in general, organic farms support higher breeding and wintering densities of a wide range of bird species than do conventional farms. These benefits are likely to derive from a combination of the use of rotations, reduced pesticides (herbicides and pesticides resulting in increased food availability), no use of inorganic fertilisers and often better hedge management. Although substantial ecological benefits may derive from this method of farming, it forms a relatively small part of total farmed area in Britain (c. 50 000 ha in 1997) and conservation benefits are likely to be localised. In contrast, field margins provide the potential to integrate key features of organic farming, such as reduced pesticide and fertiliser inputs and small areas of grass leys over a much wider scale. However, on a local scale they are less likely to introduce the mosaic of habitats or the combination of arable and livestock associated with organic farming.

27. Integrated Crop Management (ICM) is a combination of farming practices designed to balance the economic production of crops through applications of rotations, cultivations, choice of seed variety and judicious use of crop production inputs, with measures which preserve and protect the environment. This type of farm management is intermediate between conventional and organic farming but there is no clear cut definition of ICM so the spectrum is a broad one, and since the scheme is relatively new very little information exists about the wildlife benefits.

28. Options for field margin management have traditionally proved popular with the farming community since they incur minimal agronomic losses. It is encouraging that three of the five options under the new Arable Stewardship scheme (launched by MAFF in 1998) relate to field margin management (conservation headlands, wildlife strips and grass margins) and there is a need to monitor both uptake and the agronomic and environmental costs and benefits of these options.

29. Further research is required to assess the relative value of (a) margin management with whole field farming approaches designed to encourage wildlife, in particular the value of margin as opposed to whole field set-aside and wildlife benefits of Integrated Crop Management; (b) tailoring margin treatments to meet specific needs of individual species based on detailed autecological studies, (c) varying the width of field margins. There is also a need to gain a better understanding of the use birds make of farmland in winter, to date most research to date on farmland birds has focussed on breeding season requirements, and of the way invertebrate populations respond to field margin treatments.

1. INTRODUCTION

1.1 Background

The arable landscape of Britain has undergone dramatic changes since the 1940s with many wildlife habitats becoming fragmented and degraded as a result of changing agricultural policies and increased mechanisation (Helps 1994, Kirby 1995). Widespread loss of hedgerows has been well documented (e.g. Barr *et al.* 1995) and the quality of many of the remaining hedgerows and other field boundaries has been eroded through changes in farm management (Boatman 1992, Rew *et al.* 1992, Helps 1994). One consequence of these changes has been the narrowing of field boundaries and margins and the replacement of their original perennial plant community by an impoverished one often dominated by annual pest species such as Sterile Brome and Cleavers.

Field margins are usually defined as the land between the crop and the field boundary together with the extreme periphery of the crop, but generally extending no more than 12 m into the crop itself (Anon 1995a).

Managed sensitively, cereal field margins could provide nesting and feeding sites for gamebirds (Rands 1985 & 1986) and many ground feeding passerines (O'Connor & Shrub 1986), small mammals (Tew 1989, Tew *et al*. 1992, Povey *et al*. 1993), invertebrates such as butterflies (Feber *et al*. 1996, Feber & Smith 1995), plant bugs (Moreby 1994), spiders and beetles (Feber *et al*. 1995) and arable flowers such as Pheasant's Eye and Cornflower (Wilson 1994). Restoration and management of field margin habitat has been widely advocated as an approach to enhancing wildlife biodiversity on farmland and resolving some agronomic and conservation conflicts (Boatman 1994, Mineau & Mclaughlin 1996).

The wildlife value of field margins in a national context is highlighted by the inclusion of Cereal Field Margins as one of the 14 key habitats for which costed action plans have been published in the report of the UK Biodiversity Steering Group (Anon 1995a & 1995b). The latter lists key species and key habitats which are in need of special conservation measures if biodiversity is to be maintained and enhanced in Britain. The focus of the Biodiversity Steering Group's Report on cereal field margins rather than on other crops is a reflection of the dominance of cereal fields over other arable field types. A growing interest in the potential of field margins in integrating agronomic and environmental aims is reflected by the fact that field margins are incorporated in number agri-environment schemes. For example, 'Arable Stewardship' a new agri-environment scheme launched by MAFF in 1998 offers payments to arable farmers to manage their land in ways that encourage wildlife. The pilot scheme has five main land management options three of which relate to field margin managements practices (MAFF 1998).

In recent years there has been growing concern over the decline of many farmland bird species. Several have been recently added to the red list of Birds of Conservation Concern (Gibbons *et al.* 1996) which places bird species into three lists, red, amber and green with those on the red list being regarded as of the highest concern and requiring urgent action. Among red-listed species are several that are likely to use cereal field margins: Grey Partridge, Turtle Dove, Song Thrush, Tree Sparrow, Linnet, Bullfinch, Reed Bunting, Cirl Bunting and Corn Bunting. These species are also included on the Biodiversity Steering Group's lists of globally threatened/declining species (Anon 1995a & 1995b).

The general intensification of agriculture is widely thought to be the major factor causing declines in bird populations. Therefore declines are only likely to be reversed through modification of farming practices. Widespread changes to the management of cereal field margins may prove to be one effective way of enhancing populations of these species without significantly affecting agricultural productivity. It has been shown that conservation headlands, with reduced herbicide and insecticide use, can enhance the breeding productivity of Grey Partridges (Potts 1986) but it is less clear that such margin treatments benefit other bird species. Whilst there have been numerous studies of the value of hedgerows for birds (e.g. Green *et al.* 1994, Lakhani 1994, Parish *et al.* 1994, Barr *et al.* 1995, Sparks *et al.* 1996), there have been no systematic investigations of the ways in which management of cereal field margins may affect bird populations. Nor has there been any attempt to collate existing information on the role of field margins in the ecology of farmland birds. This study aims to provide a review of the current knowledge of the responses of birds to field margins and their management. The review draws on published studies of avian ecology and relevant work about the effects of margin management on vegetation structure, plant composition and invertebrates. In addition two other sources of information are also integrated into the review: expert advice on the effects of field margin management on food resources for birds (E.J.P. Marshall & W. Powell both of IACR see Section 5) and analysis of existing BTO data sets to provide information on the use of field margins by birds.

1.2 Objectives

1.2.1 General objectives

(i) To provide an appraisal of the likely responses of birds to field margin management practices.

(ii) To compare the benefits likely to be derived from field margin management with those from other options for integrating conservation into cereal agriculture.

1.2.2 Specific objectives

(i) Determine the extent to which different farmland bird species forage in field margins as opposed to field centres in order to assess which species may benefit from conservation efforts focussed on field margins.

(ii) Review the factors that are likely to determine the suitability of field margins for each species including food abundance and availability, vegetation structure and predation risk. The study will focus on species identified from objective (i) and also on widespread but declining farmland bird species that are included in the Biodiversity Steering Group's lists of globally threatened/declining species (Anon 1995a&b) and in the Birds of Conservation Concern red list (Gibbons *et al.* 1996).

(iii) Assess the probable effects of different field margin management practices, including conservation headlands, wildlife strips, sterile strips, game crops and grass strips on food resources available to farmland birds.

(iv) Assess for each bird species the value of field margin treatments relative to other approaches such as whole field set-aside, organic farming and integrated crop management for integrating conservation into cereal farming.

(v) Determine for which bird species future research on field margin management should be focused and make recommendations about the experimental requirements and types of treatments that should be examined.

(vi) Generate recommendations concerning optimum field margin management practices for benefiting declining farmland birds.

2. THE DIFFERENT MANAGEMENT OPTIONS FOR CEREAL FIELD MARGINS

2.1 Defining Cereal Field Margins

Field margins can comprise the boundary structure itself, any modified boundary strip of extended habitat, and the crop edge (Greaves & Marshall 1987), all of which may be managed or modified to the benefit of farmland wildlife. The boundary is a structure which can comprise a hedge, grass bank, wall, fence line or ditch. However for the purposes of this review field margins will be defined as in the UK Biodiversity Steering Group Report as 'strips of land lying between cereal crops and the field boundary and extending for a limited distance into the crop' (Anon 1995a). The focus on cereal field margins, rather than arable crops in general, reflects the dominance of cereals over other arable crops. The main factors that have reduced the wildlife value of cereal crops in recent decades include: Intensification of cereal production such as the use of herbicides to ensure a weed free monoculture and summer use of insecticides; a shift to winter cropping and the associated loss of winter stubbles; a reduction in the undersown area associated with the shift to winter cropping and increased use of chemical fertilisers (Anon 1995a&b).

Cereals account for 51% of the total area of arable land in Great Britain (defined as total crops plus bare fallow plus grassland less than five years old); 63% in England, 44% in Scotland and 22% in Wales. The average national field size is estimated to be 12 ha resulting in approximately 400,000 km of cereal field edge in UK. If all such boundaries included a 6 m managed margin approximately 200,000 ha of land would be brought into sensitive management. As such sensitively managed field margins could comprise a significant component of the farmed landscape and afford considerable wildlife benefits to arable areas.

2.2 Management Practices on Cereal Field Margins

The management of field margins to create conditions which benefit key farmland species can take a range of forms. The principal current categories of field margin management are outlined below. The options and the management practices are discussed in more detail in Section 5 of this review. Key characteristics of different field margin management treatments are summarised in Table 2.1.

(i) Grassland strips

These may take the form of grass-only strips, grass and wild flower strips and elevated grass strips or beetle banks. Under the Countryside Stewardship Scheme grassland fallows may be 2 m or 6 m wide and established either through natural regeneration or sowing. They may contain flowers or have them added at sowing (typically Ox-eye Daisy, Ribwort Plantain, knapweeds and Yarrow) and may differ in grass length as a result of different species composition (short grass such as Red Fescue or tall tussocky grass such as Cocksfoot) and management; they may also be raised as beetle banks or level with the field. Grass strips require little active management except some cutting to aid establishment and subsequently to prevent scrub encroachment.

(ii) Naturally regenerated (rotational) set-aside margins

Field margin strips can be created by allowing natural regeneration on set-aside land as 20 m wide margin strips. Set-aside may be either rotational, **where land is taken out of production and left as fallow for one year,** or non-rotational where land is taken out of production for a number of years. **In the latter case the vegetation undergoes a typical secondary succession of annual weeds, followed by perennials. The vegetation cover on set-aside may be established either through natural regeneration or sowing with grass cover such as Perennial Rye Grass. In practice, the latter is the norm on non-rotational set-aside and it may be considered as a form of grass margin. For the purposes of this report we consider naturally regenerated set-aside margins to refer to rotational set-aside only. Natural regeneration is more commonly used on rotational set-aside and this will favour the annual weed species and effectively result in areas of winter stubble every year.**

(iii) Uncropped wildlife strips

Uncropped wildlife strips comprise a 6 m wide strip of land adjacent to the cereal crop together with a 1 m wide sterile strip between the wildlife strip and the crop. The wildlife strip is naturally regenerated vegetation cultivated once every year or two years but not cropped. The sterile strip is maintained so as to prevent aggressive arable weeds spreading into the adjacent crop. This system is designed to encourage rare arable weeds such as Pheasant's Eye and Cornflower which germinate from seed banks that persist at field edges. This field margin management has, to date, been restricted to light and/or shallow soils and targeted at the conservation of rare arable weeds.

(iv) Conservation Headlands

Techniques of modifying the management of arable, particularly cereal, field edges were developed in Germany to conserve rare arable weed species (Schumacher 1987) and modified in the UK by the Game Conservancy Trust to enhance populations of the Grey Partridge (Sotherton *et al.* 1985, Rands 1985, Rands & Sotherton 1987). Conservation headlands comprise either a 6 m or 12 m wide strip forming the outer margin of the crop separated from the adjacent field boundary or other vegetation by a 1 m sterile strip. The conservation headland is cropped with cereals but is managed with limited insecticides (autumn cereals only) or no insecticides (spring cereals) and with reduced inputs of herbicides so as to favour wild arable plants, particularly broad-leaved weeds, and the invertebrates which live on them (Game Conservancy Trust Fact Sheet 2)

(v) Game crops or stubble strips

Farmers keen on encouraging gamebird populations often plant blocks or strips of game cover crops. Game crops or stubble strips usually comprise species like Kale, Quinoa and Maize. Strips of game cover can be included under set-aside as the Wild Bird Cover (WBC) option. The minimum requirement for the latter is a 20 m wide strip and 0.3 ha but the game WBC component may vary within this, for example with a mixture of nesting and brood cover. Stubble strips are equivalent to strips of rotational set-aside promoting annual flora and a mixture of cereal and weed seed in winter on the soil surface.

(vi) Sterile strips

Sterile strips are designed to prevent the ingress of annual weeds from the field boundary into the arable crop, to provide a clean edge to the crop to facilitate harvesting and to provide an area for gamebirds to dry out in wet weather (Bond 1987). They are usually incorporated into other field margin treatments and are not designed to benefit wildlife. However since they are so frequently adopted for weed control we consider them worth discussing here. Sterile strips are usually 0.5 to 1 m wide and are located as part of the cultivated crop edge. Sterile strips are usually created with a herbicide, either applied in the winter using a soil-acting compound, or a contact or translocated herbicide, typically glyphosate, in early summer. Alternatively, the strip can be created by rotovating a 2 m wide strip two or three times in a season.

(vii) A new initiate for cereal field margins - Arable Stewardship

An important development since this report was produced has been the launch of the Arable Stewardship Pilot Scheme. This scheme offers payments to arable farmers to manage their land in ways that encourage wildlife. The pilot scheme, which is being run in two areas of England, includes five main management options, three of which are field margin managements (MAFF 1998). The field margin options within this scheme are not specifically considered here but the three field margin options are all included in the list above. They are:

Crop margins with no summer insecticides; insecticides are not applied between 15 March and harvest over a 10-12 m crop margin. This option has two supplements - conservation headlands within which herbicides are also restricted and conservation headlands with no fertiliser (including organic and inorganic fertilisers).

Grass strips; this option has three supplements (i) grass field margins which must be at least 6 m wide, and may be established by natural regeneration or sown grasses (sown with Cocksfoot, Chewing's Fescue and Timothy and specified rates) and cut once by the end of March and then once or twice before September (ii) beetle banks which must be 2-3 m wide planted with the same seed mix as for grass margins and managed to maintain a tussocky sward (iii) uncropped wildlife strips which must average 6 m wide and be left unsown but cultivated every year or every other year in spring (to a depth of 100-150 mm) or autumn (to a depth of 75-100 mm). Herbicide application is limited and inorganic and organic fertilisers cannot be used.

Wildlife seed mixtures; These can be sown either as blocks or as field margin strips. They may be designed to produce an open sward (with summer flowering plants for foraging insects, foraging sites for birds and cover for mammals such as brown hare); a succession of seeds and cover (for example a mix of two crops one of which sets seed in its first year e.g. Teasel, Kale, Chicory, Millet); or a small grain cereal-based mixture to provide a variety of food for seed-eating birds.

3. THE USE OF CEREAL FIELD MARGINS BY FARMLAND BIRDS

3.1 An Analysis of the Extent to Which Different Farmland Bird Species Forage in Field Margins

In this section of the review, data derived from three previous studies, carried out by the British Trust for Ornithology, have been re-analysed to determine the extent to which different farmland bird species forage in field margins as opposed to field centres. It should be noted at the outset that these studies were designed to address wider 'farmland bird issues' not the specific question of the value of field margins for birds. However these data provide some indication of which bird species use field margins and are thus likely to benefit most from their management. The three studies are referred to throughout as the Manydown Farm, Organic Farm and Set-aside studies.

3.2 Methods and Study Sites

(i) Organic Farm study (wintering birds)

In 1992-1994 the British Trust for Ornithology undertook an extensive study of bird populations on organic and conventional farm systems in southern Britain (Chamberlain *et al.* 1995). Twenty-two organic farms were surveyed across England and Wales. Each organic farm was paired with a nearby conventional farm for a comparison which controlled for geographical variation in bird populations. Conventional farms were selected on the basis of their representativeness of regional conventional farming.

Study sites of similar area were defined on each farm within a pair. Each site received a minimum of three visits in autumn (September-November) and three in winter (December-February). During each visit the perimeter of every field site was walked, every bird seen recorded, its location classified into field edge (defined as up to 5 m from the field boundary) or field centre and recorded directly on to maps. Visits to each farm were carried out within a week of each other and were matched as far as possible for time of day and weather.

In addition to bird counts, data were collected on numerous habitat characteristics of field boundaries e.g. type (hedge, ditch, etc), dimensions (width, length, height), density of trees and fields.

(ii) Manydown Farm study (breeding birds)

In 1984 and 1985 the British Trust for Ornithology conducted studies on the breeding songbird populations of Manydown Farm, Hampshire as part of a wider study on 'Cereal and Gamebirds' undertaken by the Game Conservancy (Fuller 1984, Cracknell 1986). The primary aim of the BTO work was to assess the effects, on breeding songbirds, of leaving cereal headlands (the outer 6 m strip of the crop) unsprayed with insecticides. The study site comprised three farm plots each one containing one set of experimental fields, with unsprayed headlands, and one set of control fields, with sprayed headlands. The main crop types were spring barley and winter cereals. Unsprayed headlands were sprayed in autumn 1983 but not in spring whilst sprayed headlands received chemical sprays in autumn 1983 and spring 1984. The chemical sprays applied to cereals adjacent to the 'sprayed headlands' included autumn applications of grass weed herbicide, insecticide (1985 only) and molluscicide (1985 only) on winter wheat, grass and broad-leaved weed herbicide, fungicide (1984 only) and insecticide on winter barley and a broad spectrum herbicide (1984 only) on spring barley. In spring applications of fungicides, insecticides (1984 only) and grass/broad-leaved weed herbicides (1985 only) were used on winter wheat, fungicides on winter barley and fungicide and broad-leaved weed herbicide on spring barley (Fuller 1984, Cracknell 1986). The edge of all cereal crops at Manydown Farm in 1984 was marked by a rotovated strip approximately 1 m wide. This strip was kept largely free of weeds by rotovating early in spring and again in June or July. In 1985 the crop edge was marked by a 0.5 m wide strip which was kept weed free by spraying with the broad spectrum residual herbicide Atrazine.

Systematic observations of feeding birds were carried out along 100 m stretches of crop edge. The stretches were all adjacent to, and continuous with, woodland or hedgerows (edges with paths, tracks or fences between the crop edge and the hedgerow or woodland were not selected). In 1984 a total of 123 stretches were surveyed; 72 were adjacent to sprayed headlands (45 adjacent to spring barley; 19 to winter wheat and eight to winter barley) and 51 to unsprayed (16 adjacent to spring barley; 23 to winter wheat and 12 to winter barley). In 1985, a total of 48 100 m stretches were surveyed; 24 were adjacent to sprayed headlands (nine adjacent to spring barley; 15 to winter wheat and none adjacent to winter barley) and 24 to unsprayed (nine adjacent to spring barley; 12 to winter wheat and three to winter barley).

Each stretch was visited six to nine times between April and July 1984 and 16 times between April and July 1985. Three timed watches were carried out on each visit between 0630 and 1200 hours (a timed watch is one three or five minute observation in 1984 and 1985 respectively). The locations of all foraging birds seen during the timed watch were recorded in relation to zones of increasing distance from the crop edge assessed with reference to tramlines. Five zones were identified extending a total of 19 m from the hedge into the field (Table 3.1).

(iii) Set-aside study (breeding birds)

In 1996 and 1997 the British Trust for Ornithology carried out work on the value of set-aside land for birds as part of a wider study on the 'Agronomic and Environmental Evaluations of Set-aside under the EC Arable Area Payments Scheme' (Firbank 1996). Data were collected from 11 arable farm sites located in eastern and western England, where set-aside was compared to cereal, root and brassica crops. Within each site, observations were carried out on paired fields, one containing set-aside and the other containing a crop, matched for boundary characteristics (hedge presence/absence, width and height, etc.). The sites were visited three to four times between late March and early July. During each visit one, two hour, standardised count was carried out from a vantage point covering both fields simultaneously. This was followed by one 30 minute transect across each field comprising three to four parallel lines across each field a maximum of approximately 20 m apart. The former provided a comparison of birds utilising (feeding in, landing and leaving) each field. The transects provided a more thorough coverage of the mid field areas. Flocks or known individuals seen returning to a field during a count were recorded only once. Birds which moved between fields during a count were recorded as utilising both fields. Birds disturbed from one field to another during a transect were recorded as using the first field only. All birds seen were recorded and their location classified, by eye, into four distance categories 0-5, 5-10, 10-20 and >20 m from the field boundary.

3.3 Results

3.3.1 The effects of field margin strip density on winter bird density at the farm level

The effects of the presence of grass field margin strips on the density of birds recorded on the edges of fields (within 5 m of the field boundary) in winter were analysed at the whole farm level using the Organic Farm data set. Organic farms have been shown to hold higher densities of birds than conventional farms and this has been attributed, in part, to more extensive areas of good quality hedgerow on organic farms (Chamberlain *et al*. 1995). Bird density per farm was therefore related to the density of field margin strips per farm, the density of hedgerows per farm and whether the farm was under organic or conventional management using a General Linear Model procedure. Interaction terms were initially included in the models, but were subsequently dropped if found to have no significant effect. Habitat data was not collected on certain farms, particularly for field margin type which were often recorded as 'unknown'. These farms are not included in these analyses.

There were very few species where field margin strip density had a significant effect on bird density and no cases where a consistent effect was found across the two years (Table 3.2). Bird density increased with margin density for Woodpigeon in 1992 but decreased for Starling, Redwing, Robin, Linnet and Chaffinch and the density of Pied Wagtails increased with margin density in 1993 but decreased in 1992. In general the effects of margin density on bird density at the farm level were weak. In most cases a significant negative effect of margin density in 1992 was accompanied by a significant interaction between margin density and hedgerow density, indicating that the effects of field margins are not independent of the effects of hedgerow. Hedgerow density had positive effects on bird density in a number of species and also on the density of all species combined.

3.3.2 The use of field margins by birds

(i) Organic Farming study (wintering birds)

The use of field margins by birds in winter was analysed using the Organic Farm data set. The hypothesis tested was that birds were recorded in the centre of fields (further than 5 m from the field boundary) in direct proportion to the area of field centre per farm (i.e. a random distribution). Expected values for each farm were calculated using the formula $[(A_{fc}/ A_{tf}) * B_t]$ where: A_{fc} = area of the field centres, A_{tf} = total area of the fields and B_t = total number of birds recorded on the fields. Small sample sizes for individual species meant it was necessary to classify bird species into functional groups (groups of passerine or non-passerine species defined according to diet, habitat preference, Table 3.3).

Expected values were compared with the mean number of birds per survey visit using a χ^2 test (degrees of freedom were taken as (n-1), where n = the total number of farms in the sample; Table 3.4). Expected values of less than one violate the assumptions of the test (Sokal & Rohlf 1995). For this reason the hypothesis tested considers use of the field centres rather than field margins which, due to their small area, have extremely small expected frequencies of birds. Since the use of the two habitats is not independent, preference for field margins will be reflected in avoidance of field centre and avoidance of field margin will be reflected in preference of field centre, results can be interpreted accordingly. Farms for which certain species groups had expected values of less than one were omitted from the analyses.

In both years, the numbers of all species combined were significantly greater than expected in field centres (Table 3.4). This may be attributable to the fact that species which form the largest flocks tended to be species of open country that showed some avoidance of field boundaries, e.g. mixed plover flocks (Barnard & Thompson 1985). One group of species, finches, showed lower than expected numbers in field centres in both years. Open-ground passerines, large granivores and Woodpigeons and thrushes occurred less frequently than expected in field centres in one year (1994, 1993 and 1993 respectively, Table 3.4). However the result for large granivores should be interpreted with care since two farms, which had very much lower numbers of large granivores than expected in field centres, contributed a large proportion to the total χ^2. The goodness-of-fit test was no longer significant when these farms were removed (χ^2_{33} = 27.9 n.s.).

(ii) Manydown Farm data

No birds were recorded in the majority of timed watches carried out at Manydown Farm (85% (n = 948) and 81% (n = 768) in 1984 and 1985 respectively). Results from different years were considered separately due to the differences in survey methods (number of visits and duration of timed watches). The total numbers of each species recorded foraging in each field margin zone, averaged over the number of visits (six to nine in 1984, 16 in 1985) are shown in Table 3.5. There were 38 sections with no birds recorded on any visit in 1984 and three sections in 1985. These have been omitted from the analysis. The commonest species which foraged in field margins were Dunnock, Blackbird, Chaffinch, Yellowhammer, Robin and Woodpigeon with other species being recorded very rarely. Of these six commoner species, there was a tendency for greater numbers to be found in zone 2, the rotovated strip (Tables 3.1 and 3.5). However, the use of margins by birds was analysed in a similar way to the Organic Farm data set. The expected number of birds occurring in the field margin (defined as zones 1 to 3, which extends 4 m into the crop) was calculated based on the area of all zones using the formula: $[(A_{z1\text{-}3}/ A_{z1\text{-}5}) * B_t$, where: $A_{z1\text{-}3}$ = area of zones 1-3, $A_{z1\text{-}5}$ = total area of zones 1-5 and B_t = total number of birds recorded on all zones. This expected value was compared with the observed value in the first three zones.

The analysis was not possible for individual species due to low expected values, but for all species combined there were significantly higher numbers than expected in the field margin in both years (1984, G_1 = 50.1, $p<0.001$; 1985, G_1 = 20.2, $p<0.001$).

The expected numbers of birds occurring in each field margin zone were calculated in two ways (i) assuming a random distribution (calculated on the basis of zone width and birds distributed directly in proportion to the area of each zone) and (ii) non-random distribution with respect to distance from the hedge. The rationale for the second method is that the four commonest species (Blackbird, Robin, Chaffinch and Yellowhammer) are all thought to be more closely associated with hedgerows than field centres for nesting, and expected numbers were therefore calculated assuming birds show a preference for remaining closer to hedgerows. Expected values for the first model were calculated using [(width of zone/total width of all zones)* total number of birds]. To calculate expected values for the second model the distance of the mid-point of each zone to the field boundary was used as the distance measurement. Thus expected values were calculated using [1/(mid-point of each zone/total width of zones*the total number of birds)]. The numbers found in each zone and the expected frequencies of all species combined are shown in Figures 3.1 and 3.2. Valid analyses were not possible for individual species due to small sample sizes. However, when considering all species combined, significantly more birds than expected used the rotovated (zone 2) strip than the other zones under either method of calculating expected values and this was true in both years (Figures 3.1 and 3.2).

The use of field margins by birds was analysed in relation to the use of insecticides on the crop headlands (zone 3) for the four most commonly occurring species (Blackbird, Robin, Chaffinch and Yellowhammer) and for all species combined. There was little apparent difference in margin use between sprayed and unsprayed headlands (Figure 3.3). In fact the maximum frequency of sightings per visit on sprayed headlands and adjacent field margin strips often exceeded that on unsprayed headlands. Fisher exact tests comparing maximum frequencies (Fisher exact tests must use integers, hence mean values were not used) between sprayed and unsprayed crops (combining zones 1 and 2 and zones 3, 4 and 5) found no significant association in frequency between different treatments and use of zones in either year. A similar analysis was also carried out with respect to the quality of adjacent hedgerow classified into two groups: poor quality hedgerows defined as small and with many gaps, good quality hedgerows defined as tall, wide and with few or no gaps (woodland edge boundaries were omitted). There was no apparent preference for field margins adjacent to hedgerows of differing quality (Figure 3.4). Similar analyses found no association between margin use and whether the adjacent crop type was autumn or spring-sown.

(iii) Set-aside data set

The average density (mean and median) of birds on set-aside was calculated and compared between (a) two distance bands: 0-5 m and >5 m from the field edge (for comparison with the Manydown and Organic Farm studies) and (b) four distance categories or bands : 0-5, 5-10, 10-20 and >20 m from the field margin. Birds were attributed to a distance category according to their position when first seen either feeding, taking off or landing. The maximum distance from the boundary was recorded for birds which changed their position during the count period. In order to avoid pseudo-replication for strongly territorial species in particular (e.g. Skylark) the analyses were carried out using the mean density from the series of visits to each site. Small sample size meant some species had to be amalgamated into functional groups (Table 3.6). The relative use of the two or four distance categories were compared using G and Kruskal Wallis tests. Expected frequencies of birds were calculated assuming a random distribution with respect to field area i.e. that birds were distributed between the two or four distance categories in direct proportion to the relative area of these categories.

The relative use of the field edge (< 5 m from the boundary) and field centre (> 5 m from the boundary) of set-aside fields varied between the eight species and/or functional groups (Table 3.6). Four of the six species/functional groups (Table 3.6) showed a significant association with the field edge; gamebirds (G_1 = 16.9, p<0.001), thrushes (G_1 = 50.0, p<0.001), Yellowhammers (G_1 = 54.7, p<0.001) and seedeaters (G_1= 73.4, p<0.001), whilst Corvids, were the only group to show a strong preference for the field centre (G_1 = 17.3, p<0.001).

Analysis of the spatial usage of set-aside fields within four distance categories (0-5, 5-10, 10-20 and >20 m from the field boundary) reveals further variation between species and/or functional groups. Four typical ground feeding species (Blackbird, KW = 11.0, d.f. = 4, p<0.01; Song Thrush, KW = 7.7, d.f. = 4, p<0.05; Chaffinch, KW = 7.9, d.f. = 4, p<0.05 and Yellowhammer, KW = 17.6, P<0.0005) showed a strong bias towards the outer 5 m of the field. The densities of these four species at 5 m were between three and a half and six times those recorded beyond 10 m. The Dunnock was also distributed this way (KW = 19.4, d.f. = 4, p<0.001). By contrast, the foraging densities of the three Carduelis finches (Goldfinch and Greenfinch, KW = 9.0, d.f. = 4, p<0.02 and Linnet, KW = 15.8, d.f. = 4, p<0.0002) increased markedly towards the inner field areas. Densities of Skylarks (KW = 16.3, d.f. = 4, p<0.001) and a combined group of four wader species (Lapwing, Stone Curlew, Oystercatcher and Snipe) (KW = 19.5, d.f. = 4, $p<0.0002$) were significantly higher in the field centres compared to field edges.

3.4 Discussion

The analyses of data from studies on Manydown Farm, organic and inorganic farms and set-aside suggest that field edges are used, though not necessarily strongly preferred, by a range of bird species and avoided by very few. In both breeding season studies (Manydown Farm and set-aside) the overall bird density was significantly higher on field margins compared with field centres. A number of species, or groups of species groups, showed preferences for foraging in the margins rather than the centres of the fields including gamebirds (Pheasant, Grey and Red-legged Partridge), thrushes (Blackbird and Song Thrush) Yellowhammers and seedeaters (Goldfinch, Greenfinch, Linnet and Chaffinch). Within the 20 m margin strip on set-aside, Blackbird, Song Thrush, Chaffinch, Yellowhammer and Dunnock showed a strong bias towards the outer 5 m while Goldfinch, Greenfinch and Linnet were at higher densities towards inner field areas (10-20 m). On Manydown Farm a large percentage of the birds using the margins were found in the rotovated strip but there were no differences between sprayed and unsprayed headlands, hedgerow quality or crop type.

In winter such 'edge effects' were less evident. Only one group of species, finches (House Sparrow, Yellowhammers, Linnet, Goldfinch and Greenfinch) showed higher than expected numbers in field margins. At the whole farm level the effects of margin density on bird density were also weak. Only one species, Woodpigeon, increased in density with increased field margin density, whilst five species, Chaffinch, Linnet, Redwing, Robin and Starling decreased. Total species number and density of all species combined did increase with hedgerow density and effects of field margin density were not independent of hedgerow effects. However, again there was little evidence of avoidance of margins by any of the species considered, suggesting that, although birds were not strongly selecting margins, most birds will use them.

The absence of any apparent preference for field margins in winter, in contrast to the relatively strong preferences shown by birds in summer, may be due, at least in part, to the fact that many of the wintering species, e.g. plovers, occur in flocks that tend to occur in field centres (Barnard & Thompson 1985). It may also be related to the fact that birds are generally more mobile in the winter than summer when they are often constrained by the need to remain close to a nest site. The latter will more frequently be located in the field edge (in hedgerow or hedge bottom vegetation) and central place foraging theory predicts that the birds will thus also forage in these areas (Stephens & Krebs 1986).

However it may also be related to differences in the type of boundaries present in the three studies. Field margins on farms in the organic and inorganic study were largely grass strips. In contrast set-aside fields are comprised either of naturally regenerated vegetation (rotational and some non-rotational) or sown with grass such as Rye (non-rotational) and field margins at Manydown Farm were managed as conservation headlands (Table 2.1). The differences in the preference for many field margins shown by birds in winter and summer may reflect increased foraging opportunities in conservation headlands and set-aside compared to the grass field margins on inorganic and organic farms in general.
Set-aside fields contain more grains and wild seeds than autumn and spring tilled fields and probably also grass strips (Draycott *et al*. 1997 and Section 5). The reduced fertiliser and herbicide input on conservation headlands also allows the growth of arable weeds. These are weed species that are present and, in most cases important, in the diet of many granivorous birds (see Section 4). Set-aside and conservation headlands also provide important sources of

invertebrate food for birds. The lack of cultivation of the soil in winter benefits sawfly, Carabids and spiders that overwinter as larvae or pupae in the soil (Barker *et al.* 1997, Hassall *et al.* 1992, White & Hassall 1994) and the reduced insecticide input (none on spring cereal and limited on autumn cereal) will naturally promote invertebrate abundance and diversity. In addition, the botanical diversity of the swards favours invertebrate diversity and abundance (see Section 5) and many of the annual weed species support large numbers of phytophagous insects such as sawfly and Hemiptera and butterfly species (Dover 1996, Hassall *et al.* 1992, Feber *et al.* 1996).

In contrast grass-only strips have a relatively depauperate flora and fauna. Although they do support some arable weed species they are dominated by grasses such as Rye Grass and Red Fescue and hence provide mainly grass seed as food for birds. Grass swards can provide a valuable overwintering habitat for arthropods, such as Carabid and Elaterid beetles and Tipulids, living at or just below the soil surface. These species benefit from the lack of soil disturbance particularly ploughing (Lagerlof & Wallin 1993). However the relatively species poor sward supports a lower diversity and abundance of invertebrates than set-aside or conservation headlands.

At Manydown Farm, the conservation headland was divided from the hedgerow by a 0.5 - 1 m rotovated strip in which a large proportion of the birds were observed foraging. Field margins are usually rotovated in this way to maintain them as sterile strips, preventing the spread of weeds such as Barren Brome into the crop itself. It seems unlikely that such sterile strips would provide suitable feeding areas for birds except for a limited period immediately after rotovation when seeds and invertebrates are brought to the surface of the disturbed soil. In this case however the strip was only kept ‘relatively free of weeds’ rather than sterile by rotovating twice, in early spring and then in June or July, rather than three times (Table 3.1, Fuller 1984).

A group of birds not included in these two studies are birds of prey, including nocturnal hunters such as Barn Owls and raptors such as Kestrels. The main prey of these birds are small mammals and they will benefit from the creation of habitat that encourages their prey and increases hunting opportunities. A field margin habitat that attracts small mammals will be especially beneficial because this is the part of the field where predators such as Barn Owls are most likely to hunt (Tew *et al.* 1992). However, microhabitat utilisation by small mammals is a complex function of predation risks, costs of food acquisition, micro-environmental conditions and social pressures (Tew *et al.* 1992). Most small mammals favour relatively dense cover and a range of studies have shown that numbers of small mammals in rotational set-aside, with sparse cover, are low (Green 1994, Tattersall *et al.* 1997). Thus, although set-aside margins seem more likely to benefit bird species in general, by increasing invertebrate and plant food resources, grass margins may provide better foraging opportunities for birds like Barn Owls and Kestrels that prey on small mammals.

In conclusion the analyses indicate that a number of species of birds use field margins and will potentially benefit from sensitive field margin management. These include: gamebirds (Red-legged and Grey Partridge and Pheasant) Starling, Blackbird, Robin, Dunnock, House Sparrow, Chaffinch, Greenfinch, Goldfinch, Yellowhammer, Skylark, Meadow Pipit, Pied Wagtail and Song Thrush. Several of these species showed a clear preference for foraging at the edges of fields. The mechanisms could be threefold though we do not have the data to test these. First, edge effects could simply be a consequence of central place foraging. For example in the breeding season birds that are nesting in hedges may tend to forage in locations as close as possible to the nest site (Stephens & Krebs 1986). Second, food resources may be higher at the edges of the fields. This seems very likely since the abundance of dicotyledonous arable weed seedlings (Marshall 1989, Wilson & Aebischer 1995), invertebrate groups such as Coleoptera and Brachycera (Gates *et al*. 1997) all decline with distance from the field boundary. Third, predation risk may be lower at the edges of fields because birds can rapidly retreat to cover. On the other hand, hedgerows offer cover to predators such as Sparrowhawks perhaps enabling them to launch surprise attacks more easily.

Overall the results suggest that field margins may be used as foraging habitat by a wide range of bird species and avoided by very few. Conservation headlands and set-aside strips seem to be used by higher numbers of birds of a wider range of species than grass strips. This may also reflect a seasonal difference since grass strips were studied in winter and the other margins in summer. However studies of invertebrate and plant communities on conservation headlands and set-aside strips suggest they are likely to provide better foraging opportunities for farmland birds than grass strips The attractiveness of grass strips could be increased by sensitive management such as the incorporation of flowers in the grass mix sown or the creation of elevated beetle banks (see Sections 2.2 and 5). These different management practices and their likely effect on food availability for birds are discussed in more detail in Section 5.

4. FACTORS DETERMINING THE SUITABILITY OF FIELD MARGINS FOR BIRDS WITH PARTICULAR REFERENCE TO FOOD REQUIREMENTS

4.1 Introduction

The suitability of field margins, managed under different regimes, for farmland birds will be largely determined by the way in which these regimes influence food abundance and availability and vegetation structure which, in turn, influences nesting habitat and predation risk. This section documents the diet, foraging behaviour and nesting requirements for (a) farmland bird species of high conservation concern (red-listed species (Gibbons *et al.* 1996)) and species included on the Biodiversity Steering Group's lists of globally threatened/declining species (Anon 1995a & 1995b) thought to use cereal field margins: Grey Partridge, Turtle Dove, Song Thrush, Tree Sparrow, Linnet, Bullfinch, Reed Bunting and Corn Bunting; (b) species shown to forage in field margins rather than field centres from the analyses presented in Section 3 of this review.

These 22 bird species represent those most likely to benefit from sympathetic management of field margins. Consideration of their breeding biology and feeding ecology (see below) suggests that the major benefits of appropriate management of field margins will be through affecting abundance and availability of food rather than altering nesting habitat or predation risk.

The dietary information is derived from a recent review *The Diet of Bird Species of Lowland Farmland* (Wilson *et al.* 1996). The latter collates information from published papers and reports and classifies a food taxon as being important in the diet if it comprises a mean of more than 5% of the diet over all quantitative studies reviewed, or if authors of quantitative dietary studies stated that they considered it of dietary importance at some time in the annual cycle. Information on nesting and foraging habits have been drawn from papers and reports summarised in the *Handbook of the Birds of Europe, the Middle East and North Africa: the Birds of the Western Palaearctic* (Cramp & Simmons 1980, Cramp 1985, 1988, Cramp & Perrins 1993 & 1994). These general sources are not cited in the following text.

Only four of these 22 species commonly nest on the ground; Grey Partridges and Pheasants, which nest in thick ground vegetation including hedge bottoms, long grass and crops; Corn Buntings which nest in tangled grass or shrubs, arable fields or in pasture in a clump of thick weeds; and Meadow Pipits which also nest in thick ground vegetation. The remaining 18 species nest largely in hedgerows or woodlands. Thus the scope for improving nest site availability for this suite of farmland birds through field margin management is limited.

The structure of the vegetation may also affect foraging behaviour of birds (e.g. Morris & Thompson 1998). A number of studies on Skylarks have suggested that they avoid tall dense vegetation which is unsuitable as feeding or nesting habitat (Wilson *et al.* 1997, Schlapfer 1988). **The structure of the vegetation is also known to be important for gamebird chicks - it must be tall enough for concealment from predators but sufficiently open to allow easy passage (Green 1984, Hill 1985).** It has been suggested that the preference for set-aside, exhibited by a number of bird species, may be related not only to increased food abundance there but also the open sparse cover which facilitates foraging (Watson & Rae 1997, Henderson *et al.* a & b, ms submitted).

Vegetation structure may also influence predation risk of nests and of individual birds. However there is almost no information about how habitat change affects populations through influencing predation rate (e.g. Fuller *et al.* 1995). There have been sustained increases in Corvids in Britain particularly Jackdaws, Crows and Magpies (Marchant *et al.* 1990). However studies by the BTO have found no evidence that increases in the numbers of Sparrowhawks and Magpies have affected songbird populations (Thompson *et al.* 1997).

Furthermore, both forest and farmland birds can suffer high predation rates during the nesting phase from predators such as Corvids and Magpies as well as from Accipiter hawks during the fledgling and adult stage (Götmark & Post 1996, Cresswell 1997a & 1997b, Sæther 1996). Both Corvids and Accipiter Hawks are generalist predators that show some type of functional response to prey abundance (Newton 1979): as long as prey is rare it is ignored but if it becomes common it may become a major part of the predator's diet. However these predators do not take prey solely according to its relative abundance. Interspecific variation in attack success rate and degree of nest concealment and defence will alter the way in which encounter rate translates into prey capture rate, and this interspecific variation will frequently be a product of habitat variation. The vulnerability of prey to predation from Corvids and Accipiters will be modified by habitat characteristics but the nature of this modification is unknown.

Good evidence to suggest that nest cover can be an important factor determining nest survival of ground-nesting birds comes from work on Mallard (Hill 1984), partridges (Rands 1988), Sage Grouse (Gregg *et al.* 1994) and from the use of artificial nests (Clawson & Rotella 1998). Loss of cover could be significant not only for concealment of clutches but also for concealing chicks of those precocial species that avoid predators by hiding in vegetation. Several ground nesting birds adopt a different strategy to predator avoidance. Rather than concealing nests or young within vegetation, birds such as Lapwings and Ringed Plover rely on the cryptic qualities of their eggs and young. It is possible that this camouflage is less effective in structurally uniform swards such as those of grass-only strips and this may increase the predation risk of species that adopt such a strategy.

However, in general, the interaction between habitat structure and predation rate of either nests, fledglings or adults is likely to be complex and an area that requires a great deal more research. Higher abundances of Skylarks, White Wagtails and Linnets on set-aside and shrubby field-forest edges in Sweden have been attributed to a combination of reduced predation risk as a result of increased cover and low probability of spring cultivation and increased food abundance. However no evidence is presented to support this statement or indicate the relative importance of these two factors (Berg & Pärt 1994).Thus while long tussocky, dense vegetation at field margins may provide better concealment for nests, fledglings and adults than short sparse vegetation, the overall effect on predation rate is likely to be very complex.

Thus for the purposes of this review it is assumed that the major way in which management of field margins may affect bird populations is through influencing food abundance and/or availability. The major dietary items of the 22 species are summarised in Tables 4.1 to 4.5. Invertebrate taxa and plant groups are listed only if they are present in the diet and have been quantified or described as an important dietary component. A component is considered important either if it comprised a mean of at least 5% of the diet over all the quantitative studies reviewed, or if authors of dietary studies stated that they considered it of dietary importance at some time in the annual cycle (see Wilson *et al.* 1996). It should be noted that further study may show other taxa to be important.

4.2 Breeding Biology and Foraging Ecology of Bird Species that Use Field Margins

4.2.1 Species of high conservation concern

(i) Grey Partridge, Red-legged Partridge[1], Pheasant

Partridges and Pheasants occupy a range of arable habitat types including cereals, field crops, meadows and grass pastures. They are resident in Britain, nesting in late April/early May on the ground in thick vegetation, including hedge bottoms, long grass, young plantations and crops. Partridges feed by picking seeds and invertebrates from plants and from the ground. Invertebrates are taken only during the breeding season and most are fed to chicks. Otherwise the diet comprises a variety of cereal grains, weed seeds e.g. Polygonaceae, Caryophyllaceae and green plant material. They take a wide variety of Arachnida, Hemiptera, Diptera, Hymenoptera and Coleoptera and the larvae of the latter two groups. Spiders, crane flies, ground beetles, weevils, rove beetles, leaf beetles, grasshopper nymphs, ant pupae, caterpillars, sawfly larvae, ichneumon wasps at both adult and larval stages and a variety of plant bugs (e.g. Delphicidae, Cicadellidae) and aphids are all important dietary components. Pheasants appear to take a wider range of foods than Partridges. They will use their feet to dig for roots and tubers and fly up into trees to take fruit. The chick diet is similar to Partridges but, unlike Partridges, adults will also take some invertebrate food through the autumn and winter, usually ants, earthworms and beetles. Pheasants also take a wider range of plant foods than Partridges with the most important dietary items being cereal grain, acorns, seeds and roots of sorrels, roots of various Compositae and seeds of bistorts, goosefoots, chickweeds.

(ii) Turtle Dove

Turtle Doves are ground feeders but also feed in low trees such as Hawthorn. The species is a migratory one wintering in Africa, breeding in Britain from mid May to mid August. They tend to be associated with small fragments of woodland, also scrub and orchards, preferably near cropland or fields with weeds (especially fumitory) or deposits of spilt seeds or grain. They nest in trees, shrubs or hedges, often Hawthorn.

Turtle Doves take a variety of plant material, including grain, weed seeds, fruit and green material. Invertebrates form a relatively minor component of the diet at all seasons. Most food is taken by pecking from vegetation and the ground. Other than crop milk nestling doves are generally fed a very similar diet to that available to adults at the same time of year with the exception of larger items e.g. large fruits. They will take leaves, buds, fruits and seeds from a huge range of plant families (20 families). Seeds of goosefoots and saltworts, fumitories, Charlock, Sunflowers, Millet and Fescues are the most important components. Seeds of bistorts and medicks may also be important in some areas. Turtle Doves rely quite heavily on the seeds of arable weeds and non-crop grasses with seeds of cereal, brassica and legume crops being far less important in the diet. The arthropod component of the diet is a minor one, although Arachnids, caterpillars, Hymenoptera and various beetles are taken along with earthworms and snails.

(iii) Song Thrush

[1] Red-legged Partridge and Pheasant are not species of high conservation concern but are discussed here due to high degree of overlap with Grey Partridge.

The Song Thrush is mostly resident across its breeding range but northern populations are partially or entirely migratory and more birds move if the weather is severe. Many birds breeding in Britain and Ireland winter in north-west France, northern Spain and Portugal. They have a prolonged breeding season from early March to late August and nest in trees and shrubs, often against the trunk supported by twigs or branches. They will also use creepers on a wall, ledge or bank and sometimes nest on, or close to, the ground in dense vegetation.

The diet of the Song Thrush comprises a wide range of invertebrates, searched for in ground litter, and fruit. The most important soft-bodied invertebrate prey include earthworms, snails and slugs, caterpillars, fly larvae, beetle larvae and Hymenopteran larvae. Caterpillars and earthworms are the most important foods for adults and nestlings during the breeding season with the latter also being fed spiders, beetle and Dipteran larvae. The plant component of the diet consists primarily of fleshy fruits of a wide variety of families with fruits of Yew, Holly, Privet, Mistletoe, Hawthorn and Bramble, and Ivy, all emerging as important. In a study of the fruit diet of Song Thrushes in suburban Oxford, the diet comprised largely earthworms from December-March (94% of c. 900 feeding records), snails in July-September (62%), caterpillars in June (72%) and fruit in September-November (93%) (Davies & Snow 1965). Analyses of stomach contents of adult thrushes (collected throughout the year) suggested fruits and seeds to be the most important dietary items (42% of items) followed by insects (36% of items, largely adult and larval beetles) and earthworms (15%). In the case of nestlings the most important dietary items were Lepidoptera and Diptera larvae (63% and 15% of items) respectively followed by Elateridae and Noctuidae larvae and spiders (6-8%) (Collinge 1924-27).

(iv) Tree Sparrow

Tree Sparrows now have a very patchy distribution within farmland but tend to be associated with free standing trees or small isolated woodlands in open country with well-spaced mature broad-leaved trees. The species is resident in Britain and mainly sedentary, although it also exhibits eruptive movements from time to time. Breeding takes place from late April to mid August, nesting predominantly in holes in trees, buildings or earth banks. The bird forages mainly on the ground for both seeds and invertebrates or by removing seeds and invertebrates from herbaceous plants. Sparrows will also perch on ripening cereals to remove grain and clamber round in foliage of bushes and trees in order to obtain invertebrates.

The Species is predominantly granivorous with plant material making up 85-90% of the total diet over the whole year but invertebrate prey comprising up to 30% of the diet during the breeding season, especially when feeding young. Newly hatched chicks are fed almost entirely on invertebrates but the proportion of invertebrate prey fed to nestlings declines as chicks approach fledging and the composition of the invertebrate food shifts from smaller soft-bodied items e.g. aphids to larger prey e.g. weevils, caterpillars and grasshoppers. Tree Sparrows take seeds and fruits of 35 families, including especially the seeds of bistorts, goosefoots, amaranths, chickweeds and mouse-ears, Forget-me-nots and cereal grain and the seeds of a variety of wild grasses.

Tree sparrows also take a wide range of invertebrate groups but Hemiptera, Lepidoptera, Diptera and Coleoptera and Orthoptera dominate. There is little detailed quantitative information to show which taxa are of greatest importance within these orders but Tree Sparrows do take spiders, aphids, bush crickets, caterpillars, Dipteran larvae and weevils.

(v) Linnet

Linnets frequent farmland that affords both nest sites, in the form of low vegetation such as shrubs and bushes, and ready access to food plants and ground foraging areas. Linnets take small to medium sized seeds and are probably more dependent on seeds than any other western Palaearctic finch apart from Crossbills or Twite with a seed diet predominating even during nestling period. It feeds largely on the ground or in very low bushes (< 1 m above the ground) and herbaceous plants and takes seed both directly from plants as well as from the ground. In winter Linnets form large mixed flocks with other seedeaters in open country, feeding much more on ground than in summer. The species may also forage in groups in the breeding season when food is plentiful. They breed from mid April to early August and nest very low in dense, often thorny trees or in hedges and scrub or, less frequently, on the ground.

A very wide taxonomic range of seeds and fruits are included in the diet. Thirty-four plant families are recorded in the diet of Linnets but they specialise on seeds of bistorts and docks, chickweeds and mouse-ears, cultivated and wild brassicas (e.g. Charlock and Oilseed Rape), a wide variety of Compositae (e.g. Dandelion, thistles, Groundsel, Sow Thistle) and some grass seed including Meadow Grass and cereal grain. In Britain, nestlings seem to feed almost entirely on seeds - especially of Dandelion, Groundsels, Sow Thistle, chickweeds, wild and cultivated Cruciferae and docks. An ongoing study on nestling diet of Linnets on mixed farm in Oxfordshire (Moorcroft *et al.* 1997) reveals most of the grass seed to be Meadow Grass. Presence/absence analysis showed Dandelion to be the most important items early (May) broods and unripe Oilseed Rape seeds were the most frequent item in all broods from June onwards. Other important items included chickweeds in May and June nests, Sorrel (mainly in later broods), Sow Thistle in June and July and thistles in August. The main difference between this study in 1995 and Newton's in 1967 was that in the latter study the main 'brassica' component of nestling diet was seeds of Charlock, fed to broods in July and August. Charlock is now a rare weed controlled by modern herbicides and Linnets have replaced it with seed of unripe Oilseed Rape. Seeds of Compositae (mainly Dandelion, plus some Groundsel) now seem to be the main foods of early nesting Linnets. Dandelion was also important in Newton's study but so was Chickweed which was rare in the 1995 work whilst Sow Thistle has increased in importance.

Invertebrates comprise a very small proportion of the diet, even during nestling provisioning although Linnets do take some aphids, caterpillars, small beetles and their larvae, small flies, ants and parasitic wasps. The only animal foods recorded by Moorcroft *et al.* (1997) were aphids and a few small larvae (probably caterpillars).

(vi) Bullfinch

In Britain, Bullfinches breed mainly in broad-leaved woodland but also often in thickets and tall dense hedges. They are resident in Britain and largely sedentary with the winter and summer distributions being very similar. Nesting begins in early April with peak egg laying in early May. The species nests in thick bushes and trees of a variety of species, often evergreens. Bullfinches forage mainly in woodland thickets and hedgerows, moving to open country in late autumn to early spring. The species rarely feeds on the ground and hardly ever more than c. 10 m from cover. The diet comprises a wide variety of fleshy fruits from native trees and seeds of many trees, shrubs and herbs. Bullfinches are seed predators and usually extract seeds from the fruit itself whilst still on the plant.

The diet is composed mainly of fleshy fruits and herbs, buds and shoots with invertebrates being important in the diet of the young. Important seeds in the diet include those of Elm, Maple, nettles, goosefoots, docks and sorrels, chickweeds, Charlock and Shepherd's-purse, Buttercup, Meadowsweet, Lady's Mantle, Hawthorn and Blackthorn (buds and leaves) and Bramble, Dog's Mercury and spurges, violets, Bilberry and their relatives, Honeysuckle, Groundsel, Dandelion and Sow Thistle and flowers of Willow and Oak. Seeds of Birch and Ash may be important in years when these trees crop heavily. Snow and Snow (1988) found that seeds of Rowan and Whitebeam, Elder, Guelder Rose and Honeysuckle, Buckthorn and Privet were most frequently taken by Bullfinches. Nestlings are fed primarily on the same seed foods as adults especially smaller seeds such as Groundsel, Dandelion, Shepherd's-purse, Chickweed and Dog's Mercury. Young nestlings are also fed considerable numbers of invertebrates mostly caterpillars, spiders and snails.

(vii) Reed Bunting

This species tends to be associated with marshes, fens and bogs as a result of their dependence on associated vegetation types rather than a special need for water. It tends to occupy tall herbage and small shrubs found in marshy and swampy areas bordering fresh or brackish waters. It also occupies farmland in lower breeding densities. The species is mainly sedentary in Britain with a winter distribution that is widespread and similar to that of the summer range but birds usually withdraw from upland areas and some winter visitors are received from western Scandinavia.

Reed Buntings feed on seeds and other plant material taking invertebrates in the breeding season and also opportunistically during the rest of the year. They forage for plant and animal material on the ground among sedges, rushes and reeds, in pasture and marshy grasslands and also low in waterside bushes and trees. Outside the breeding season they are found more often in open countryside, cultivated fields and weedy areas well away from water and often in flocks with other seed eaters.

Reed Buntings have a fairly diverse seed diet with goosefoots, amaranths, chickweeds and mouse-ears, cultivated and wild crucifers (e.g. Oilseed Rape and Pennycresses), Lupins and seeds of wild grasses such as Meadow Grass, Millet, Fescues, Rye-grass and Cockspur. Cereal grain does not appear to be an important part of the diet. Reed Buntings take a wide taxonomic range of invertebrates but the most important taxa are springtails, spiders, dragonflies and damselflies, caterpillars, crane flies and as the most important components. Nestlings are fed entirely on invertebrates with spiders, adult Diptera, mayflies, sawfly, caterpillars and Orthoptera as the main components.

(viii) Corn Bunting

This species has a strong affinity for arable farmland particularly barley (Donald & Evans 1995). The species is resident in Britain and tends to breed relatively late in the year, from early June to mid July in Scotland and from late May in England. It nests mainly on the ground in thick tangled grass or shrubs, in a depression in the soil of arable fields or in pasture, often in a clump of thick weeds. Corn Buntings are largely granivorous but switch partially to an invertebrate diet during the breeding season and feed their nestlings almost entirely on invertebrates. They feed mainly on the ground but will also forage in low bushes especially when gleaning invertebrates during the breeding season.

Corn Buntings take seed foods from a limited range of plant families (eight) and specialise on the grain of cultivated cereals. In fact no other plant family is classified as important as a food source in the published literature. Seeds of Polygonaceae are the only other seeds taken regularly by

Corn Buntings. Nestlings may be fed unripe cereal grain especially in cold or wet weather conditions when invertebrate activity is low. The species also takes a wide taxonomic range of invertebrates but feeds primarily on grasshoppers and crickets, caterpillars, crane flies, earwigs, dung flies and chafers. Nestling diet is similar to that of the adults with the addition of varying amounts of partially ripe cereal grain.

(ix) Cirl Bunting

The Cirl Bunting has a very restricted range in Britain since it is limited to areas with mean January temperatures above 6^{o}C requiring areas with mild winters, low rainfall and sunshine. It avoids extensive open farmland and is confined to small fields with plenty of hedgerow and tall trees. These factors restrict it to south west England where it is resident and essentially sedentary (Evans 1992) They breed from early May to late August nesting low down and well hidden in dense trees, shrubs or creepers.

Cirl Buntings are largely granivorous but, like Corn Buntings, switch partially to an invertebrate diet during the breeding season and feed their nestlings almost entirely on invertebrates. They forage mainly on the ground but will sometimes forage in low bushes especially when gleaning invertebrates. A range of taxonomic groups are included in the diet but caterpillars, crane flies, bush crickets, grasshoppers, various beetles and sawfly larvae are recorded as important. Little is known of the adult invertebrate diet. However, like Yellowhammers adults specialise in feeding on cereal grain, principally barley, and the seeds of wild grasses (e.g. Meadow Grass, Rye-grass, Fescues and Couch although seeds and fruit of other taxa are sometimes taken including Compositae, bistorts, docks, sorrels and chickweeds. Oily seeds such as those of many Cruciferae are avoided. Unripe cereal grain has been reported as important nestling food especially in wet conditions when invertebrate prey may be less easy to obtain.

4.2.2 Species shown to use field margins in Section 3

(i) Finches: Chaffinch, Greenfinch, Goldfinch (for Linnet see above)

Goldfinches and Greenfinches overlap considerably in habitat preferences. The former is often found associated with human settlements especially where patches of tall weeds and other concentrated food sources are present. Outside the breeding season Goldfinches rely on Compositae such as thistles, Dandelion, Ragwort and burdocks and, as a result, the species tends to be associated to rough grasslands and overgrown wastelands. The species is migratory in Britain, although a small number of birds do remain to winter and hard-weather southward movement also occurs. Breeding takes place from mid May to early August. The nest is usually well-hidden in inaccessible outermost twigs of trees on average about 6 m from the ground (Cramp & Perrins 1994). Greenfinches are associated with tall densely leafed trees and forage for seeds under appropriate trees, on bushes or on crop weed and other plants in fields. They occupy a range of habitats where tall trees and ready access to ground patches or other sources of seeds fruits and insect food are present together in the breeding season. Outside the breeding season they may use areas away from trees e.g. on farm fields, salt marshes, shingle banks and other open sites. In Britain the species is partially migratory with the winter distribution being more concentrated in lowland and coastal areas than in summer. They breed from mid April to mid August with a peak in mid May and nests are usually located against the trunk or in a strong fork of a dense bush, small tree often in a hedge.

Chaffinches are basically arboreal and in the breeding season occupy deciduous, mixed and coniferous woods and forests. In winter they frequent open areas of farmland up to some distance from tree cover. British birds are very sedentary. Immigrants winter mainly in southern and central Britain and Ireland and are chiefly of Scandinavian origin. The species breeds from late April to mid June and the nests are located in the fork of a tree or bush, on a branch or on several thin twigs on average c 4 m from the ground.

These three finch species are primarily granivorous. They all take some invertebrate species during the breeding season and when feeding nestlings, but the importance of this component of the diet varies between the fringilline finches. For example, Chaffinches switch partially to an invertebrate diet during the breeding season and feed their nestlings invertebrates, whilst for Greenfinches and Goldfinches a seed diet predominates even during the nestling period. Chaffinches take seeds from the ground but rarely directly from the plants; they glean insects from the foliage of shrubs and trees. Greenfinches take seed from the ground and also perch in bushes and trees to take seeds from fleshy fruited species. Goldfinches prefer to perch on the flowers or seed-heads of herbaceous plans to extract seeds directly rather than foraging on the ground. They will also feed in trees taking seeds of Pine and Alder.

Chaffinches take a wide variety of invertebrate taxa during the breeding season, with Arachnida, Lepidoptera, Diptera, Hymenoptera, Trichoptera, Hemiptera and Coleoptera comprising important parts of the diet. This species had the most varied diet of any Fringillidae in a major study by Newton (1967). Within this broad diet, spiders, caterpillars, crane flies and their larvae, non-biting midges, ants, weevils, caddisflies and aphids are the most important animal components. Invertebrates comprise a much smaller proportion of cardueline diet even during nestling provisioning although Greenfinch and Goldfinch all take some aphids, caterpillars, small beetles and their larvae, small flies, ants and parasitic wasps.

A very wide taxonomic range of seeds and fruits are taken by all three finches but dietary specialism varies considerably between the species. Forty-four plant families are recorded in the diet of the Chaffinch with Beech Mast, and the seeds of bistorts and docks, goosefoots and oraches, chickweeds, Charlock and cultivated brassicas, Groundsel and mugworts and cultivated cereals. Greenfinches take a greater variety of seeds than Goldfinches. The most important seed foods are Spruce, Elm, Beet and other Chenopodiaceae, docks and bistorts, chickweeds, wild and cultivated brassicas and other Cruciferae (e.g. Charlock), Groundsel, Dandelion and Burdock and cultivated cereals. Greenfinches are also seed predators of fleshy fruited plants and the seeds of Yew and Bramble, roses, Rowans and Whitebeam are also important in the diet. Nestling diet is similar to that of adults but with a slightly higher proportion of invertebrates especially aphids and caterpillars.

Despite being similar in size and structure to Linnets, Goldfinches show a different dietary range (23 families compared with 34 in Linnets). Goldfinches are more arboreal than Linnets and the diet includes seeds of Alder and Crab-apples as important components along with Teasel and many Compositae (e.g. Groundsel, thistles, Dandelion, knapweeds and burdocks). Seeds of wild grasses and cultivated cereals are relatively unimportant in a diet which is dominated by the seeds of Compositae whenever they are available. Little is known of the diet of nestling Goldfinches but there is some evidence that invertebrates (e.g. caterpillars, aphids and small beetles) are more important than in the diet of nestling Linnets especially for newly hatched chicks and in early season nests when relatively few seeds are available.

(ii) Yellowhammer

Yellowhammers occupy a wide range of habitats. Their main requirements seem to be low woody vegetation, taller song posts and open ground for foraging. It is resident and sedentary in Britain and the winter distribution is rather similar to that in summer except for a tendency to withdraw from upland areas. The species has a fairly extended breeding season with eggs being laid from early April to early September. The nest is nearly always on or very close to the ground and well hidden amongst grass or herbage. Typically they will nest against a bank or base of a hedge, small tree or bush or well inside bramble.

Yellowhammers are granivorous outside the breeding season but switch to a partly invertebrate diet during the breeding season and feed their nestlings almost entirely on invertebrates. They feed mostly on the ground but will sometimes forage in low bushes, especially when gleaning invertebrates. Yellowhammers take a wide taxonomic range of invertebrates but the most important taxa in the diet are Collembola, Orthoptera, Lepidoptera and Coleoptera with springtails, grasshoppers, caterpillars, weevils and rove beetles as the most important components. Nestling diet is almost entirely invertebrates but of a wider range than taken by adults including adult and larval Lepidoptera, beetles, adult Diptera, sawflies, spiders and Orthoptera. They take a more limited range of seed-foods (16 families) than the finches, specialising on cereal grain and the seeds of wild grasses (e.g. Meadow Grass and Rye-grass, Fescues and Couch), although seeds and fruits of other taxa are sometimes taken including composites, bistorts, docks, sorrels and chickweeds. Oily seeds such as those of many Cruciferae are avoided. Unripe cereal grain has been recorded as an important nestling food, especially in wet conditions when invertebrate prey may be less easy to obtain.

A recent study of diet and foraging behaviour of Yellowhammers on mixed arable and livestock farmland in Leicestershire revealed unripe cereal grain to form a major part of the nestling diet. Invertebrates were fed to all broods with Lepidoptera larvae and Araneae and Tipulidae being the most important invertebrate groups taken (Stoate *et al.* in press)

(iii) Blackbird, Robin

Blackbirds inhabit an exceptional diversity of habitats ranging from dense woodlands to heathland and frequent various types of farmland. They tend to forage mainly on the ground except when berry crops are ripe. In Britain approximately 75% of the breeding population is resident. Some birds from southern England winter in north west France whilst considerable numbers of birds from Scandinavia winter in Britain. They breed from mid March to late July with nest sites typically placed against the trunk of a small tree or bush or against a wall hidden within creepers and occasionally in piles of brushwood. Robin is more commonly associated with habitats that provide some degree of cool shade, moisture and cover of at least medium height woodlands but also frequent farmland. Although largely a ground feeder, Robins also seek a wide variety of raised perches. British and Irish populations are mainly resident although some birds do migrate south west as far as southern Iberia. They breed from early April to late June often nesting in hollows in tree stumps, on banks among tree roots from ground level up to c. 5 m.

Both these species are omnivorous and take a wide variety of invertebrates, seeds and fruits, both on the ground and in trees and bushes. During the breeding season, invertebrates predominate in the diet of both adults and nestlings, although some fruit may also be fed to nestlings. Although Blackbird and Robin take a similar range of taxa, the composition of the diet of the two species is, unsurprisingly, very different. Soft-bodied invertebrate prey including earthworms, slugs and snails, caterpillars, fly larvae, larvae and Hymenopteran larvae are the most important components of the Blackbird diet although a very wide variety of other groups is recorded. caterpillars and earthworms are particularly important foods for Blackbird and nestlings, which are also given spiders, beetle larvae and dipteran larvae. Because soft-bodied prey predominate in the diet it is very difficult to identify them from stomach or faecal samples and so little quantitative information exists on the diet of adult or nestlings. Robins take an equally wide variety of prey but caterpillars, ants and their larvae, weevils and leaf beetles are the most important dietary components

The plant component of these two species consists primarily of fleshy fruits of a wide variety of families, with fruits of Yew, Holly, Privet, Mistletoe, Hawthorn and Bramble, and Ivy, all emerging as important. The plant component of Robin diet is similarly composed primarily of fleshy fruits with those of Oleaceae, Elders and Bramble predominating. In their study of the fruit diet of British bird species Snow and Snow (1988) considered that the most important components (> 5% of total fruit eaten) of the fruit diet for Blackbird to be Hawthorn (23% of total fruit eaten), Ivy (13%), Holly (9%), Yew (7%) Cherry (7%) and for Robin; Spindle (21%), Elder (16%), Ivy (12%), Dogwood (8%), Bramble (5%), *Viburnum* spp (mainly Wayfaring tree) (5%).

(iv) Dunnock

In Britain dunnocks are associated with a wide variety of scrub grown habitats and may be found in coppice woodland with vigorous ground cover, field hedgerows, parks and gardens. The species is resident and largely sedentary in Britain breeding from early April to late July. Dunnocks nest in bushes hedges or low trees 0.5-3.5 m above the ground.

The Dunnock is primarily insectivorous although a significant proportion of the winter diet comprises seeds. It specialises on very small invertebrate prey found on the ground surface often amongst loose soil or leaf litter and in herbaceous vegetation. Nestlings are fed much the same invertebrate diet as is taken by adults. A wide range of invertebrate prey is taken with Arachnida, Collembola, Hemiptera, Diptera and Coleoptera being the most important groups. Within these orders springtails, Harvestman, spiders, aphids, weevils and rove beetles are the most important groups.

Plant foods include the seeds and fruit of 29 plant families. The most important components being seeds of nettles, bistorts and docks, chickweeds, spurreys and mouse-ears, amaranths and the grasses (Millet) and *Holcus* (soft grasses). The most frequently taken fruit is Elder.

(v) Starling

Starlings are associated with a huge variety of habitats limited only by the availability of nest sites (suitable holes in trees, walls, earth banks, etc.). They will forage on grasslands, arable fields, refuse tips and flood land. They are resident in Britain and breed from mid April to mid June nesting in holes in trees, cliffs, buildings and occasionally in grass banks.

Starlings are primarily invertebrate feeders. They feed their nestlings almost exclusively on invertebrates taken mostly by probing the soil for soft-bodied prey such as earthworms and arthropod larvae, but also directly from the ground surface, vegetation and even by hawking for flying insects. A variety of grain, weed-seed and fruit may be taken outside the breeding season especially by young birds and when invertebrate food is less easily available. Overall Starlings take a huge range of animal and plant foods and are highly responsive to annual, seasonal and daily variations in the availability of alternative food sources.

Invertebrate food is dominated by the larvae of Lepidoptera, Diptera, Hymenoptera and Coleoptera, notably leatherjackets, caterpillars and the larvae and pupae of snipe flies, March flies, ants and ground beetles. Adult ground beetles, weevils, rove beetles, spiders and earwigs may also be important when larvae are unavailable. Nestling food is dominated by a relatively small number of invertebrate taxa - notably leatherjackets, adult Bibionidae, moth caterpillars, larval and adult beetles and earthworms. In most studies, one or a few taxa are of overwhelming importance (e.g. leatherjackets in British studies) during the nestling provisioning. Whitehead (1994) has shown that leatherjackets are strongly preferred to earthworms when adults are feeding either themselves or nestlings.

Starlings take a variety of fleshy fruits in late summer and autumn and cereal grain is an important component of the diet over the winter period when invertebrates are scarce. Of the fruit diet Privet, Cherry, Rowan Berries, Sloe and Elderberry are all important but a wide range of other fruits and weed seeds are taken opportunistically. In their study of the fruit diet of British bird species Snow and Snow (1988) considered that the most important components (> 5% of total fruit eaten) of the fruit diet for Starlings to be Dogwood (43%), Yew (18%), Elder (16%), Bramble (7%), Ivy (6%).

(vi) House Sparrow

Sparrows are remarkably flexible in their habitat preferences. They seem to avoid extremes of very dense vegetation or very open tree-less landscapes except for seasonal foraging on some arable crops. They are present almost anywhere constant food supply is assured by human activity. In Britain they are resident and sedentary, breeding from April to August, usually nesting in holes in buildings and other man-made structures although they will also nest in trees and creepers on walls.

House Sparrows are predominately granivorous birds with plant material making up 85-90% of the total diet over the whole year but invertebrate prey making up 30% of the diet during the breeding season, especially when feeding young. Newly hatched chicks are fed mostly on invertebrates but the proportion of invertebrate prey fed to nestlings declines as the chicks approach fledging and the composition shifts from smaller soft bodied items (e.g. aphids) to larger prey (e.g. weevils, caterpillars and grasshoppers).
A wide variety of invertebrate groups is recorded in the diet of House Sparrows but Hemiptera, Lepidoptera, Diptera and Coleoptera and Orthoptera dominate. There is little detailed quantitative information to show which taxa are of greatest importance within these orders but both species take many spiders, aphids and other plant bugs, grasshoppers, crickets, bush crickets, caterpillars, Dipteran larvae and weevils. Most of these are also fed to nestlings.

House Sparrows also take seeds and fruits of 40 plant families. Amongst this diversity, the seeds of bistorts, purslanes, mouse-ears, cranesbills, Meadow Grass, Cockspur and Finger-grass, plus the grain of cultivated cereals are particularly important.

(vii) Meadow Pipit, Pied Wagtail

Meadow Pipits are very much ground dwellers and associated with open areas of rather low, fairly complete vegetation cover. Often associated with heathlands and moorlands. The species is resident in Britain although birds may vacate upland areas in winter. House Sparrows breed from early April to late July, nesting usually on the ground concealed in vegetation. Pied Wagtails are commonly associated with waterside habitats but also frequent areas distant from water especially where human activities have created bare patches or low vegetation such as in agricultural areas. The species is resident in Britain with upland areas usually vacated in winter. Pied Wagtails bred from early April to early August usually nesting in holes or crevices in a wide range of natural or artificial sites.

These two species are largely invertebrate feeders taking a range of hard and soft bodied invertebrates from the ground surface, ground vegetation and, in the case of wagtails, in the air. Nestlings are fed entirely on the same invertebrates that comprise adult foods. Hemiptera, Diptera, Hymenoptera and Coleoptera, spiders and caterpillars are all important in the diet of Meadow Pipits. Within Hemiptera, Meadow Pipits take very small insects including aphids, Psyllids and scale bugs. No detailed quantitative information is available for Pied Wagtail although crane flies, fruit flies, dung flies, midges and blow flies are all important in the diet. Sawflies, ichneumon wasps and ants are the most important Hymenopteran components of the diet across both species. Ground beetles, weevils and leaf beetles are all important components of both species diet but less so for Meadow Pipit for which rove beetles are the most important beetle species. Both species tend to feed on small, soft-bodied prey (e.g. aphids, Psyllids) to young nestlings but provide larger more chitinous items as the chicks grow. Diptera and caterpillars may be particularly important in the nestling diet of Pied Wagtails but very few data are available.

Meadow Pipits have been recorded taking the seeds of 14 plant families but only those of Eyebright and Meadow Grass are recorded as important dietary components. Plant material has not been recorded in the diet of Pied Wagtail.

4.2.3 Diurnal raptors and nocturnal species

A third group of bird species that may benefit from field margin management are raptors and diurnal species such as owls. These may benefit from increased hunting opportunities resulting from the creation of suitable habitat for their main prey small mammals. Principally, this category includes three species that commonly frequent farmland; Barn Owl, Tawny Owl and Kestrel. A fourth species, Little Owl, may also benefit but is generally less dependent on small mammals than the other species.

In Britain the most important foods of both adult and nestling Barn Owls are three species of small mammals; Short-tailed Vole, Common Shrew and the Wood Mouse. Barn Owls do take some invertebrates, mainly Orthoptera and large beetles, but these are very minor components of the diet.

Little Owls take a variety of vertebrate and invertebrate prey, the most important components of the overall diet being mice (Murinae) and voles (Microtinae), shrews (Soricidae) birds up to the size of thrushes, beetles, grasshoppers and crickets. In terms of number of prey items taken invertebrates may comprise in excess of 90% of the diet but vertebrate prey usually represents by far the majority by weight. Tawny Owls feed mainly on small rodents largely mice *Apodemus* Bank Voles, Short-tailed Voles but will also take birds, amphibians, shrews, earthworms and beetles.

Kestrels feed mainly on small mammals especially voles with birds usually secondary. In Britain, Short-tailed Voles usually predominate in the diet followed by Bank Voles. but they will also take invertebrates such as earthworms, caterpillars, centipedes and a number of studies have recorded large numbers of Dor-beetles (Geotrupidae).

4.3 Summary

The suitability of field margins, managed under different regimes, for farmland birds will be largely determined by the way in which these regimes influence food abundance and availability and vegetation structure which, in turn, influences nesting habitat and predation risk. Consideration of the breeding biology and feeding ecology of farmland bird species most likely to benefit from sympathetic management of field margins suggests that the major benefits will be through affecting abundance and availability of food rather than altering nesting habitat or predation risk.

Only four species commonly nest on the ground, thus the scope for improving nest site availability for this suite of farmland birds through field margin management is limited. The structure of the vegetation may affect foraging behaviour and predation risk. However, in general the interaction between habitat structure and predation rate and foraging behaviour is poorly understood.

Thus for the purposes of this review it is assumed that the major way in which management of field margins may affect bird populations is through influencing food abundance and/or availability, particularly invertebrates and seeds. Raptors and diurnal species such as owls may also benefit from the creation of suitable habitat for their main prey; small mammals. The potential benefits for these species are considered in relation to margin management in Section 5. However, the main focus of this review is on the effects of margin management on invertebrate and seed-eating birds, the major dietary items of which are detailed in Tables 4.1 to 4.4. and summarised in Table 4.6 and 4.7. In general the most important invertebrate taxa (orders), measured in terms of the number of birds to include them in the diet, are Coleoptera, Diptera and Lepidoptera. The most important plant foods are seeds of annual and perennial weeds (particularly Polygonaceae, Caryophyllaceae, Chenopodiaceae, Compositae and Cruciferae) and grasses seeds. In the following section the way in which the abundance of these plant and invertebrate prey may be altered by managing field margins in different ways will be considered.

5. FIELD MARGIN MANAGEMENT PRACTICES AND FOOD RESOURCES FOR BIRDS

5.1 Definitions

In this section the effects of the different field margin treatments described in Section 2 on invertebrate and plant abundance and availability for birds are considered. We consider the grass strips (which include grass-only strips, grass and wild flower strips (sown or allowed to regenerate naturally) and beetle banks), rotational set-aside margins allowed to revegetate naturally, uncropped wildlife strips (cultivated approximately annually, not sown with a crop), conservation headlands, game cover or stubble strips and sterile strips, created with herbicides or rotavation.

Four important caveats need to be made concerning the validity of such comparisons. Firstly, the relative value of a number of these margin treatments will vary considerably between different geographic locations in Britain usually reflecting differences in soil type and fertility and/or differences in the existing seed bank. For the purposes of this report we assume that the comparisons relate to ideal conditions, for example that a naturally regenerated sward has developed from a good seed bank. Secondly, the relative value of a number of these margin treatments will change with time after establishment. This is particularly true in the case of naturally regenerated and, to a lesser extent, sown grass strips. For the purposes of this report, although we consider long-term management requirements of treatments where relevant, the comparisons between treatments are made in the first one to two years after establishment. Third, many of these margin managements provide different benefits at different times of year making direct comparisons difficult, for example a diverse grass and flower sward may provide abundant food for birds in summer but will provide much less in winter when a stubble strip may be more valuable. Fourth, data concerning the floral composition and diversity of margin treatments is relatively good and hence and comparisons are relatively easy. However, little data exist on invertebrate abundance and diversity on different field margin management treatments. There are very few quantitative studies, especially comparative ones, with the exception of those relating to conservation headlands. The studies that have been done are usually limited to a small number of sites and carried out over one or two years only. Since invertebrate abundance and diversity varies a great deal between and within years attempts to assess the relative value of field margin treatments based on such studies are necessarily very preliminary.

Interest in the value of field margins for birds has historically focussed on hedgerows stimulated by high rates of hedgerow loss in the 1940s and 1950s (O'Connor 1987). The importance of hedgerows for a range of bird species is reflected in the extent of existing literature (e.g. Lakhani 1994, Parish *et al*. 1994 & 1995, Barr *et al*. 1995). Although the focus of this review is on field margins rather than field boundaries the value of such margins for wildlife in general and birds in particular, will be heavily influenced by field boundary characteristics. **In the light of their importance we begin this section with a brief consideration of the management of the boundary, hedgerows and herbaceous flora of the hedge bottom.**

5.2 Management of the Boundary

The importance of hedgerows for a large proportion of the British avifauna has been highlighted in a number of reviews of habitat use by birds in a lowland arable landscape. For example, in a study by Lack (1992), 27 species of bird of a total of 55, considered routinely used hedges for nesting and feeding. In a second study O'Connor *et al*. (1987) showed bird density to increase with hedgerow density with c. 50% of species considered (24 of 57 species) occurring in higher numbers where field boundary density was higher. Sensitively managed hedges and hedge bottom vegetation provide a range of resources for many birds including nest sites, song perches, food supply and protection from predators (Barr *et al.* 1995). Hedges probably hold a greater number of breeding birds than any other feature in farmland (Lack 1992) and are important foraging habitats throughout the year. In addition there is evidence to suggest that well-managed hedgerows increase the value of adjacent field margins as foraging habitats for granivorous and insectivorous birds. For example, true bugs (Hemiptera: Heteroptera) are found in significantly higher numbers in headlands adjacent to hedges or woods than grass, probably because hedgerows provide suitable habitat for oviposition and overwintering sites for eggs (Moreby 1994). For species like Pheasants, field margins are important only if adjacent to woodland edges or shrubby cover and are used early in spring by males setting up territories (Aebischer *et al.* 1994).

Given the importance of field boundary characteristics in determining the potential use of field margins for birds (Clarke *et al.* 1997) the following two sections (5.2.1 and 5.2.2) consider briefly the effect of different hedgerow structure and management on the value of the hedgerow itself and the adjacent margin for birds.

5.2.1 Hedges

Hedges can contain a variety of shrub, tree and climber species and may have a herbaceous flora (see below) in the hedge bottom. Many hedges were planted, particularly following Enclosure Acts and Awards, and are man-made structures. However, some originate from the original ancient woodland and date back to Saxon times (Pollard *et al*. 1974).

Hedges are important for several farmland bird species, both as food sources and for nesting and roosting, often as hedges represent relic woodland habitat. Different bird species require different structures during the breeding season. For example, (Green *et al*. 1994) note that although most species prefer tall hedges with many trees, some species such as Dunnocks, Willow Warblers and Lesser Whitethroats prefer tall hedges with few trees, short hedges with few trees are favoured by Yellowhammers, and Cirl Buntings tend to nest in thorny hedgerows often dominated by Hawthorn and Bramble (Evans 1997). In general, however, bird species richness increases with the size and species richness of the hedgerow (Parish *et al*. 1994).

The production of berries is of particular importance for some bird species. Shrub species such as Hawthorn, Blackthorn, Dog Rose and Bramble produce fleshy fruits. Other climbing species, such as Ivy, Black Bryony and White Bryony also produce many berries. Management of the hedge by trimming will affect berry numbers available to birds. Details of the effects of different timing and frequency of hedge trimming are under investigation at present at IACR-Long Ashton (Maudsley *et al*. 1997). However, previous work shows that autumn trimming will remove berries and annual trimming does not leave much two-year-old wood on which most fruit is borne (Maudsley unpubl. data). Ivy berries are also valuable for birds in winter. Removal of Ivy from hedgerow trees is not to be encouraged, particularly as the species does little damage to mature trees and provides nesting cover.

Hedgerows are also important sources of invertebrate food items for birds. Some of the shrub species support a wide range of arthropods, including groups which are important as bird food, such as Lepidoptera larvae and phytophagous Coleoptera and Hemiptera. For example Hawthorn, a dominant shrub in many hedgerows, has about 230 species of phytophagous insects and mites associated with it, whilst both Hazel and Dog Rose support over 100 species each (Duffey *et al.* 1974). Hedgerows not only support a diverse phytophagous arthropod fauna feeding on foliage, fruits and seeds, but also sustain many species which inhabit dead wood and bark. Generally, the more diverse the woody flora of the hedgerow the more diverse will be the arthropod fauna associated with it (Pollard *et al.* 1974, Morris & Webb 1987). Furthermore, different shrubs flower at different times in the season, providing a continuity of resources for the insect community over an extended period and thereby maintaining species diversity (O'Connor 1987).

Hedgerow management can have a significant influence on the abundance and diversity of insects, enhancing invertebrate diversity by increasing the variety and availability of different of micro-habitats (Dowdeswell 1987, Dennis & Fry 1992). The width, height and overall foliage density all appear to be important for insect abundance and diversity (Morris & Webb 1987). The bird population is also affected by hedgerow structure. The positive relationship between bird species richness and hedgerow size (Parish *et al.* 1994) may in part be related to the abundance of invertebrate food in such hedgerows particularly in the nesting season. Thick hedges with abundant foliage provide increased foraging areas for insectivorous birds (O'Connor 1987). On the other hand, thin, gappy hedges and those severely trimmed by mechanical methods will contain a correspondingly poorer arthropod fauna. Mechanical trimming and the neglect of traditional hedgerow management techniques such as 'laying' (which maintains a dense base to the hedge) are deleterious to the insect fauna (Morris & Webb 1987).

The presence and abundance of trees within the hedgerow is also associated with bird species richness (Parish *et al.* 1994) and this relationship could be influenced by the increased availability of arthropod food items provided by large trees. Oak in particular supports a vast array of insects (Morris 1974), including many Lepidoptera larvae which are important as an avian food source.

5.2.2 Herbaceous flora of the boundary

Extensive studies of hedges and hedge bottom flora have shown little connection between the shrub flora and the adjacent herbaceous flora of the hedge bottom (Cummins & French 1994). The herbaceous flora will reflect the local environmental conditions, including soil type, farming practices, management and the structure of the margin. For example, if a ditch is present, riparian or aquatic species may occur.

The herbaceous boundary flora can be diverse, exemplified by Devon and Cornish banks. If the boundary has a complex structure, the flora may contain representatives of woodland, scrub, tall herb, grass or aquatic communities. However, in intensive arable land on neutral soils, the flora can be depauperate, made up of a few competitive-ruderal species, such as Couch Grass, Hogweed, Cow Parsley and thistle species. In general, high fertility will encourage dominance of a few nitrophilous species at the expense of low-growing species and reduce species diversity. This may not in itself reduce feeding opportunities, unless birds are specifically associated with particular plant species. The presence of sown grass strips adjacent to the hedge may afford protection from pesticides, fertiliser and cultivation. Experimental comparisons of floristic diversity in hedge bases with and without adjacent sown grass strips revealed significantly higher diversity in the presence of a grass strip (Moonen & Marshall in prep.).

It is common practice to cut the herbaceous flora of the field edge at the same time as cutting the hedge. Cutting annually in late summer removes any over-wintering seed heads on grasses and flowers. While much seed will have fallen or been eaten by September, nevertheless, annual cutting also reduces vegetation cover and therefore opportunities for nesting by Pheasants or partridges. Biennial cutting or structured cutting, with the area nearest the crop cut annually and areas further away cut less often, could provide better food resources for birds, particularly in winter.

Floral diversity within the hedge base will also influence invertebrate abundance and diversity, as will the density of the herbaceous flora. Hedge bottoms have an abundant ground fauna which includes important bird food items such as Carabid beetles which benefit from a dense herbaceous flora. Spiders and Harvestmen also constitute a valuable food resource for a number of bird species and these arthropods particularly benefit from a complex vegetation structure both at the hedge base and within the shrub layer of the hedge itself (Hassall *et al.* 1992).

5.3 Management of Modified Field Boundary Strips

5.3.1 Grass margins: sown grass strips, sown grass and wild flower strips

(i) Plant community

Sown grass strips created at the edge of arable fields have a variety of functions, including protecting pre-existing habitat from agricultural operations, creating new habitat, preventing annual weed ingress and forming access routes round fields. Under the Countryside Stewardship Scheme, farmers can be supported for creating 2 m wide or 6 m wide margin strips either as grass only or as grass and flower strips.

Sowing simple mixtures of agricultural grasses can have significant impacts over time on the diversity of adjacent hedge bottom flora, associated with reduced disturbance and fertiliser contamination (Moonen & Marshall in prep.). Where weed control is the only aim of field margin restoration, grass only mixtures are the most cost-effective solution since dominant species like Red Fescue and Smooth Meadow Grass from a dense sward base very rapidly (Smith *et al.* 1994). The flora of sown grass strips created only with agricultural grasses, e.g. Ryegrass, or simple mixes based on Red Fescue, often have low species diversity (West & Marshall 1996, Marshall & Moonen 1997). Grass mixes on fertile soils are usually competitive, giving few opportunities for species to colonise from adjacent areas or the soil seed bank. By sowing perennial herbaceous species, the annual weed populations are often reduced in abundance and the succession is accelerated (Smith *et al*. 1994, Marshall & Nowakowski 1995, West & Marshall 1996).

Grass strips may also be created through natural regeneration although in practice they are usually sown. The creation of grass margins through natural regeneration results in a curtailed succession of plant species. Typically, the pattern of secondary succession occurring on naturally regenerating agricultural land (see below), passes through a community dominated in the first year by annual weed species, with some biennials, such as Spear Thistle. Perennial species usually dominate in the second and subsequent years.

In areas where soil fertility is relatively low and the soil seed bank and local flora are good allowing a sward to regenerate naturally may be more cost effective and result in a sward of higher conservation value. In terms of the potential value for birds, naturally regenerated grass strips will approximate to naturally regenerated (rotational) set-aside margins in year one and resemble sown grass and wildflower strips as the years progress. Thus they are not considered separately but their value can be assessed from these two treatments.

Using mixtures of grasses and wild flower seeds to create field margin strips has been investigated for some years (Marshall & Nowakowski 1991, Smith *et al*. 1993). Typical grasses include those of the basic mix plus species such as Common Bent and Sheeps' Fescue. Flower species frequently sown include Yarrow, Black Knapweed and Ox-eye Daisy (Clarke *et al.* 1997). Some consideration should be made of seed provenance and where possible local provenance seed should be used rather than general agricultural or amenity grassland mixes (Feber pers. comm.). In contrast to naturally regenerated sown swards, sown strips will develop a cover that contains a relatively high proportion of perennial species in the first few years after establishment. Grass and flower strips, whether sown or naturally regenerated, are more likely to provide food for bird species over a longer period, particularly where the plants flower and seed at different times through the year. The flowering periods for a range of species often included in grass flower seed mixtures are given in Table 5.1. While most grasses will flower from mid-summer, some dicotyledonous species will flower early and others late.

Grass and grass and flower strips need to be mown, typically once a year, to prevent suckering shrub species, such as Blackthorn and Bramble, from colonising. Mowing after harvest in August, when arable farmers can reach the margin strip easily, will cut seeds from the panicles and flower heads. It is usually recommended that the cuttings be removed in the hay, to reduce soil fertility and encourage botanical diversity. Grass strips are commonly mown once a year in August or September to maintain the grass cover and prevent scrub encroachment. A second cut may be carried out in late spring. Cutting the grass strips in spring, up to the beginning of April, may reduce flowering of early species, but will have little effect on later species. This practice is suggested for sites with high soil fertility and a tendency for perennial grasses to dominate the margin strip (Marshall & Nowakowski 1995).

In the absence of annual cutting, sown grass and flower strips may lose species diversity over time, as the seed mix adapts to local conditions (Marshall & Nowakowski 1995). Plant species richness has been shown to decline on grass margins that have been left uncut compared to margins that have been cut in spring or autumn (Smith *et al.* 1993). However, there may be an advantage in leaving part of the grass strip, closest to the field boundary, uncut, increasing the structural diversity of the strip and providing valuable over-wintering sites for small mammals and invertebrates (see below) and for ground nesting birds such as Yellowhammer. In addition this may also encourage less than annual cutting of hedges and since most hedgerow species flower on second year wood this will increase fruit and berry abundance for birds in the autumn (Maudsley pers. comm.).

(ii) Invertebrate community

Grass swards can provide a valuable habitat for arthropods living at or just below the soil surface, many of which are potential food items for birds. These include Carabid beetle

adults and larvae as well as Elaterid beetle larvae (Wireworms) and Tipulid fly larvae (leatherjackets). These insects particularly benefit from the lack of soil disturbance, especially that caused by ploughing (Lagerlof & Wallin 1993). Many grassland insects are sensitive to disturbance and even moderate trampling can significantly reduce the numbers of invertebrates present in grassland litter (Morris & Webb 1987). Therefore, the type and frequency of use of grassland strips (e.g. as footpaths, vehicle tracks or bridle ways) will influence the invertebrate fauna.

Management of the sward, particularly the frequency and timing of mowing and spraying, can also have significant effects on the invertebrate community, largely through altering the structural diversity of the sward. Coleoptera (Carabids and Staphylinids), Arachnida (Aranaea) and Lepidoptera (e.g. Meadow Brown and Gatekeeper) are all more abundant on field margin plots that are left uncut than on those that are cut regularly on an annual basis. This is particularly true if the grass is mown in mid-summer rather than spring or autumn (Feber *et al.* 1995 & 1996, Baines *et al.* 1998). Mowing in summer coincides with the time at which many butterflies are ovipositing and the larvae of some are feeding or completing development and so will have disruptive effects on all these stages (Feber *et al.* 1996). However, although uncut swards appear to support more diverse and abundant invertebrate communities lack of management in the long term may be detrimental. Swards left unmanaged will decline in plant species richness (see above) with possible consequences for invertebrate assemblages. Whether cuttings are removed or not can also affect invertebrate numbers and diversity. For example removal of cuttings is associated with lower species richness of Araneae over the short to medium term. This may be linked to increased structural diversity in swards where cuttings have not been removed, or to increased prey availability with higher numbers of Collembola utilising decomposing plant material (Baines *et al.* 1998). However, over the longer term leaving cuttings *in situ* may maintain levels of soil fertility with deleterious consequences for plant and animal diversity.

The incorporation of perennial wild flowers into grass strips will greatly enhance the insect fauna by providing host plants for a variety of phytophagous species. The technique can allow the creation of reasonably diverse vegetation rapidly, which can be colonised by invertebrates within 12 to 14 months (Thomas *et al*. 1994). The invertebrate community will be strongly influenced by whether these swards are established by sowing or natural regeneration. For example, Araneae abundance and diversity were higher on grass and flower swards established by sowing a complex seed mixture rather than by natural regeneration (Baines *et al.*1998). This has been related to increased structural diversity in sown swards many of which were dominated by robust branching species like *Leucanthemum vulgare* that are better able to accommodate the specific site requirements for web building. In addition, taller vegetation may also support higher prey densities (Baines *et al.* 1998). However, where local sources of flora are species rich natural regeneration may still be a preferred option for sward establishment. Not only may this be more cost effective but may also overcome concerns about the provenance of the agricultural and amenity seed mixes frequently used on field margins.

The benefits to invertebrates of sown swards will depend largely on their precise species composition. Sowing can have negative effects on some invertebrates by excluding plant species on which they depend the common Stinging Nettle, for example, is an important host of polyphagous predators (Perrin 1975) and its abundance was significantly reduced by sowing (Smith *et al.* 1994). The inclusion of broad-leaved weed species has been shown to have enormous benefits for the value of such strips to nectar feeding invertebrates which

will utilise such strips, if suitable flowers are present (Harwood *et al*. 1992, Cowgill *et al*. 1993, Smith *et al*. 1994). Butterfly abundance was significantly higher on swards sown with a species rich wild flower mixture rather than unsown swards (Feber *et al.* 1996). The four most heavily used nectar sources were Black Knapweed, Greater Knapweed, Field Scabious and Ox-eye Daisy and these were much more abundant on sown rather than unsown swards. Plots sprayed with glyphosphate herbicide in late June/early July declined in butterfly abundance over three years, a decline that was almost certainly related to a decline in perennial nectar sources in the sprayed vegetation (Feber *et al.* 1996). The nectar and pollen are very important food sources for a range of different insects including Coleoptera, Diptera and Hymenoptera as well as adult Lepidoptera. Some adult insects need to feed on nectar or pollen to mature their full complement of eggs and to provide energy whilst foraging for larval food plants or, in the case of predatory and parasitic species, suitable arthropod prey for oviposition. The inclusion of appropriate larval food plants in mixtures can attract more specialist feeders (Smith *et al.* 1994). Nectar-rich flowers and those with exposed nectaries, such as umbellifers are particularly useful.

Thus, in addition to the functions of sown grass strips, the inclusion of wild flowers can enhance the biodiversity of the field margin, and possibly populations of associated beneficial invertebrates that either pollinate crops (Corbett 1995) or predate crop pests (Wratten & Powell 1991).

(iii) Bird community

Grass and grass and flower strips receive little or no pesticides, as is the case for all the field margin management options considered here with the exception of sterile strips. Leaving field margins unsprayed with herbicides or subjecting them to very reduced inputs has important wildlife benefits. Increased use of herbicides in cropped areas has resulted in reductions in the diversity and abundance of annual weeds (Evans 1997). Field margins untreated with herbicides developed flora with higher abundance of Meadow Grass, Chickweed, *Fallopia convolvulus,* Knotgrass and *Chenopodium album* all important food plants for birds (Moreby 1997). Spraying may also result in a decline in perennial nectar sources (Feber *et al.* 1996). In addition, many weeds such as Knotgrass and Hemp-nettle support large numbers of phytophagous insects (Morris & Webb 1987). Sawfly larvae are particularly important for species like the Corn Bunting when feeding chicks and numbers of these insects have been drastically reduced by application of herbicides which kill the larval food plant (Ward & Aebischer 1994). Increased numbers and diversity of spiders (especially Linyphiidae) and butterflies on organic compared with conventional farmland may also be related to reduced pesticide input (Feber *et al.* 1997, Feber *et al.* in press). Thus the reduced use of pesticides associated with almost all field margins considered here will increase food availability for farmland birds.

Considering grass strips more specifically, with regard to sources of bird food, the flora of grass-only strips will provide mainly grass seeds and the invertebrate community will be relatively impoverished compared with grass and flower strips. However, a number of birds do feed on seeds of grasses such as *Poa spp*. and *Lolium spp*. Starling, Dunnock, House and Tree Sparrow, Turtle Dove, Cardueline finches and Meadow Pipits for example all include grass seed in their diet (Section 4, Table 4.2 and 4.4). In addition grass strips provide suitable habitat for invertebrates such as Carabid and Elaterid beetles and Tipulid larvae. These are recorded as important in the diet of a number of species of high conservation concern such Cirl Bunting, Corn Bunting, Grey Partridge as well as Pheasant,

Chaffinch, Starling, Yellowhammer and Skylark (Section 4, Tables 4.1 and 4.3). Skylarks have been recorded frequently flying from nesting sites in cereals to forage in grass strips for food for their young, highlighting the value of an intimate mix of grass and cereals that may be achieved through field margin management (Evans *et al.* 1995). Yellowhammers have also been observed feeding during the breeding season on grass strips managed, experimentally, in a range of different ways (J. Wilson pers. comm.). Similarly in summer, Cirl Buntings utilise rough or semi-intensified grassland for foraging and early in the season they feed chicks on spiders, beetles, caterpillars and leaf material from dicotyledonous plants with grasshoppers and bush crickets becoming more important later in the season (Evans 1997, Evans & Smith 1992).

In general, however, grass and flower strips that provide a range of plant and invertebrate food sources are likely to support a wider range of bird species than grass-only strips. They comprise a mixture of plants that flower at different times of year (Table 5.1) and hence provide food over a longer period of the summer. Grass-only strips comprise no perennial herbs and very few biennial plants and are likely to support fewer Hemiptera, Hymenoptera and Araneae (W. Powell pers. obs.). Studies involving experimental sowing of land with a basic grass mix, a tussocky grass mix, a diverse grass mix, a grass/wildflower mix and a 'bee' mixture (includes species such as White Mustard, Field Marigold and Common Mallow and is designed to provide nectar sources for bees and other insects) revealed the latter to have highest bird usage (Clarke *et al.* 1997). The lowest usage was on the basic grass mix whilst tussocky grass, grass and wildflower and diverse grass were all used at intermediate levels. The five species most commonly using the margin strips were Yellowhammer, Red-legged Partridge, Pheasant, Skylark, Wood Pigeon, Greenfinch and Linnet (Clarke *et al.* 1997). Similarly, although Cirl Buntings use grassland for foraging early in the breeding season they also take a wide range of weed seeds and occur in higher numbers in fields with more dicotyledonous weeds. This suggests that a grass and flower mix would benefit this species to a greater extent than grass only (Evans & Smith 1992).

On both grass and grass and flower strips, the availability of seeds and invertebrates may also be influenced by the cutting management. If cuttings are removed after harvest in August seeds will also be removed. If cuttings are left on the strip, most material will probably be available for bird species that will forage on the ground. This does, however, have the undesirable effect of possibly enhancing soil fertility. An advantage of autumn cutting is that it will leave short swards over winter that are favoured by many species, especially thrushes that feed on soil invertebrates. Cutting in mid summer usually has detrimental effects on the invertebrate community and management is better undertaken in spring and autumn. Care should be taken to ensure the timing of this cut is not so late that it overlaps with the breeding season of ground nesting bird species. Grass strips are only valuable for gamebirds if at least part of them is allowed to grow up and provide cover. However, a dense grass strip, promoted by less than annual cutting, may reduce the availability of invertebrates to a number of ground feeding species since tall dense vegetation is likely to make foraging less efficient than in open, patchy or short swards. Ideally strips should be cut every two to three years on a rotational basis around a farm to support a healthy population of gamebirds (Aebischer *et al.* 1994) and maximise structural diversity to benefit invertebrate diversity.

A dense grass strip, promoted by less than annual cutting, may also favour small mammal populations and hence increase hunting opportunities for raptors such as Kestrels and nocturnal hunters such as Barn Owls. The Wood Mouse is one of the most common small rodents associated with field boundaries **in arable land (Montgomery &** Dowie 1993) and frequently features in the diet of birds like Kestrels and Barn Owls. They are the only small rodents able to exploit agricultural habitats at all times of the year and permanent populations are to be found in fallow, plough, seed beds and standing crops (Harris & Woollard 1990). In fields where the field margin provides limited cover, Wood Mice make more use of thicker hedges (Montgomery & Dowie 1993). Shrews and voles will only move out of arable hedgerows into cereal fields when suitable cover is available. **B**ank Voles, for example, are associated with a dense ground cover and rarely move more than 5 m from the hedge and only when the crop provides sufficient cover (H**arris & Woollard 1990,** Tew *et al.* 1992). Harvest Mice are effective colonisers of agricultural habitats. During the summer they require areas of dense monocotyledonous vegetation for cover and nest-building (H**arris & Woollard 1990).** Field Voles are more closely associated with short grassland. They feed on recumbent species of grass such as Bent-grass and not the more erect grasses such as Cocksfoot and interaction between providing food and cover for this species **is rater** complex. Thus the creation of field margins that provide suitable cover for small mammals may increase both absolute numbers and availability since individuals may be encouraged to leave the dense hedgerow base where birds may find them difficult to capture.

Small mammal numbers are also influenced heavily by food availability. For example, overwinter survival of wood mice has been shown to correlate well with food supply in woodland in England and Sweden (Watts 1969, Bergstedt 1965) mainly grain from sowings, weed seeds and fragments of root crops and also soil arthropods and earthworms (Green 1979). Grass strips may provide less abundant food than some of the other margin treatments for example, conservation headlands (see 5.3.5), but they can provide grass and flower seed and ground-dwelling invertebrates **and** tall, relatively dense, grass swards provide ideal cover for a range of small mammals.

5.3.2 Beetle banks

(i) Plant community

Beetle banks are created by sowing a 1 m or 2 m wide strip of perennial grasses across the centre of large arable fields, often on a bank (Thomas *et al.* 1991, Thomas *et al.* 1992). Such banks could also be incorporated as part of a wider grass field margin. The grasses used in this option are typically tussocky species, such as Cocksfoot and Yorkshire Fog, which are suitable over-wintering habitat for ground beetles and suitable nesting cover for gamebirds. Management of beetle banks, where they become permanent features of the farm, is a modified form of grass margin strip management. Typically, cutting is applied on an irregular basis, less than once a year, so that the tussocky grass cover is maintained. Therefore, grass seed supplies are likely to be better maintained for birds than on annually cut strips.

(ii) Invertebrate community

The invertebrate community will resemble that of grass strips (see 5.3.1). Carabid and Elaterid Beetles and Tipulid fly larvae all benefit from reduced soil disturbance (Lagerlof & Wallin 1993) and the irregular cutting deployed on beetle banks will favour Carabids, Staphylinids Aranaea and Lepidoptera (Feber *et al.* 1995 & 1996, Baines *et al.* 1998). However, the main purpose of beetle banks is to provide an overwintering refuge for predatory Carabid and Staphylinid beetles. These species habitually seek shelter in field margin vegetation, especially tussocky grass and the invertebrate community of beetle

banks will be biased towards these groups (Luff 1966, Sotherton 1985, Thomas *et al.* 1991). Invertebrates requiring a more plant species rich sward or proximity to boundary features are less likely to benefit from beetle banks established across the centre of fields than from those established as part of marginal grass strips.

(iii) Bird community

The tussocky grass cover generated on beetle banks maintains a better grass seed supply than grass-only strips and the ground beetles that overwinter at such sites are important prey items for many bird species including Grey Partridge, Starling, Blackbird, Meadow Pipit and Pied Wagtail (Table 4.1 and 4.3). These beetle banks may also benefit grasshoppers that favour mosaics of long and short grass with patches of bare earth for oviposition (van Wingerden pers. comm.) and overwintering spider populations including lycosids (Bayram 1993). However beetle banks are usually only 1.5 to 2 m in width and they are unlikely to provide significant benefits for birds unless they are incorporated into a wider grass strips simply because of their small scale. One caveat should be added here. Although overwintering predatory arthropods can reach very high densities in suitable tussocky habitats (Thomas *et al.* 1991), they are not necessarily easily accessible to foraging birds due to the density of the vegetation. However, there is very little information on the winter predation by birds of invertebrates in such grass tussocks.

Beetle banks, because of their tussocky nature, are likely to support higher small mammal populations than other grass strips. Small mammals prefer tussocky, dense vegetation, possibly because such cover provides protection, better food supplies and a more favourable abiotic environment (Birny *et al.* 1976, Povey *et al.* 1993). Consequently beetle banks may be more attractive to bird species like Kestrels and Barn Owls.

5.3.3 Naturally regenerated (rotational) set-aside margins

(i) Plant community

Natural regeneration has been allowed to occur on set-aside land, including 20 m wide margin strips, and has been used as an option for field margin strip creation (West & Marshall 1996, Marshall & Moonen 1997). Set-aside takes one of two forms; rotational, where land is taken out of production and left as fallow for one year, and non-rotational where land is taken out of production for a number of years. In practice, most non-rotational set-aside is sown with green cover such as Perennial Rye Grass (Henderson *et al.* a & b ms submitted). As such it may be considered a form of grass strip and for the purposes of this review the term 'naturally regenerated set-aside margins' will be used to refer to rotational set-aside only

Rotational set-aside will favour the annual weed species and result in areas of winter stubble every year which are important feeding areas for birds (see below).As in the case of grass margins any management on set-aside strips should be implemented outside the breeding season. However, much rotational set-aside is sprayed with glyphosphate in early summer to control all green vegetation prior to cultivation for the next crop. This results in less disturbance of birds than repeated cutting and also has the advantage that the dead vegetation retains some structure. Cutting set-aside or natural regeneration margin strips will influence the availability of seed and invertebrates, as noted above (5.3.1), cutting in autumn will remove seed heads and whether these remain available to birds may depend on whether these cuttings are removed or left.

(ii) Invertebrate community

With regard to invertebrate food items, allowing natural regeneration to occur on set-aside margins may benefit insect abundance and diversity by generating a botanically and structurally diverse sward. However the relative value of a naturally regenerated and sown swards will depend on the species composition of the latter (see 5.3.1), determined in turn by soil type, the existing seed bank or seed mix and cutting regime (Gates *et al.* 1997).

Rotational field margins may provide an important source of invertebrate food for birds. However, higher numbers of invertebrates on set-aside land may be favoured by leaving set-aside in place for more than one year providing better ground cover (Gates *et al.* 1997). Cultivation of soil during the winter causes high mortality of insects such as sawfly that overwinter as pupae in the soil (Barker *et al.* 1997), Carabids with long larval stages in the soil and may also affect spiders (Hassall *et al.* 1992, White & Hassall 1994). In the case of sawfly, provided rotational set-aside is not cultivated until adult emergence is complete in spring (peak emergence of sawfly is in early May), the habitat provides a key overwintering site and refuge. Two of the main grass weeds Barren Brome and Black Grass, do not set seed until late May so cultivation in late May (third week) will encourage sawfly overwintering and not prejudice weed control (Barker *et al.* 1997). It should be noted, however, that cultivation at this time would be highly damaging to ground nesting species such as Skylarks.

(iii) Bird community

Set-aside can increase the habitat quality and diversity in agricultural systems, for example by introducing grassland and fallows into arable areas. Reduced availability of weed seed, particularly during winter but also in spring has been cited as a probable cause of declines of a number of seed-eating farmland bird species (Stoate 1996, Campbell *et al.* 1997, Draycott *et al.* 1997). Set-aside fields contain more grains and wild seeds than autumn and spring tilled fields although variation between fields is high (Draycott *et al.* 1997). The most common species are *Chenopodium spp*. and Knotgrass. These species that are present, and in most cases important, in the diet of many granivorous birds e.g. Grey and Red-legged Partridge, Tree Sparrow, Greenfinch and Bullfinch. The number of seed-eating birds utilising set-aside fields in winter has been shown to increase with the weediness of those fields (Wilson *et al.* 1995).

The creation of 'stubble strips' through the adoption of rotational set-aside on field margins, which removes land from production for a year and creates weedy stubble over winter, may have significant benefits for birds. Stubble fields have become increasingly rare in modern farming as the extent of autumn, rather than spring, sown cereals has increased. Moreover a reduction in the practise of undersowing, a frequent component of traditional mixed farming also removes a reason for stubbles being left over winter (Brickle 1997). Furthermore, the quality of remaining stubble as a food source for seed-eating birds has probably declined as more efficient harvesting reduces levels of spilt grain and increased herbicide use reduces the diversity and abundance of annual weeds (Evans 1997). Stubble fields are used extensively by seed-eating birds including Corn Buntings (Donald & Evans 1995) and Skylarks (Wilson *et al.* 1995). Cirl Buntings, which are restricted largely to south Devon, feed almost exclusively on stubble fields in winter (Evans & Smith 1994) and show a marked preference for feeding in the margins of fields, rarely more than 30 m from cover (Evans & Smith 1994). In fact, the reintroduction of winter stubbles through set-aside and Countryside Stewardship schemes resulted in a marked

increase in the UK Cirl Bunting population (Evans 1997). Recent research by RSPB (Wilson *et al.* 1995) and BTO (Henderson *et al.* a & b ms submitted) has shown strong selection for naturally regenerated rotational set-aside stubbles over other field types by a range of over-wintering and breeding birds such as Skylark and Linnet.

The basis of this preference probably lies with increased food availability though there have been no direct comparisons of invertebrate and seed availability in the two types of set-aside. One would expect invertebrate diversity to be higher on non-rotational set-aside sown with a favourable seed mix for reasons discussed under 5.3.1. However, it is possible that rotational set-aside offers a higher availability of invertebrates, including spiders. The diverse vegetation structure of rotational set-aside provides open areas and bare ground patches that allow invertebrates to be more easily caught than from denser sown swards and spilt seed may be more easily collected than from rank grass regardless of absolute abundance (Clarke *et al.* 1997).

Set-aside margins appear to be used by most species of birds that potentially benefit from set-aside. An important exception is Skylark which, although it breeds at high densities on set-aside compared with conventionally managed cropped fields (Wilson *et al*. 1997), avoids set-aside situated along field boundaries (Chaney *et al.* 1997). Whilst current data suggest that field margin set-aside is heavily used by birds in the breeding season (Henderson *et al.* a & b ms submitted) more data are needed on how winter birds respond to field margin set-aside as opposed to whole field set-aside.

Very little information exists as to whether set-aside provides favourable habitat for small mammals. Tattersall *et al.* (1997) suggest that small mammal densities may, in fact, be relatively low in one-year set-aside compared with adjacent crops. Low trapping success of small mammals (mice, shrews and voles) in one-year set-aside fields have been attributed to poor cover on naturally regenerated and sown set-aside fields (Green 1994, Plesner *et al*. 1995). Thus it seems likely that naturally regenerated rotational set-aside will not particularly enhance small mammal populations and will be of less potential benefit for species like Barn Owls and Kestrels than dense grass swards. On the other hand non-rotational set-aside may offer better habitat quality for small mammals.

5.3.4 Uncropped wildlife strips (cultivated approximately annually, not sown with a crop)

(i) Plant community

Within the Breckland ESA, prescriptions exist for uncropped wildlife strips (Critchley 1994). These strips are designed to encourage the rare Breckland annual flora, particularly species of Speedwells. A 6 m wide strip of land at the edge of an arable field is cultivated approximately annually, sometimes biannually, in the autumn but the crop is not sown. Soil disturbance allows annual plant species to germinate, grow and set seed. The control of the weed grass Barren Brome is allowed on the strips and perennial grasses are discouraged by annual cultivation (Critchley 1996). It is important to note that the application to date of Uncropped Wildlife Strips is very localised and restricted to light and/or shallow soils. The treatment has been targeted at the conservation of rare arable weeds and may not be appropriate to other soil types.

These strips may provide areas of high seed availability, particularly where annual weeds, such as members of the Chenopodiaceae, are allowed to flower. Annual cultivation can

take place during the autumn or spring. The timing of cultivation has a major impact on the weed plant communities that develop (Chancellor 1985). Spring cultivation will favour a number of rarer spring germinating annual arable weeds (flowers) as well as other annuals, notably Knotgrass. As such it is probably more valuable than autumn cultivation, in terms of wildlife benefits, since the switch to winter crops has resulted in a shift in arable weed communities to autumn germinating species. Winter cultivation of these strips is most common in Breckland ESA where this option is available to farmers. Unless the strips are left for two years, biennial plants are unlikely to flower on these strips. Annual species are likely to be most abundant.

(ii) Invertebrate community

Many of the annual plants that utilise disturbed ground and which form the main botanical component of uncropped wildlife strips support a wide range of phytophagous insects, especially Hemiptera, Coleoptera and Lepidoptera. Plants such as Knotgrass, Hemp-nettle and Scentless Mayweed can support large numbers of associated insects of value as bird food. Many of these annual species are also valuable pollen and nectar sources (Morris & Webb 1987). In a comparative study, Hassall *et al.* (1992) found that strips of uncropped headland held a greater abundance and variety of arthropods than conservation headlands when established along margins of the same fields, and provided a good habitat for spiders and Carabid beetles as well as phytophagous groups. However, this study was only carried out at one site (The Brecklands) and in one year and the generality of the results cannot be assessed.

(iii) Bird community

Uncropped wildlife strips provide a range of potential benefits for both seed-eating and insectivorous birds. These strips may provide good feeding areas for seed-eating birds, particularly where annual weeds, such as members of the Chenopodiaceae, are allowed to flower. As for naturally revegetated set-aside the diverse vegetation structure or wildlife strips provides open areas and bare ground patches that allow spilt seed to be more easily collected than from rank grass, and invertebrates are probably also more easily caught from these areas (Clarke *et al.* 1997). The annual weeds, e.g. Chenopodiaceae, that are maintained as a result of this cultivation are important components in the diet of six of the nine Birds of Conservation Concern considered in this review and are also taken by Skylarks and Cardeulis finches (Table 4.3 & 4.4).

Wildlife strips also support large numbers of invertebrates. Spiders, Carabid beetles and Heteroptera are all more abundant in uncropped wildlife strips than in conservation headlands in cereal fields. Ploughing and cultivation have a major effect on Carabid populations especially those with long larval stages in the soil and may also affect spiders (Hassall *et al.* 1992, White & Hassall 1994). Uncropped headlands unlike conservation headlands are usually not ploughed but rotovated three out of every four years and only once in the autumn of any one year when it is least likely to affect invertebrate populations. The diverse vegetation structure may also enable invertebrates to be more easily caught from these areas by birds (Clarke *et al.* 1997).

5.3.5 Conservation headlands and low-input crop edges

(i) Plant community

The techniques of modifying the management of arable, particularly cereal, field edges were developed in Germany to conserve rare arable weed species (Schumacher 1987) and modified in the UK by the Game Conservancy Trust to enhance populations of the Grey Partridge (Sotherton *et al*. 1985, Rands 1985, Rands & Sotherton 1987). By reducing or eliminating the use of agrochemicals in the outside edge of the cereal crop, broad-leaved weed species are allowed to grow. The sparse canopy cover that results from reduced fertiliser input encourages rare annual arable flowers or weeds (Kleijn & Van der Voort 1997). In Europe, the headlands are usually not sprayed or fertilised (Jörg 1994), though management prescriptions vary. In the UK, insecticides and most fungicides are excluded on spring sown crops. Insecticide use is only permitted on autumn sown crops up to 15 March. Selected herbicides are allowed for the control of competitive grass weeds.

(ii) Invertebrate community

With reduced insecticides (none on spring cereals and limited on autumn cereals) and reduced herbicides applied, invertebrates, some associated with particular weed species, are also encouraged, including groups such as sawflies and certain Hemiptera that are important food items for gamebird chicks. Not only are partridge populations enhanced by the conservation headland technique, but invertebrate groups are also enhanced (Dover 1996 , Hassall *et al*. 1992). Many annual weeds, which benefit from conservation headland management, support large numbers of phytophagous insects and some are valuable nectar and pollen sources. However, conservation headlands do not appear to support as great an abundance of arthropods as uncropped wildlife strips, partly due to the differences in management and cover type, the former comprising largely crop plants and being ploughed as opposed to shallowly cultivated every year; ploughing, is know to have a detrimental effect on invertebrates living on the soil surface or in the upper soil layer.

More individual butterflies and more species of butterflies are found in conservation headlands than in fully sprayed headlands. Observations of butterfly behaviour in conservation headlands showed that they were being exploited for nectar and occasionally for oviposition by some species (Dover 1989). However, if established next to a severely degraded boundary, the nectar source that such headlands provide are unlikely to support large numbers of adult butterflies. Most of the broad-leaved plant species that increase when headlands are left unsprayed are annuals and the nectar supply from these may be poorer than from perennials. In addition, headlands themselves cannot support breeding populations of butterflies. Few perennial plants can survive the harvest and cultivation operations in arable crops. Breeding on conservation headlands is therefore restricted to a few bi- or multi- voltine species such as the common Pierids (Large and Small Whites) whose larvae can utilise annual host plants and complete their development before harvest. Conservation headlands are thus most likely to be beneficial to butterflies when they augment the resources provided by well managed permanent field margins (Feber & Smith 1995).

(iii) Bird community

Conservation headlands were developed initially for the conservation of gamebirds within farmland and they have been shown to have significant benefits in terms of brood size and chick survival for Grey and Red-legged Partridge and Pheasant (e.g. Chiverton 1994). In the breeding season, partridges require suitable nesting and brood rearing areas. Grey

Partridge and Pheasant chicks both require an insect-rich diet in the first few weeks of life (Hill 1985, Potts 1986) and chick survival has been correlated with the abundance of cereal arthropods (Rands 1986). These insects have been shown to be more abundant close to field boundaries than in field centres. Red- legged Partridge chicks feed on insects and grass seeds in both cereals and root crops and their food supply is also more abundant in the field margin. As a result, all three gamebird species feed chicks at field edges rather than field centres where arthropod and weed seed food are most abundant (Sotherton & Rands 1987). Cereals can provide the insects that the chicks require as long as there are enough broad-leaved weeds present as insect hosts. The reduced use of herbicides ensures this is the case (Aebischer *et al.* 1994).
The structure of the vegetation in which chicks forage is also important. It must be tall enough for concealment from predators but sufficiently open to allow easy passage. In wet weather chicks must be able to avoid becoming soaked through by constant contact with wet vegetation and if wet, must be able to dry out. The structure of cereal crops is ideal and radio tracking studies have shown that hens lead chicks from the nest site into adjacent cereal crops to feed (Green 1984, Hill 1985).

The wider benefits of conservation headlands to non-gamebird species has been less well studied. In terms of seed supply, conservation headlands encourage broad-leaved weeds. In addition, cereal seed is available in the stubble after harvest. Thus, they should benefit a range of seed-feeding birds. However to date the effects of conservation headlands on passerine birds remain equivocal (Green *et al*. 1994, see also Section 3.3.2.). A study in The Netherlands revealed Blue-headed Wagtail to use unsprayed crop edges significantly more than crop centres but Meadow Pipit and Skylark showed no such preference for unsprayed margins (Snoo *et al.* 1994). The difference may have been related to the fact that only small differences in soil invertebrates, the main prey of Skylarks, were apparent whereas Wagtails also feed on invertebrates higher up the plants and in the air.

In general it seems likely that conservation headlands will provide a valuable source of invertebrates and seed for a range of bird species. The diversity and abundance of both food types is likely to be less than that of uncropped wildlife strips (where these are appropriate) and may be higher or lower than the very variable levels on naturally regenerated strips. Conservation headlands have been shown to benefit small mammal populations. The diet of Wood Mice consists principally of seeds (70%), animal matter (15%) and forbs (5-10%). Radio tracking studies show that Wood Mice are able to recognise and make use of locally high food availability. Arable dwelling Wood Mice feed on many of the plant and animal species known to benefit from conservation headlands and they have been shown to actively seek out experimental plots where food abundance has been increased by reducing herbicide applications (Tew *et al.* 1992). Thus, conservation headlands may increase Wood Mouse populations and so benefit predators of Wood Mice on arable farms, particularly as they bring the small mammals close to hedgerows where avian predators are most likely to hunt (Tew *et al.* 1992)

5.3.6 Game cover strips

(i) Plant and invertebrate community

Farmers keen on encouraging gamebird populations often plant blocks or strips of game cover crops. A variety of species can be planted, including small grain cereals, Maize, Millet, Kale, Quinoa, Fodder Beet, Sunflower, Teasel, Parsnip, Chicory and various

grasses. The commonest cover crops are Maize and Kale. These crops provide cover and food for a variety of bird species, as well as gamebirds. Under some circumstances, the cover crop will last only through the year, but can be allowed to "tumble down" on set-aside land. Typically game cover crops are planted as field margin blocks, often alongside farm woods where gamebirds are raised and released, or as part of 20 m set-aside margins.

Seed supplies are usually good on game cover strips especially over winter. Seeds can be provided by the sown crop such as Kale or Quinoa but also by weeds that establish in the block. While game cover strips will not support the variety of insects and other arthropods that occur in more botanically diverse habitats such as uncropped wildlife strips or naturally regenerated (rotational) **set-aside margins, some of the crops used can support large numbers of pest insects such as aphids and caterpillars which are a valuable food source for some farmland birds. Kale, for example, is used as a food plant by a variety of Lepidoptera (Carter 1984).**

(ii) Bird community

The presence of game cover strips or blocks in winter provides similar benefits to those provided by rotational set-aside strips (see 5.3.3). In particular the creation of stubble may provide an important food resource not only for gamebirds such as Grey and Red-legged Partridge but also for songbird species such as Corn Buntings, Yellowhammers, Skylarks and Linnets (Brickle 1997). Foraging Yellowhammers have been shown to prefer set-aside managed under the spring sown Wild Bird Cover option (WBC) relative to other habitats such as woods, pastures and cereals (Stoate & Szczur 1997). Wild Bird Cover planted with a mixture of seed-bearing crops could represent an important 'stubble substitute' for seed-eating birds (Stoate & Szczur 1997). The relative value of different game cover and winter crops in terms of their utilisation by birds in winter is the subject of an ongoing study by the Game Conservancy Trust and British Trust for Ornithology.

5.3.7 Sterile strips

(i) Plant and invertebrate and bird community

Sterile strips are designed to prevent the ingress of annual weeds from the field boundary into the arable crop, to provide a clean edge to the crop to facilitate harvesting and to provide an area for gamebirds to dry out in wet weather (Bond 1987). The strip is usually 1 m wide and is located as part of the cultivated crop edge, otherwise the hedge bottom (see 1.2 above) is damaged. The strip is usually created with a herbicide, either applied in the winter using a soil-acting compound, or a contact or translocated herbicide, typically glyphosate, in early summer. Alternatively, the strip can be created by rotovating a strip, perhaps 2 m wide, round the field edge on two or three occasions through the season.

The objective of the strip is to maintain a weed-free area between the crop and the boundary. As such, it has no value to birds that feed on plants and little value to those that feed on insects. However regular mechanical rotavation of the soil will bring seeds and invertebrates to the surface at intervals and so increase their availability to birds such as Robin and Thrushes. In addition open areas are important for many gamebirds to dry out after foraging in wet vegetation.

6. CONCLUDING DISCUSSION

6.1 The Relative Value of Different Field Margin Managements for Providing Food Resources for Birds

The different structures that can be found or created at field margins create markedly different habitats and thus different opportunities for plants and invertebrates, which may produce food for farmland birds. It is worth re-stating the important caveats associated with comparisons of field margin treatments already outlined in the introduction to Section 5. Namely, that the relative value of a number of these margin treatments will vary with geographic locations, time after establishment and time of year. For the purposes of this review we consider ideal conditions and make comparisons between treatments in the first or second year of establishment. With respect to time of year we have not compared the treatments in winter and summer separately but have considered treatments at the time of year when they are likely to be of maximum benefit to birds. In general, the best winter food supplies (mainly seeds) will be provided by options that create stubble strips. These include game cover crops and naturally regenerated rotational set-aside. In summer, plant (seeds, fruits and green plant material) and invertebrate food will be highest on those options that are botanically most diverse. Grass and flower strips, uncropped wildlife strips (in limited geographic locations) and naturally regenerated (rotational) **set-aside field margins are likely to offer the highest food availability followed by conservation headlands.**

Although comparisons of flora between margin treatments are relatively easy very little data exist on invertebrate abundance and diversity on different field margin types. There are very few quantitative studies, especially comparative ones, with the exception of those relating to conservation headlands. The studies that have been done are usually limited to a small number of sites and carried out over one or two years only. Since invertebrate abundance and diversity varies a great deal between and within years attempts to assess the relative value of field margin treatments based on such studies are necessarily very preliminary.

In general, systems which promote botanical diversity will automatically stimulate arthropod diversity, but vegetation structure is also important as discussed above. Such systems include grass and flower strips and uncropped wildlife strips (in limited geographic areas). Schemes which encourage a rich variety of flowering plants are particularly beneficial because of the value of pollen, nectar, seeds, seed-heads and overwintering woody stems to a range of insects. Floral diversity is an important factor for increasing the abundance of Heteroptera, Lepidoptera, Coleoptera and Diptera. Depending on the seed mix used, sown swards on grass and flower strips and uncropped wildlife strips are likely to favour the highest diversity of insect food plants, followed by naturally regenerated (rotational) **set-aside and conservation headlands. As mentioned in Section 5, however, insect diversity *per se* may be less important to birds than insect abundance and availability. It is important to remember that the encouragement of a diverse and abundant insect fauna will not automatically address the food requirements of all farmland birds which depend upon invertebrates either as adults or nestlings. Much more information is needed on the key food items required for particular bird species so that management schemes can be tailored to their needs. Management of margins to increase certain key insect groups rather than just encouraging general arthropod diversity may be more profitable for some individual bird species although the current level of data on dietary requirements of birds is insufficient to assess this. It is also important to assess the**

accessibility of food items under different margin management schemes since the birds need to be able to utilise enhanced food supplies. For example, although grass and flower strips may be roughly similar to naturally regenerated (rotational) set-aside margins, in terms of their value of their invertebrate fauna for birds, the accessibility of these invertebrates is likely to be higher in the open patchy sward of the latter than a dense grass sward. Indeed, the same is true for seed supplies i.e. that abundance does not necessarily equal availability.

How the different types of margins are managed will affect invertebrates in complex ways and also influence availability of fruits and seeds. In the case of hedges, for example, annual trimming will reduce berry production. Margin strips, which may require cutting to maintain a perennial herb cover and prevent shrub encroachment, need to be managed to achieve practical objectives, as well as optimising habitat and food resources for bird species. Under conditions of high soil fertility, two cuts per year may be required whereas less frequent cutting may be required on poorer soil. Naturally regenerated cover will also be strongly influenced by soil fertility and by the quality of the existing seed bank. The management regimes necessary for different field margin or boundary habitats will also influence the associated invertebrate fauna. The type of wildflower mix used in sown swards for example may heavily influence the presence or absence of certain invertebrates by including or excluding vital adult or larval food plants. Similarly, the timing and frequency of soil cultivation may effect survival of pupal and larval stages of some invertebrate species. Certain life stages of many of the insect groups that are important as bird food develop in the upper soil layers, particularly pupal stages of some Lepidoptera, Coleoptera and Diptera and larval stages of certain Coleoptera and Diptera. These are damaged by soil cultivation techniques, especially ploughing, and so field margin management schemes which do not involve soil cultivation are more useful for encouraging these groups.

Thus, the overall wildlife benefits of a given margin treatment may vary considerably between sites depending on factors such as soil type, existing seed bank, wildflower mix used or management applied. However some attempt can be made to rank the different management treatments according to the level of plant and insect food availability associated with each individual option. Based on the dietary information for each of the 22 bird species considered (Tables 4.1 to 4.4) and the 'capability' of different margin treatments to provide seeds/fruits or invertebrates (Tables 6.1 and 6.3). The extent to which these margin managements 'meet the requirements' of the birds, can be crudely assessed based on the percentage of important dietary items provided by each option for each species. For example, for House Sparrow the seeds of cereals, grasses, annual weeds and perennial herbs have all been quantified as important (Table 4.4). Grass and flower strips produce two of these seed sources: grasses and perennial herbs, both in abundance. Thus for House Sparrow this option scores 50% i.e. 50% of dietary items known to be important are present in the field margin under this option. Similar calculations can be made for each species and the total number of species for which 'grass and flower' strips provide >30% and >50% of important prey items calculated. This has been repeated for each option and for both plant and invertebrate prey and the results are summarised in Tables 6.4 and 6.5.

In general, the tables support the findings of the analyses in Section 3. The least valuable options, in terms of providing food resources for birds, are grass-only strips. Natural regenerated (rotational) **set-aside strips, uncropped wildlife strips (in limited geographic locations) and conservation headlands offer greater foraging opportunities for a greater**

range of birds than grass strip options with the exception of grass and wildflower mixes. The highest availability of plant food for the 22 bird species considered is provided by naturally regenerated (rotational) **set-aside margins. These provide moderate or abundant seeds from cereals, biennials and grasses and some seeds from annual weeds and perennial herbs. They also provide food sources in winter through the creation of stubble strips. Conservation headlands, grass and flower strips and uncropped wildlife strips (in limited geographic locations) are also extremely valuable for birds. Conservation headlands provide moderate levels of cereal and annual weed seed and some grass seed. Uncropped wildlife strips provide abundant annual weed seed and lower levels of grass, biennial and perennial herb seed but their value is probably restricted to light soils of low fertility. Grass and flower strips provide abundant annual weed and perennial herb seed and some biennial seeds.**

Assessing the relative value of the invertebrate communities of these different treatments is extremely difficult. There are very few quantitative data from studies comparing the different regimes and those that do exist are often restricted to single sites and one or two years. Invertebrate communities will differ markedly between these treatments and at different times of year within treatments. Thus whilst overall abundance may be rather similar between, perhaps, uncropped wildlife strips and grass and flower strips, the actual species composition is likely to differ extensively. The importance to birds of differences in species composition is difficult to determine because dietary information is not sufficiently detailed to assess the extent to which bird species may or may not depend on key species. In addition the extent to which abundance of invertebrates reflects their availability to birds will vary between different sward structures. The way in which foraging is modified by sward structure has not been assessed beyond the rather simple observation that open patchy swards are likely to facilitate foraging by most birds whereas a tall dense sward will hinder it. Thus, while grass and wildflower strips may provide relatively food seed and invertebrate food resources for birds, if the sward is tall and dense the availability of this resource may be considerably reduced. Overall it is difficult to identify any major differences between grass and flower strips, naturally regenerated (rotational) set-aside strips or uncropped wildlife strips (in limited geographic locations) in terms of their value as sources of invertebrates for birds. However, it is clear that grass only strips (whether as simple marginal strips or elevated beetle banks in the field centre) are the least valuable for invertebrates.

This rather crude assessment is based only on the effects of altering seed and invertebrate food availability. Field margin management treatments that benefit small mammals will also benefit the birds that feed on them - such as Barn Owl and Kestrel. Microhabitat utilization by small mammals is a complex function of predation risks, costs of food acquisition micro-environmental conditions and social pressures. In general relatively dense grass margins are likely to provide the best habitats, particularly in terms of cover, for voles, mice and shrews in arable areas**. However, their numbers are also known to be heavily influenced by food availability both in the long (over-winter survival) and short term (responding to local food abundance) and conservation headlands which also provide moderately good cover but abundant weed and cereal seeds and invertebrates are also likely to benefit small mammals and thus the birds that feed on them.**

The optimum management for birds would be a treatment that provides stubble strips in winter and a diverse sward in summer. This may be achieved through a combination of a grass and flower margin or uncropped wildlife strip (in limited geographic locations)

adjacent to a naturally regenerated (rotational) **set-aside strip or a stubble strip. The inclusion of a form of winter stubble is, in our view, essential to maintain populations of seed-eating farmland birds. The inclusion of a 'permanent' treatment such as a grass strip will also promote the invertebrate fauna since it will provide key over wintering sites for a range of species, a tussocky grass strip will also provide ideal habitat for small mammals and hence increase hunting opportunities for birds such as Barn Owls and Kestrels. By maximising the diversity of habitat structures present at the field edge, the opportunities for birds should be further enhanced. Thus the presence of a well-managed hedge with hedgerow trees, together with a tussocky grass hedge bottom will enhance the wildlife value of most of the management treatments of the margin itself.**

In conclusion, sensitively managed cereal field margins are an important mechanism by which to introduce spatial and structural heterogeneity to farmed landscapes without having a serious detrimental effect on the remaining cropped area. Estimates of a current national average field size of 12 ha suggests there is about 400,000 km of cereal field edge. There have been no detailed studies of the optimum field margin width in terms of agronomic and environmental costs and benefits. However, studies of the impact of herbicide drift on native flora indicate that distances for no measurable effect are approximately 6 m or above (Marrs & Frost 1997, Marrs *et al.* 1991). If all such boundaries included a 6 m managed margin 200,000 ha of land would be brought into sensitive management with considerable wildlife benefits (Anon 1995 a & b). The results of this review suggest these benefits would be maximised if the margins were managed in ways that provide a diverse sward in the summer e.g. sown or naturally regenerated grass and wildflower mix or uncropped wildlife strips (in limited geographic locations) and areas of stubble over winter i.e. rotational set-aside.

6.2 Margins Compared with Other Approaches to Enhancing Farmland Bird Populations

6.2.1 Introduction

The initial intention was to compare the relative value of field margins and other approaches to enhancing farmland bird populations for each bird species individually. However, for the vast majority of the species considered here the food requirements are broadly similar and this would involve a great deal of repetition. The relative benefits, in terms of food resources or nesting habitat, that are derived from field margins, whole-field rotational set-aside, organic farming and ICM for each species individually are summarised in Table 6.6.

Our overall conclusion is that it is difficult to identify clear and distinct benefits that attach to individual approaches. The table suggests that, on a local scale, the benefits derived from set-aside, field margins and organic farming are broadly similar. In part, this is because there is much variation within each system/approach and only a qualitative assessment can be made of the relative benefits of each. It is likely that <u>area for area</u> field margins are a almost certainly a very efficient way of achieving bird conservation benefits in summer but, in winter, the benefits of field margins for feeding birds have yet to be clearly demonstrated. There are exceptions to this, a small number of species are known to avoid field margins in winter and summer or both. For example, wintering Golden Plover, wintering and breeding Lapwing and breeding Skylarks are unlikely to benefit from field margin management but will benefit from whole farm approaches.

In the following sections we discuss the merits of different approaches to enhancing biodiversity on farmland, relative to an approach based on field margins. Where special benefits accrue to particular species, or groups of species, these are discussed.

6.2.2 Whole field set-aside

Studies on the use made by breeding birds of set-aside land tend to suggest that many of the benefits of whole field set-aside could be gained from set-aside field margins (Henderson *et al.* a, b ms submitted). First, very few species with the exception of Skylark, Lapwing and Stone Curlew, avoided the margins of set-aside fields in summer and a number of species occurred more frequently than expected in field margins rather than field centres (see 3.3.3). Second, the abundance of plant and invertebrate prey is likely to decrease with distance from the boundary; weed seedlings and a number of invertebrate groups show decreasing densities with distance from field boundary (Marshall 1989, Wilson & Aebischer 1995, Gates *et al.* 1997).

Although many species of farmland bird show preferences for set-aside in winter (Buckingham *et al.* in press), very little is known about their spatial distribution within set-aside or stubble fields in winter. However the widespread integration of set-aside into the arable landscape is likely to have provided an important refuge for many farmland birds that are declining in numbers (Evans 1997). Set-aside can increase habitat diversity and quality by effectively re-introducing fallow into arable systems and, through rotational set-aside, create widespread weedy stubble fields that persist over winter. The latter provide an important food resource for seed eating birds whilst fallow may provide valuable nesting cover in spring, particularly for gamebirds and Skylarks (Evans 1997). The potential conservation benefits of set-aside are large partly because of the habitat it creates and partly as a result of the scale over which the scheme operates. However set-aside is unlikely to feature in the agricultural landscape for much longer, with proposals to abolish it in the year 2000 (EC 1997, RSPB 1997). Options for field margin management have traditionally proved popular with the farming community since they incur minimal production losses. An option to manage field margins in a way that incorporates some of the features of set-aside, particularly natural regeneration and overwinter stubbles, may provide a means of providing important conservation benefits over a wide geographical scale.

6.2.3 Organic farming

Organic farms exhibit some of the features that have become rare on conventionally managed farmland during the last 30 years. These usually include a mixed farm structure with livestock and arable in close association. Specific features include rotations incorporating grass leys and legumes, reliance on animal and green manures rather than synthetic fertilisers and no use of synthetic pesticides (Fuller 1997). To some extent, organic farming reverses recent trends in agricultural intensification. Two major comparisons of birds on conventional and organic farms, one in Denmark (Christensen *et al.* 1996) and one in Britain (Chamberlain *et al.* 1995) suggest that organic farming may provide significant benefits since, in general, they supported higher breeding and wintering densities of a wide range of species. This conclusion is supported by single species studies of Yellowhammer (Petersen 1994) and Skylark (Wilson *et al.* 1997), both of which exhibited higher breeding success (brood size and nest survival respectively) on organic compared with conventional farms. Potentially, organic farms offer a wide range of benefits to most farmland species.

Evidence suggests that the benefits of organic farming to birds are likely to derive from a range of factors including use of rotations and increased food availability, since the abundance of weeds and some invertebrate groups is higher in organic than conventional cereals (Brookes *et al.* 1995). However, although substantial benefits may be derived from organic farming it forms a relatively small part of the total farmed area in Britain (50,000 hectares was farmed organically in April 1997). This area is growing but it is unlikely to provide the widespread changes in the farmed landscape that were evident, for example, as a result of set-aside scheme. The conservation benefits associated with organic farming are likely, therefore, to be localised. Sensitively managed field margins involve reduced pesticide and fertiliser inputs and may even generate small strips of grass leys, mimicking some of the key features of organic systems. The advantage of field margin management is that there is the potential to integrate such changes over a very large geographical scale. On a local scale, however, field margins are unlikely to introduce the mosaic of habitats, of arable and livestock, associated with organic farms.

6.2.4 Integrated Crop Management

Integrated Crop Management (ICM) is a combination of farming practices which are designed to balance the economic production of crops, through applications of rotations, cultivations, choice of seed variety and judicious use of crop production inputs, with measures which preserve and protect the environment (LEAF 1995). Essentially it involves modern farming practices whilst minimising pesticide and energy inputs. For example, rather than selecting a high yield, high pesticide input cereal variety, an ICM farm may select lower yield but more resistant variety. This type of farm management is intermediate between conventional and organic farming but there are no clear cut definitions of ICM farming and so the spectrum of farm types is a broad one. The scheme is also relatively new and to date very little information exists about the wildlife conservation benefits of ICM.

The benefits to birds of organic farming, with stricter controls on use of synthetic pesticides and fertilisers, are likely to be greater than ICM. But any reduction in the use of these chemical inputs and increases in the diversity of crop rotations are likely to confer wildlife benefits. Thus, in general, the advantages and disadvantages of field margins with respect to ICM farm management are likely to be similar, but perhaps less marked, to those discussed in the context of organic farming. Field margins are likely to be integrated over a much wider scale geographically but perhaps offer smaller benefits at the local scale.

6.2.5 Arable Stewardship

Arable Stewardship is a new MAFF pilot scheme which offers payments to arable farmers to manage their land in ways that encourage wildlife. The pilot scheme, which is being run in two areas of England, is part of Countryside Stewardship. There are five main land management options three of which are field margin managements (MAFF 1998).

Crop margins with no summer insecticides; insecticides are not applied between 15 March and harvest over a 10-12 m crop margins. This option has two supplements - conservation headlands within which herbicides are also restricted and conservation headlands with no fertiliser (including organic and inorganic fertilisers).

Grass strips; this option has three supplements (i) grass field margins which must be at least 6 m wide, and may be established by natural regeneration or sown grasses (sown with Cocksfoot, Chewing's Fescue and Timothy and specified rates) and cut once by the end of March and then once or twice before September, (ii) beetle banks which must be 2-3 m wide planted with the same seed mix as for grass margins and managed to maintain a tussocky sward, (iii) uncropped wildlife strips which must average 6 m wide and be left unsown but cultivated every year or every other year in spring (to a depth of 100-150 mm) or autumn (to a depth of 75-100 mm). Herbicide application is limited and inorganic and organic fertilisers cannot be used.

Wildlife seed mixtures; these can be sown either as blocks or as field margin strips. They may be designed to produce an open sward (with summer flowering plants for foraging insects, foraging sites for birds and cover for mammals such as brown hare); a succession of seeds and cover (for example a mix of two crops one of which sets seed in its first year e.g. Teasel, Kale, Chicory, Millet); or a small grain cereal-based mixture to provide a variety of food for seed-eating birds

6.3 Recommendations and Guidelines

1. The major way in which field margins benefit bird conservation of farmland birds is through providing increased food availability. The optimal field margin management treatment in this respect is one which creates a diverse sward structure in the summer and an area of stubble in the winter. Thus a margin comprised of grass and wildflower strip or an uncropped wildlife strip (in limited geographic areas) adjacent to an area of naturally revegetated (rotational) set-aside strip, which can provide stubble strips in winter, would maximise the benefits for farmland birds. The highest plant and invertebrate food abundances throughout the year are offered by uncropped wildlife strips, naturally revegetated (rotational) set-aside strips and grass and wildflower strips. Grass-only strips or beetle banks alone appear to have less value as sources of seeds or invertebrates. The value of uncropped wildlife strips is extremely dependent on the location and soil type. They provide the greatest benefits in light soil of low fertility e.g. the Brecklands where they encourage the growth of rare annual plants. Similarly, the value of grass and wildflower strips and naturally regenerated cover are highly dependent on the seed mixes used and the existing seed bank respectively as well as soil type and fertility.

2. The optimal width of field margins has not been assessed but many advisory publications recommend 6-12 m and in the absence of evidence to the contrary we would not wish to contradict this.

3. The timing of any management of field boundaries, e.g. cutting of grass strips to prevent scrub encroachment, must be selected with care. In particular avoid cutting during the breeding season of ground-nesting birds like Skylarks. **Cultivation of soil during the winter causes high mortality of insects such as sawfly that overwinter as pupae in the soil. Provided land is not cultivated until adult emergence is complete in spring (peak emergence of sawfly is in early May) the margin will provide a key overwintering site and refuge.**

4. The location of field margins with respect to hedgerows and woodland can significantly affect their value for birds. If margins are to be managed on only a proportion of the fields on a given farm then, where possible, these should be adjacent to well maintained hedges or farm woods that provide valuable nesting habitat for birds.

6.4 Future Research

1. A major gap in our knowledge about the conservation benefits of field margins is the relative value in relation to whole-field farming approaches designed to encourage

wildlife. The introduction of schemes such as Arable Stewardship may provide a valuable opportunity to examine this. The scheme will provide financial incentives for farmers to adopt one or more of a number of options to encourage wildlife: overwintered stubbles, undersown spring cereals, insecticide restricted crop margins, grass margins and sown or naturally regenerated strips, beetle banks, uncropped wildlife strips and wildlife seed mixes (e.g. winter seed and summer nectar). These options will vary in the extent of land they cover and may provide an opportunity to compare management of field margins with practices deployed over whole fields (e.g. stubbles and undersowing).

2. There have been no direct studies to date comparing farmland bird communities on similar farms with and without field margins to assess to overall benefits of margin management *per se* on bird populations. Once again, Arable Stewardship and English Nature's Habitat Restoration project might provide valuable opportunities for such a study. The latter scheme is currently in operation at four trial areas: the Alde Estuary, Suffolk; the Ouse Valley, Milton Keynes; the Sherwood area, Nottingham; and Blackmore Vale, Somerset. Farms could be selected across these four areas where cereal field margins are to be restored and matched with control farms (matched for farm type, boundary characteristics etc as far as possible) where no field margin restoration is planned. Bird abundance, distribution and foraging behaviour could be determined on the same farms before and after restoration and between farms with and without restoration. However, one problem with such an approach may be that under schemes such as these, individual farms are unlikely to take up field margins alone i.e. in isolation from other management options.

3. Research on farmland birds has focussed on their requirements in the breeding season, The use birds make of different farmland habitats in winter is less well known. In the context of field margins this is particularly true of conservation headlands. More work is needed on the species using these headlands in winter and the spatial pattern of that use.

4. Very little is known about the extent of any accrued benefits to birds derived from leaving conservation headlands, or other margin types, in place for several years. A valuable approach would be to establish an experimental set-up where bird density and diversity changes can be monitored, over time, on replicated plots (margins) in order to develop cost-benefit curves in terms of wildlife changes over time and level of management inputs.

5. Very little is known about the value of simply leaving unsprayed (organic) strips of grass or crops as field margins. These could be viewed as one extreme of conservation headlands and it may be valuable to determine the relative cost-effectiveness of the two options.

6. There have been no quantitative studies of the optimal width of field margins with respect to the costs and benefits in agronomic and environmental terms.
7. The benefit of tailoring margin treatments to meet the specific needs of individual species of birds has been highlighted by research on the Cirl Bunting (Evans 1997). Current and future research on the key dietary and habitat needs of many of the farmland birds should provide the basis for similar approaches to be adopted for other bird species.

8. A major problem in assessing the value of field margin management treatments for birds is the lack of quantitative studies of invertebrate communities associated with different treatments.

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Table 2.1 Summary of the key characteristics and management practices of different field margin management treatments.

Management	Vegetation type	Width	Key management practices
Grass only strips	Sown with agricultural grasses	2 m or 6 m	Reduced fertiliser and pesticide[1] input. May be cut to maintain a grass cover and prevent scrub encroachment.
Grass and wild flower strips	Sown with grass flower mix or allowed to regenerate naturally	2 m or 6 m	Reduced fertiliser and pesticide input. May be cut to maintain a grass cover and prevent scrub encroachment.
Beetle banks	Sown with tussock- forming grass species e.g. *Dactylis glomerata Holcus lanatus*	1.5 - 2 m	Reduced fertiliser and pesticide input. Can be left uncut for longer periods of time than grass or grass and flower strips
Naturally regenerated rotational set-aside	Naturally regenerated vegetation of primarily annual weeds e.g. Chenopodiaceae and Polygonaceae	20 m (min)	No fertiliser or pesticide input. Cultivated/ploughed in annually but no crop sown.
Naturally regenerated non-rotational set-aside (considered as a form of grass strip)	Naturally regenerated vegetation of primarily annual weeds followed by perennial species typically native species *e.g.Holcus lanatu,s Agrostis spp*, *Dactylis glomerata* with forbs tolerant of residual phosphates	20 m (min)	No fertiliser or pesticide input.
Uncropped wildlife strip	Naturally regenerated vegetation of primarily annual weeds e.g. Chenopodiaceae and Polygonaceae	6 m	No fertiliser or pesticide input. May be cultivated approximately annually [2] but no crop is sown
Conservation headlands	Sown arable crop with some naturally regenerated annual weed species	6-12 m	Reduced fertiliser & herbicide input. Reduced insecticide on autumn-sown crops. No insecticide on spring-sown crops.
Game cover crop or wildlife seed mixes	Sown vegetation of a mix of seed bearing plants such as quinoa and kale or nectar sources	c 20 m [2]	Cultivated/ploughed in at 1 - 2 year intervals
Sterile strips	No vegetation	1-2 m	Created with soil-acting herbicide in winter or translocated or contact herbicide in summer or by rotovating c. 3 times a season

[1] **Pesticide is used to refer to insecticide and herbicide**
[2] Under Arable Stewardship uncropped wildlife strips may require shallow ploughing annually; [2] may be incorporated as part of a 20 m set-aside strip.

Table 3.1 The five field margin zones used in the Manydown Farm study. The area of each zone and the position of the tramlines was the same for each 100 m stretch of crop edge surveyed. (Headland refers to the area before the first tramlines which may be sprayed with pesticide.)

Zone	Description	Width		Distance of mid point of zone from hedge	
		1984	1985	1984	1985
1	Grass strip	0.5 m	0.5 m	0.25 m	0.25 m
2	Rotovated strip, clear of vegetation	1.0 m	0.5 m	1.0 m	0.75 m
3	Near-crop headland	3.0 m	3.0 m	3.0 m	2.5 m
4	Mid-crop headland	3.0 m	3.0 m	6.0 m	5.5 m
5	Far-crop between first and second tramlines	12.0 m	12.0 m	13.5 m	13.0 m

Table 3.2 The effects of grass boundary strip density (km/ha) at the whole farm level on the density of birds in field edges (within 5 m of field boundary). Farm type (organic or conventional) and hedgerow density are included as covariables. Interaction terms were dropped from analyses when no significant effect was detected. MAR = margin density, HED = hedgerow density, FTYP = farm type. Sample size = 37 farms in 1992, 33 farms in 1993. Sign (-) and (+) indicates direction of effect.***P<0.001, **P<0.01, *P<0.05.

Species	1992	1993
Red-Legged Partridge	n.s.	n.s.
Grey Partridge	n.s.	n.s.
Pheasant	n.s.	n.s.
Woodpigeon	MAR**(+) MAR×FTYP*	n.s.
Skylark	n.s.	n.s.
Meadow Pipit	n.s.	n.s.
Pied Wagtail	MAR*(-)	MAR*(+)
Starling	MAR**(-)MAR×HED**	HED*(+) HED×FTYP*
Magpie	n.s.	HED**(+)
Jackdaw	HED*(-)	n.s.
Rook	n.s.	n.s.
Carrion Crow	n.s.	n.s.
Dunnock	n.s.	HED*(+)
Robin	MAR**(--) MAR×HED***	HED*(+)
Blackbird	HED***(+)	HED*(+)
Redwing	MAR**(-) MAR×HED***	n.s.
Song Thrush	n.s.	n.s.
Mistle Thrush	n.s.	n.s.
Fieldfare	n.s.	n.s.
House Sparrow	n.s.	n.s.
Greenfinch	n.s.	n.s.
Goldfinch	n.s.	n.s.
Linnet	MAR*(-) HED*(-) MAR×FTYP**	n.s.
Chaffinch	MAR*(-) MAR×HED***	HED*(+)
Yellowhammer	n.s.	n.s.
All species	HED***(+)	HED*(+)

Table 3.3 Species and species groups from the Organic farm study used in the analysis of field margin utilisation (see Table 3.4).

Group	Code	Species
Gamebirds	GAME	Galliformes
Large invertebrate feeders	INVL	Moorhen, Laridae, Charadriidae, Scolopacidae
Large granivores	GRANL	Columbidae
Open-country passerines	OPENP	Skylark, Motacillidae, Starling, Wheatear
Corvids	CORVI	Corvidae
Wood/hedge passerines	WOODP	Dunnock, Wren, Robin, Paridae, Long-tailed Tit, Nuthatch
Thrushes	THRUS	Turdidae
Finches	FINCH	House Sparrow, Fringillidae, Emberizidae
Finches	FINCH excl EMB	House Sparrow, Fringillidae
Yellowhammer	EMB	Yellowhammer
All species	ALL	

Table 3.4 The total number of birds counted in field centres (mean of three to six visits) and the expected total (to the nearest integer) based on the total area of field centres (ie distribution is random) from the Organic Farm study. Birds are divided into functional species groups (codes are as in Table 3.3). n = Number of farms (total n = 48 in 1992-93, n = 49 in 1993-94). Farms with expected values <1 have been omitted. *P<0.05 **P<0.01 **P<0.001, (df = n-1).

(a) 1992-93

Species group	Mean number of birds in field centre	Expected number of birds in field centre	n	χ^2
GAME	91	123	23	21.9
INVEL	613	531	22	14.5
GRANL	850	848	36	76.7***
OPENP	928	944	37	54.6*
CORVI	884	793	41	25.3
WOODP	5	19	9	15
THRUS	302	323	2	41.1
WOODP + THRUS	308	349	33	54.9**
FINCH	428	545	32	113.7***
FINCH (excl. EMB)	334	452	30	100.59***
EMB	88	86	13	17.07
ALL	4522	4276	48	110.7***

(b) 1993-94

Species group	Mean number of birds in field centre	Expected number of birds in field centre	n	χ^2
GAME	82	103	16	11.7
INVEL	956	835	27	20.4
GRANL	978	901	31	19.7
OPENP	1154	1035	41	32.2
CORVI	804	715	42	15.4
WOODP	6	9	5	3.6
WOODP + THRUS	1623	1485	40	44.0
FINCH	520	586	30	60.1***
FINCH (excl. EMB)	488	550	28	56.66**
EMB	29	30	8	2.68
ALL	6414	5759	49	97.3***

Table 3.5 Mean frequency per visit of birds using different field margin zones from the Manydown Farm study. Values have been summed across all field boundaries where at least one bird was recorded (n = 86 in 1984, 45 in 1985). Observation periods were three minutes in 1984, 5 minutes in 1985. Description of zones 1-5 are given in Table 3.1.

(a) 1984

Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Woodpigeon	0.13	2.11	0.39	0	0
Skylark	0	0	0	0	0.14
Starling	0	0	0	0	0.14
Dunnock	1.53	2.58	1.50	0.35	0.39
Willow Warbler	0	0.29	0	0	0
Robin	0.68	1.28	0.36	0	0
Blackbird	2.42	7.20	1.75	0.24	0.35
Song Thrush	0.14	0.27	0.55	0	0
Mistle Thrush	0	0.46	0	0	0
Great Tit	0.13	0	0	0	0
Long-tailed Tit	0	0.29	0	0	0
House Sparrow	0	0.5	0	0.13	0.29
Chaffinch	0	2.63	1.30	0.13	0.64
Yellowhammer	0.25	0.97	0.60	0	0.13
All species	5.26	19.06	6.69	0.83	2.09

(b) 1985

Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Woodpigeon	0	0	0	0	0.13
Starling	0	0	0	0.06	0
Wren	0	0.19	0.06	0	0
Dunnock	0.69	1.63	0.94	0.69	0.56
Whitethroat	0.19	0.06	0	0	0
Willow Warbler	0.06	0	0.06	0	0
Blackbird	0.25	2.69	0.19	0.25	0.63
Song Thrush	0	0.44	0	0.06	0.06
Blue Tit	0.38	0.13	1.0	0.06	0
Great Tit	0.13	0	0.06	0	0
House Sparrow	0	0.06	0.19	0.13	0
Goldfinch	0.31	0	0	0	0
Chaffinch	0.06	0.94	0.25	0	0.06
Yellowhammer	0.19	0.50	0.25	0.38	0.63
All species	2.25	6.25	3.06	1.56	2.25

Table 3.6 Species two-letter codes, scientific binomials and functional groups (FG) of bird species recorded in the set-aside study.

Species		FG	Species		FG
SU	Shelduck *Tadorna tadorna*	DU	B.	Blackbird *Turdus merula*	TH
K.	Kestrel *Falco tinnunculus*	RA	ST	Song Thrush *T. philomelos*	TH
BZ	Buzzard *Buteo buteo*	RA	M.	Mistle Thrush *T. viscivorus*	TH
PH	Pheasant *Phasianus colchicus*	GB	RR	Redwing *T. iliacus*	TH
G.	Grey Partridge *Perdix perdix*	GB	FF	Fieldfare *T. pilarus*	TH
RL	Red-legged Partridge *Alectoris rufa*	GB	RO	Rook *Corvus frugilegus*	CR
MH	Moorhen *Gallinula chloropus*		JD	Jackdaw *C. monedula*	CR
OC	Oystercatcher *Haematopus ostralegus*	WA	C.	Carrion Crow *C. corone*	CR
SC	Stone Curlew *Burhinus oedicnemus*	WA	MG	Magpie *Pica pica*	CR
L.	Lapwing *Vanellus vanellus*	WA	J.	Jay *Garrulus glandarius*	CR
SN	Snipe *Gallinago gallinago*	WA	SG	Starling *Sturnus vulgaris*	
SD	Stock Dove *C. oenas*	PI	TS	Tree sparrow *Passer montanus*	SE
WP	Wood pigeon *Columba palumbus*	PI	HS	House sparrow *P. domesticus*	SE
TD	Turtle Dove *Streptopelia turtur*	PI	GO	Goldfinch *Carduelis carduelis*	SE
CD	Collared Dove *S. decaocto*	PI	GR	Greenfinch *C. chloris*	SE
S.	Skylark *Alauda arvensis*	S.	CH	Chaffinch *Fringilla coelebs*	SE
MP	Meadow Pipit *A. pratensis*		LI	Linnet *C. cannabina*	SE
PW	Pied Wagtail *Motacilla alba*	IN	SK	Siskin *Carduelis spinus*	SE
D.	Dunnock *Prunella modularis*	IN	RB	Reed Bunting *Emberiza schoeniclus*	SE
WR	Wren *Troglodytes troglodytes*	IN	Y.	Yellowhammer *E. citrinella*	SE
R.	Robin *Erithacus rubecula*	IN	CB	Corn Bunting *Miliaria calandra*	SE

RA	RAPTORS:	Birds of Prey
WA	WADERS:	Charadriidae
GA	GAMEBIRDS:	mostly artificially maintained populations of pheasants and partridges
PI	PIGEONS:	non-feral Columbidae
S.	SKYLARK:	Skylark only
IN	INSECTIVORES:	Dunnock, Wren, Robin, Pied Wagtail
TH	THRUSHES:	Turdidae
CR	CROWS:	Corvid, but mainly Rook, Carrion Crow and Jackdaw
SE	SEEDEATERS:	ground-feeding finches, buntings and sparrows

Table 4.1 Animal foods of bird species listed in UK Biodiversity Action Plans and thought to use field margins. Invertebrates listed are dietary components of adults and nestlings unless otherwise indicated. Where season (s; summer, w; winter) is not indicated the seasonal information is not available.

Bird Species	Lepidoptera	Diptera	Colleoptera	Hymenoptera	Arachnida	Others
Grey Partridge (summer)	larvae	Tipulidae	larvae Carabidae Curculionidae Staphylinidae Chrysomelidae	Formicidae (p) Symphyta Ichneumonidae Braconidae		Acrodidae Delphicidae Cicadellidae Orthoptera Hemiptera
Turtle Dove						Mollusca
Song Thrush (summer)	larvae (Noctuidae)	larvae	larvae (Elateridae)	larvae	Araneae	Annelida Mollusca
Tree Sparrow[1] (winter)	larvae	larvae	Curculionidae		Araneae	Orthoptera Hemiptera
Linnet (summer)	larvae	Muscidae	Curculionidae Coccinellidae Elateridae Chrysomelidae		Araneae	Hemiptera
Bullfinch	larvae		adults		Araneae	Mollusca
Reed Bunting	larvae larvae	Tipulidae Tipulidae Chironomidae Tabanidae	Curculionidae	Symphyta (larvae)	Araneae	Collembola Odonata Ephemeroptera Orthoptera
Corn Bunting	larvae	Tipulidae	Scarabidae		Araneae	Orthoptera Dermaptera
Cirl Bunting (Mainly N) (summer)	larvae	Tipulidae	Curculionidae Staphylinidae	Symphyta		Orthoptera

Table 4.2 Main plant foods of bird species listed in UK Biodiversity Action Plans but shown to use field margins in Section 3. Items listed are dietary components of adults and nestlings unless otherwise indicated (A; adult diet, N; nestling diet). Fr; fruit, sd; seeds, w; winter, s; summer. [1]species showing a preference for field margins in winter in only one of two years (Organic Farm study), [2]species showing a preference for field margins in winter (Organic farm study) and avoidance in summer (Set-aside study)

Bird Species	Cereal (seeds)	Grass (seeds)	Annual weed (seeds)	Biennial seeds	Perennial herb seeds	Others
G. Partridge (mainly A, w & s)	unspecified		Polygonaceae Caryophyllaceae Borginacea		Polygonaceae Leguminosae Borginacea	Labiatae (fr) unspecified green plant material
Turtle Dove (A & N, w & s)		Festuca Setaria	Fumariaceae Chenopodiaceae Cruciferae Polygonaceae Compositae	Cruciferae	Compositae Polygonaceae Leguminosae	unspecified green plant material
S. Thrush (mainly A, w & s)						Oleaceae (fr) Rosaceae (fr) Taxaceae (fr) Aquifoliaceae (fr) Araliaceae (fr) Loranthaceae (fr)
T. Sparrow[1] (A & N, w & s)		Poa Echinochloa Digitaria Lolium Setaria	Polygonaceae Chenopodiaceae Amaranthaceae Caryophyllaceae Borginacea		Polygonaceae Borginaceae Caryophyllaceae	
Linnet (A & N, w & s)	unspecified	Poa	Polygonaceae Caryophyllaceae Chenopodiaceae Cruciferae Compositae	Cruciferae	Polygonaceae Compositae Caryophyllaceae Cruciferae	
Bullfinch (A & N, w)	unspecified	Poa	Polygonaceae Caryophyllaceae Cruciferae Chenopodiaceae Compositae Cruciferae	Cruciferae	Polygonaceae Ranunculaceae Compositae Cruciferae Caryophyllaceae	Rosaceae (sd) Ulmaceae (sd) Aceraceae (sd) Urticaceae (sd) Euphorbiaceae (sd) Violaceae (sd) Ericaceae (sd) Caprifoliaceae (sd) Salicaceae (fl) Fagaceae (fl) Ranunculaceae (sd)
Reed Bunting (A & N, w & s)	unspecified	Poa Lolium Festuca Elymus	Chenopodiaceae Amaranthaceae Caryophyllaceae Cruciferae	Cruciferae	Leguminosae Cruciferae Caryophyllaceae	Rosaceae (fr)
Corn Bunting (mainly A, w)	unspecified		Polygonacea		Polygonacea	
Cirl Bunting (mainly A, w & s)		Poa Lolium Festuca Elymus	Compositae Polygonaceae Caryophyllaceae		Polygonaceae Caryophyllaceae Compositae	

Items are listed only if they are present in the diet and have been quantified or described as an important dietary component (see Wilson *et al*. 1996). Further data may show other taxa to be important.

Table 4.3 Animal foods of bird species not listed in Biodiversity Action Plans but shown to use field margins in Section 3. Invertebrates listed are dietary components of adults and nestlings in summer and winter and mainly adults in winter. [1] species showing a preference for field margins in winter in only one of two years (Organic Farm study), [2] species showing a preference for field margins in winter (Organic Farm study) and avoidance in summer (Set-aside study); [3] important in the diet of Meadow Pipits only.

Bird Species	Lepidoptera	Diptera	Colleoptera	Hymenoptera	Arachnida	Others
Red-legged Partridge		Acalypterata	Curculionidae Nitidulidae unspec larvae	Formicidae Braconidae	unspecifie d	Orthoptera Hemiptera
Pheasant		Tipulid	Carabidae Curculionidae Staphylinidae Elateridae unspec larvae	Formicidae Symphyta unspec larvae	unspecifie d	Orthoptera Hemiptera Dermaptera Annelida
Starling[1] (winter)	larvae (Noctuidae)	larvae (pupae) Rhagionidae Bibionidae Tipulidae	larvae Carabidae	Larvae		Annelida
Blackbird (summer)	larvae	larvae/adult	larvae/adult	larvae/adult		Mollusca Annelida Hemiptera
Robin (summer)	larvae		Curculionidae Chrysomelidae			
Dunnock (summer)	larvae		Curculionidae Staphylinidae			Aphididae Collembola Opiliones
House Sparrow[1] (winter)	larvae	larvae	Curculionidae		Araneae	Orthoptera Hemiptera
Chaffinch (summer)	adult & larvae	Tipulidae	Curculionidae	Formicidae	Araneae	Orthoptera Hemiptera Trichoptera
Greenfinch[2] (winter)			Curculionidae Coccinellidae Elateridae Chrysomelidae			Hemiptera
Goldfinch[2] (winter)			Curculionidae Coccinellidae Elaterida Chrysomelidae			Hemiptera
Yellowhammer (summer)	larvae		Curculionidae Staphylinidae Chrysomelidae Elaterida		Araneae	Collembola Orthoptera
Meadow Pipit[1] Pied Wagtail[1] (winter)	larvae[3]	Tipulidae Drosophilidae Scatophigidae Chironomidae Calliphoridae	Carabidae Curculionidae Chrysomelidae Staphylinidae	Symphyta Ichneumonidae Formicidae	Araneae[3]	Hemiptera

Table 4.4 Main plant foods of bird species not listed in UK Biodiversity Action Plans but shown to use field margins in Section 3. Items listed are dietary components of adults and nestlings unless otherwise indicated (A; adult diet, N; nestling diet). Fr; fruit, sd; seeds, rt; roots. [1] species showing a preference for field margins in winter in only one of two years (Organic Farm study), [2] species showing a preference for field margins in winter (Organic Farm study) and avoidance in summer (Set-aside study)

Bird species	Cereal (seeds)	Grass (seeds)	Annual weed (seeds)	Biennial seeds	Perennial herb seeds	Others
Red-legged Partridge	unspecified	Arrhenatherum unspecified	Polygonaceae Caryophyllaceae Chenopodiaceae Compositae		Polygonaceae Caryophyllaceae Compositae	Rosaceae (fr) Fagaceae (fr)
Pheasant	Triticum Hordeum Avena unspecified	Poa Agrostis Arrhenatherum unspecified	Polygonaceae Caryophyllaceae Chenopodiaceae Compositae		Polygonaceae Caryophyllaceae Compositae Labiate (fr)	Rosaceae (fr) Fagaceae (fr) Leguminosae (fr) Solanacea (rt)
Starling[1] (winter)	unspecified	unspecified	unspecified			Rosaceae (fr) Ligustrum (fr) Vitaceae (fr)
Blackbird (summer)						Rosaceae (fr) Arialaceae (fr)
Robin (summer)						Rosaceae (fr) Fagaceae (fr) Anacardiacea (fr) Celastraceae (fr) Caprifoliaceae (fr) Arialaceae (fr) Oleaceae (fr)
Dunnock (mainly A) (summer)		Setaria Holcus	Polygonaceae Caryophyllaceae Amaranthaceae		Urticaceae Polygonaceae Caryophyllaceae	Caprifoliaceae (fr)
House Sparrow[1] (mainly A) (winter)	unspecified	Poa Echinochloa Digitaria	Polygonaceae Portulaceae Caryophyllaceae Geraniacea		Polygonaceae Caryophyllaceae Geraniacea	
Chaffinch (summer & winter)	unspecified		Polygonaceae Caryophyllaceae Cruciferae Chenopodiaceae	Cruciferae	Polygonaceae Compositae Cruciferae Caryophyllaceae	Fagaceae (sd)
Greenfinch[2] (winter)	Triticum unspecified	Poa	Polygonaceae Caryophyllaceae Cruciferae Chenopodiaceae Compositae	Cruciferae	Polygonaceae Compositae Cruciferae Caryophyllaceae	Pinaceae (sd) Ulmaceae (sd) Taxaceae Rosaceae
Goldfinch[2] (winter)	unspecified	Poa	Polygonaceae Compositae Chenopodiaceae Compositae		Polygonaceae Compositae	Betulaceae (sd) Dipsacaceae (sd) Rosaceae
Yellowhammer (summer & winter)	Triticum unspecified	Lolium Festuca unspecified	Polygonaceae Compositae Caryophyllaceae		Polygonaceae Compositae Caryophyllaceae	
Meadow Pipit[1] (winter)		Poa	Scrophulariaceae			

Table 4.5 Key to Tables 4.3 and 4.4. English names and main dietary species within the families listed as important dietary items for the 23 bird species considered. P, perennial species; b, biennial species; a, annual species.

Plant family	Main dietary items listed in the literature
Aceraceae	Maple (p)
Aquifoliaceae	Holly, (p)
Amaranthaceae	Amaranths (a)
Araliaceae	Ivy, (p)
Betulaceae	Alder, (p)
Caprifoliaceae	Elder, (p)
Caryophyllaceae	Mouse-ears, Chickweeds (a / p)
Celestraceae	Spindle Tree (p)
Chenopdiaceae	Goosefoots, Oraches, (a)
Compositae	Sorrels, Mugworts, Dandelion, Burdock, Thistles, Knapweeds, (a / p)
Cornacea	Dogwood (p)
Cruciferae	Charlock, wild/cultivated brassicas (a / b)
Dipsacaceae	Teasel (p)
Ericaceae	Heather (p)
Fagaceae	Oak (p)
Geraniacea	Cranesbills (p)
Ligustrum	Privet (p)
Loranthaceae	Mistletoe (p)
Pinaceae	Spruce (p)
Oleaceae	Privet (p)
Poa	Meadow grass
Polygonaceae	Bistorts (a / p)
Portulacaceae	Ppurslanes (a)
Prunus	Wild cherry, sloe (p)
Ranunculaceae	Buttercup (p)
Rubus	Bramble (p)
Rosaceae	Sorbus, Rubus Crategus (p)
Salaceae	Willow (p)
Scrophulariaceae	Eyebright (a)
Taxaceae	Yew (p)
Ulmaceae	Elm (p)
Violaceae	Violet (p)
Vitaceae	Vine family, Virginia creeper

Table 4.6 The animal foods known to be included in the diet of 33 farmland birds summarised, by order, from Tables 4.1 and 4.3. The invertebrate orders are ranked in order of importance assessed in terms of the number of bird species known to include them in the diet.

	Number of bird species to include invertebrate group in the diet		
Invertebrate order	UK Biodiversity Action Plan Species	Other Farmland birds	Total
Coleoptera	8	12	20
Lepidoptera	8	8	16
Diptera	7	8	15
Arachnida	6	6	12
Hymenoptera	4	7	11
Hemiptera	3	7	10
Orthoptera	5	5	10
Mollusca	3	1	4

Table 4.7 The plant foods known to be included in the diet of 33 farmland birds summarised from Tables 4.2 and 4.4. The plant groups and genera (annual, biennial and perennial weeds that have been recorded in the diet of at least five bird species only) are ranked in order of importance assessed in terms of the number of bird species known to include them in the diet.

	Number of bird species to include plant group in the diet		
Plant group or genera	UK Biodiversity Action Plan Species	Other Farmland birds	Total
Plant group			
Annual weed (seeds)	8	10	18
Perrenial herbs (seeds)	8	8	16
Grass (seeds)	6	9	15
Cereal (seeds)	5	8	13
Biennial (seeds)	4	2	6
Weed *genera*			
Polygonaceae	7	8	15
Caryophyllaceae	6	7	13
Chenopodiaceae	5	5	10
Compositae	4	6	10
Cruciferae	4	2	6

Table 5.1 Flowering periods of some commonly sown grasses and dicotyledonous species.

	Flowering period	
Species	**(Clapham *et al*. 1968)**	**(Fitter *et al*. 1980)**
Agrostemma githago		**May-August**
Centaurea cyanus		**June-August**
Papaver rhoeas	**June-August**	**June-October**
Achillea millefolium	**June-August**	**June-November**
Centaurea nigra	**June-September**	**June-September**
Daucus carota	**July-August**	**June-September**
Galium verum	**July-August**	**June-September**
Leucanthemum vulgare	**June-August**	**May-September**
Malva moschata	**July-August**	**July-August**
Primula veris	**April-May**	**April-May**
Ranunculus acris	**June-July**	**April-October**
Rumex acetosa	**May-June**	**May-August**
Silene dioica	**May-June**	**March-November (Hubbard 1968)**
Cynosurus cristatus	**June-August**	**June-August**
Festuca rubra	**May-July**	**May-July**
Phleum pratense	**July**	**June-August**
Poa pratensis	**May-July**	**May-July**

Table 6.1 The capability of different field margin treatments to produce seeds or fruits of different plant groups for birds.(- = absent, + = low; ++ = medium, +++ = high)

	Cereal seeds[1]	Grass seeds	Annual weed seeds	Biennial seeds	Perennial herb seeds	Climber berries	Shrub berries	Tree fruits
Examples of plant species:	wheat barley	cocksfoot fescue brome	chickweed fathen knotgrass	spear thistle hogweed	red campion oxeye daisy yarrow clover	bramble bryony ivy	hawthorn blackthorn	ash oak
Margin structures								
Hedges	-	-	-	-	-	+++	+++	+++
Hedge bottom	-	+	-/+	++	+++	-	-	-
Sown grass strips	-	+++	-	-/+	-	-	-	-
Sown grass & flower strips[2]	-	+++	-	+	+++	-	-	-
Beetle banks	-	+++	-	-	-	-	-	-
Uncropped strips	+/-	+	+++	+	-	-	-	-
Natural regen. rot. set-aside strips	++	++	++	+++	+	-	-	-
Conservation headlands	+++	+	++	-	-	-	-	-

[1] = best provided by winter stubbles.
[2] = naturally regenerated grass and flower strips are considered equivalent to rotational set-aside strips in year one and sown grass and flower strips in subsequent years.

Table 6.2 Common plant families, with examples of species and main life-history traits

Papaveraceae	Common Poppy	annuals
Fumariaceae	Fumitory	annuals
Urticaceae	Nettle	perennials
Chenopodiaceae	Fathen	annuals
Caryophyllaceae	Chickweed	annuals, perennials
Polygonaceae	Dock	annuals, perennials
Brassicaceae	Charlock, Shepherd’s-purse	annuals
Primulaceae	Cowslip	perennials
Rosaceae	Bramble, Cinquefoil	perennials
Fabaceae	Clover, Vetches	annuals, perennials
Onagraceae	Willowherb	annuals, perennials
Euphorbiaceae	Sun Spurge	annuals, perennials
Geraniaceae	Cranesbill	annuals, perennials
Apiaceae	Cowparsley	biennials
Solanaceae	Back Nightshade	annuals, perennials
Convolvulaceae	Field Bindweed	perennials

Table 6.3 The relative potential value of different field margin treatments for encouraging arthropod groups of value as bird food .(+ = lowest; +++ = highest). The rankings are not intended to provide an indication of the value of these treatments for invertebrate biodiversity *per se*.The nature of the invertebrate communities will differ greatly but the assessment made here is with respect to food resources for birds.

Margin	Lepidoptera (larvae)	Coleoptera	Diptera	Hemiptera	Hymenoptera	Araneae
Hedge	+++	+++	++	++	++	+++
Hedge Bottom	++	+++	++	+++	+++	+++
Grass Strip (sown)	+	++	++	+	+	+/++
Grass & Flower Strip (sown)[1]	++	++	++	++	++	++
Beetle bank	+	++	+/++	+	+	++
Natural Regenerated Rotational Set-Aside. Strip	++	++	++	++	++	++
Uncropped (Wildlife) Strip[2]	++	++	++	++	++	++
Conservation headland	+	++	++	++	++	++

[*]The potential of many of the field margin treatments as sources of invertebrate and seeds food items will be influenced by management regimes and environmental factors such as soil type. Hedgrow structure and hedge bottom flora, for example, can vary considerably, affecting their value as insect habitats. Therefore these rankings should be regarded as approximations based on ideal conditions.

[1] Naturally regenerated grass and flower strips are considered equivalent to rotational set-aside strips in year one and sown grass and flower strips in subsequent years.

[2] Uncropped wildlife strips have been shown to be support higher abundances of arthropods than conservation headlands but the data are extremely limited and they have been ranked the same.

Table 6.4 The value of different management regimes in providing plant food for 22 species of birds that forage in field margins.

	No of bird species for which > 30% of plant groups in the diet are also present or in moderate or high abundance in the field margin (see Table 6.1)		The rank of each management for birds	No of bird species for which > 50% of plant groups in the diet are also present or in moderate or high abundance in the field margin (see Table 6.1)		The rank of each management for birds
Management	**Present**	**Moderate or high abundance**	**Rank**	**Present**	**Moderate or high abundance**	**Rank**
Grass only	6 (3)	3 (1)	5	1 (0)	0	5
Gr +flower	18 (8)	15 (5)	2	16 (7)	12 (5)	2
Beetle bk	16 (7)	6 (1)	4	12 (8)	3 (0)	4
Nat regen	19 (8)	17 (7)	1	17 (8)	15 (7)	1
Wildl strip	18 (8)	4 (2)	3	18 (8)	1 (0)	3
Cons Headl	18 (8)	15 (5)	2	18 (8)	15 (5)	1

Plants recorded in the diet are only those present in the diet and quantified or described as an important dietary component (Wilson *et al.* 1996). Figures in brackets refer to the number of the bird species that also listed as Biodiversity Action Plan Species (Anon 1995 a & b). The ranking of these options on the number of species for which food availability is high, 1 = best option (benefits many bird species) 6 = worst (benefits few bird species)

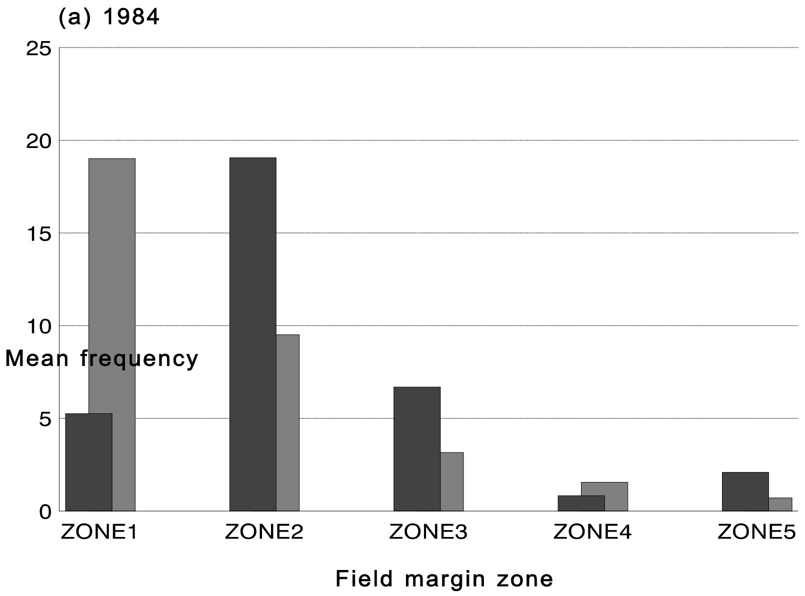
Table 6.5 The value of different management regimes in providing invertebrate prey for 22 species of birds that forage in field margins.

	No of bird species for which > 50% of invertebrate taxa in the diet are also present in moderate abundance in the field margin (see Table 6.3)	The rank of each management for birds	No of bird species for which > 75% of invertebrate taxa in the diet are also present in moderate abundance in the field margin (see Table 6.3)	The rank of each management for birds
Management	**Moderate abundance**	**Rank**	**Moderate abundance**	**Rank**
Grass only	**13 (5)**	**3**	**0**	**3**
Gr +flower	**21 (8)**	**1**	**21 (8)**	**1**
Beetle bk	**12 (5)**	**2**	**0**	**3**
Nat regen	**21 (8)**	**1**	**21 (8)**	**1**
Wildl strip	**21 (8)**	**1**	**21 (8)**	**1**
Cons headl	**21 (8)**	**1**	**18 (7)**	**2**

Invertebrates recorded in the diet are only those present in the diet and quantified or described as an important dietary component (Wilson *et al.* 1996). Figures in brackets refer to the number of the bird species that are also listed as Biodiversity Action Plan Species (Anon 1995 a & b). The ranking of these options on the number of species for which food availability is high, 1 = best option (benefits many bird species) 6 = worst (benefits few bird species)

Table 6.6. The value of field margins, whole-field set-aside, organic farming and integrated crop management in providing food resources in summer (s) and winter (w) and nesting habitat (n) for farmland birds. It is assumed that the field margin treatment is one of the optimal management treatments identified in Section 5; naturally regenerated rotational set-aside, conservation headlands, grass and wildflower strips or uncropped wildlife strips (in limited geographic locations (see text Section 6.1 and Tables 6.4 and 6.5). The impacts of each farming practice is defined as ‘+’ = improvement or ‘-’ no improvement in food or nesting resource compared conventional farming, ‘?’ information unavailable.

	Margins			whole field set-aside			organic farming			integrated crop management		
	s	w	n	s	w	n	s	w	n	s	w	n
Biodiversity Action Plan Species												
Grey Partridge	+	+	+	+	+	+	+	+	+	?	?	?
Turtle Dove	+	+	+	+	+	+	+	+	+	?	?	?
Song Thrush	+	+	-	+	+	-	+	+	-	?	?	-
Tree Sparrow	+	+	-	+	+	-	+	+	-	?	?	-
Skylark	-	-	-	+	+	+	+	+	+	?	?	?
Linnet	+	+	+	+	+	+	+	+	+	?	?	?
Bullfinch	+	+	-	+	+	-	+	+	+	?	?	-
Reed Bunting	+	+	-	+	+	-	+	+	-	?	?	-
Corn Bunting	+	+	+	+	+	+	+	+	+	?	?	?
Cirl Bunting	+	+	+	+	+	+	+	+	+	?	?	?
Skylark	-	-	-	+	+	+	+	+	+	?	?	?
Spotted Flycatcher	+	-	-	+	-		+	-	+	?	?	?
Other farmland birds												
Red-legged Partridge	+	+	+	+	+	+	+	+	+	?	?	?
Pheasant	+	+	+	+	+	+	+	+	+	?	?	?
Starling	+	+	-	+	+	-	+	+	-	?	?	-
Blackbird	+	+	-	+	+	-	+	+	-	?	?	-
Robin	+	+	-	+	+	-	+	+	-	?	?	-
Dunnock	+	+	-	+	+	-	+	+	-	?	?	-
House Sparrow	+	+	-	+	+	-	+	+	-	?	?	-
Chaffinch	+	+	-	+	+	-	+	+	-	?	?	-
Goldfinch	+	+	-	+	+	-	+	+	-	?	?	-
Yellowhammer	+	+	+	+	+	+	+	+	+	?	?	?
Meadow Pipit	+	+	-	+	+	+	+	+	+	?	?	?
Pied Wagtail	+	+	-	+	+	+	+	+	+	?	?	?
Raptors and Owls	+	+	-	+	+	-	+	+	-	?	?	-
Lapwing	-	-	-	-	+	-	+	+	+	?	?	?
Golden Plover	-	-	-	-	+	-	-	+	-	?	?	-
Stock Dove	+	+	-	+	+	-	+	+	-	?	?	-
Collared Dove	+	+	-	+	+	-	+	+	-	?	?	-
Woodpigeon	+	+	-	+	+	-	+	+	-	?	?	-
Swallow	-	-	-	+	-	-	+	-	-	?	-	-
House Martin	-	-	-	+	-	-	+	-	-	?	-	-
Sand Martin	-	-	-	+	-	-	+	-	-	?	-	-
Yellow Wagtail	+	+	-	+	+	+	+	+	+	?	?	?
Mistle Thrush	+	+	-	+	+	-	+	+	-	?	?	-
Wren	+	+	-	+	+	-	+	+	-	?	?	-


(a) 1984
25
20
15
10
5
0
Mean frequency
ZONE1
ZONE2
ZONE3
ZONE4
ZONE5
Field margin zone

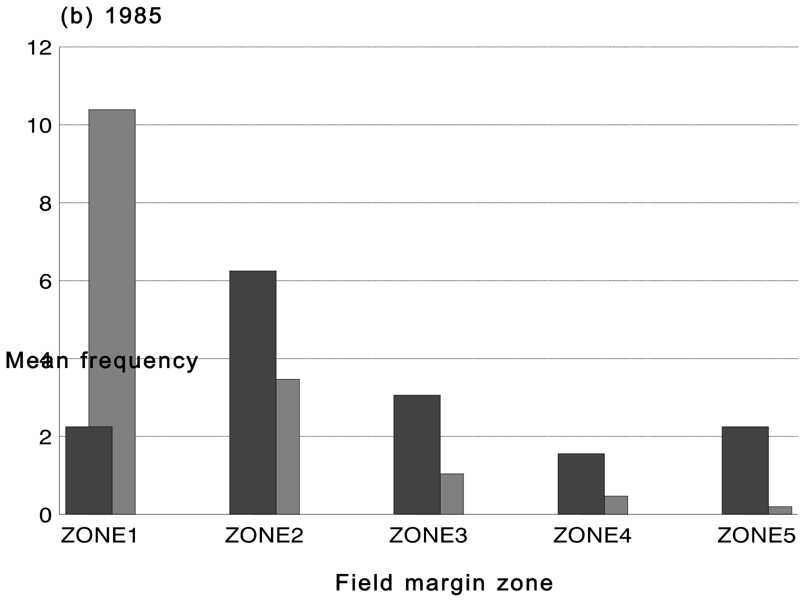
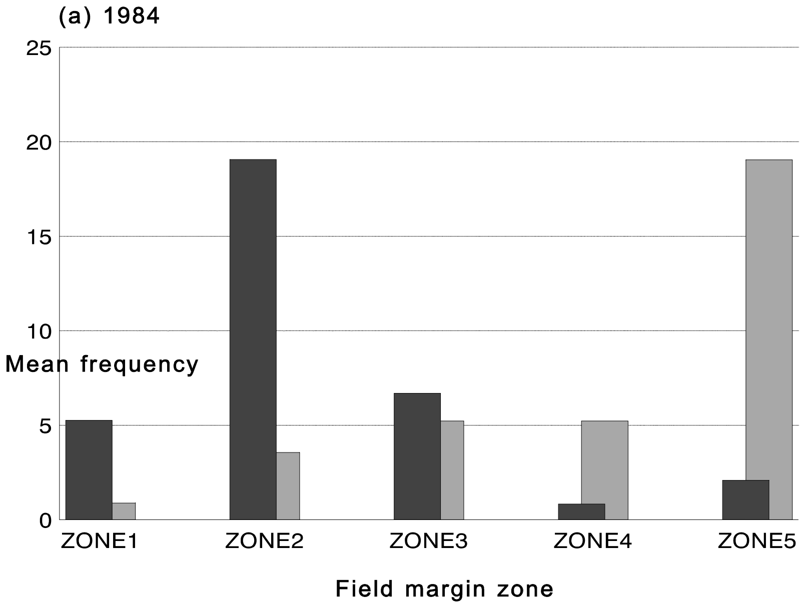

(b) 1985
12
10
8
6
4
2
0
Mean frequency
ZONE1
ZONE2
ZONE3
ZONE4
ZONE5
Field margin zone

Figure 3.1 The expected (black bars) and observed (grey bars) frequency of all bird species (averaged over the number of observation visits) in five field margin zones at Manydown farm. (a) 1984, $G_4 = 26.50$ $P<0.001$; (b) 1985, $G_4 = 37.68$ $P<0.001$. The description of the zones are given in Table 3.1. Expected frequencies are calculated assuming a random distribution of birds across all zones i.e. birds are distributed directly in proportion to each the area of each zone. These data are from Manydown Farm, Hampshire. Zones are defined in Table 3.1 (see text for full explanation)


(a) 1984
25
20
15
10
Mean frequency
5
0
ZONE1
ZONE2
ZONE3
ZONE4
ZONE5
Field margin zone

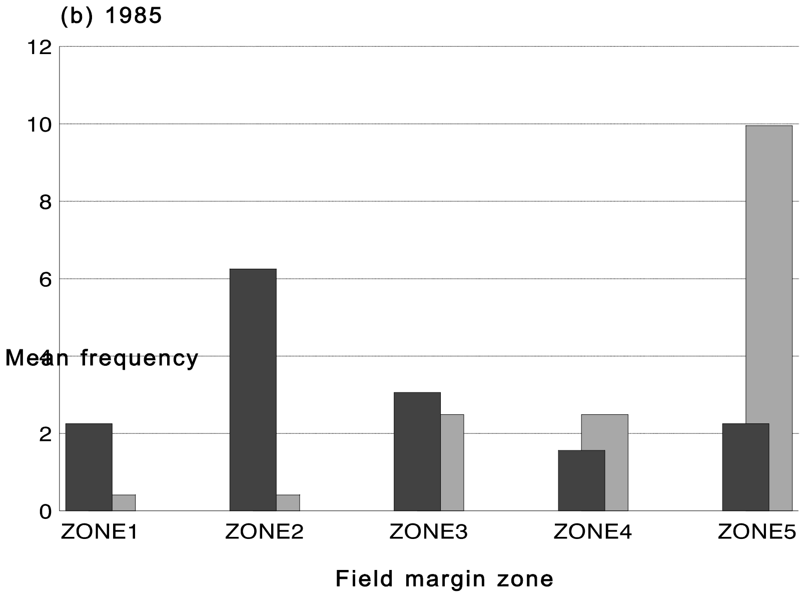
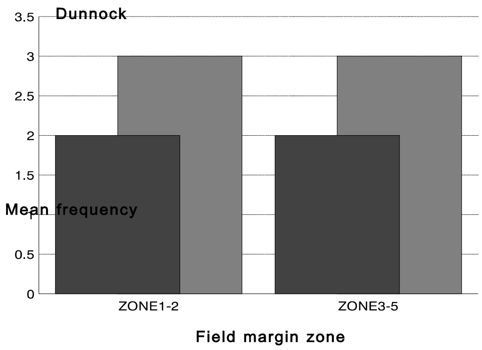
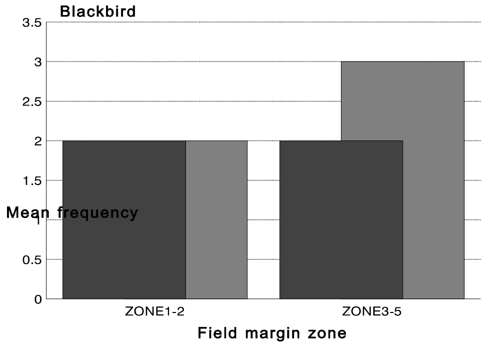
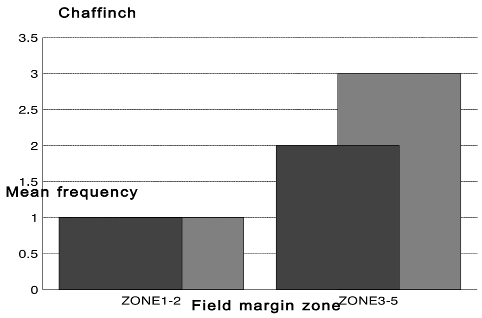

(b) 1985
12
10
8
6
Mean frequency
4
2
0
ZONE1
ZONE2
ZONE3
ZONE4
ZONE5
Field margin zone

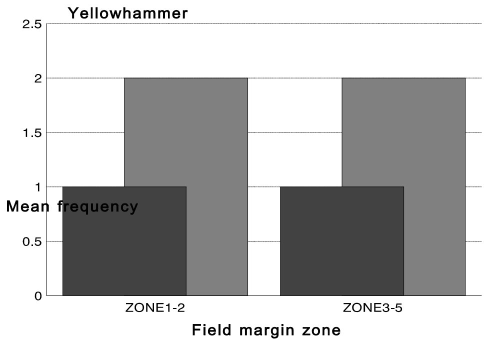
Figure 3.2 The expected (black bars) and observed (grey bars) frequency of all bird species (averaged over the number of observation visits) in five field margin zones at Manydown farm.(a) 1984, G_4 = 73.79 P<0.001; (b) 1985, G_4 = 22.84 P<0.001.(A) 1984 and (B) 1985. The description of the zones are given in Table 3.1. The description of the zones are given in Table 3.1. Expected frequencies are calculated assuming a non-random distribution of birds across the zones with respect to distance from hedge i.e. closer association with hedgerows than field centres.These data are from Manydown Farm, Hampshire. Zones are defined in Table 3.1 (see text for full explanation)


Dunnock
3.5
3
2.5
2
1.5
Mean frequency
0.5
0
ZONE1-2
ZONE3-5
Field margin zone


Blackbird
3.5
3
2.5
2
1.5
Mean frequency
0.5
0
ZONE1-2
ZONE3-5
Field margin zone

(A)


Chaffinch
3.5
3
2.5
2
1.5
Mean frequency
1
0.5
0
ZONE1-2
ZONE3-5
Field margin zone


Yellowhammer
2.5
2
1.5
1
Mean frequency
0.5
0
ZONE1-2
ZONE3-5
Field margin zone

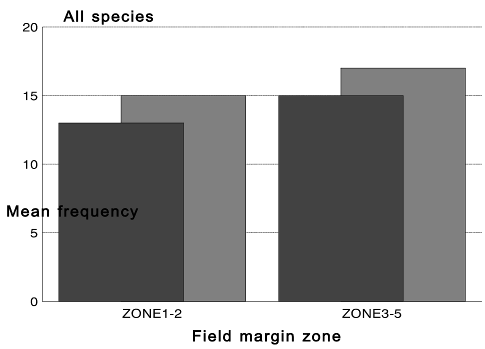
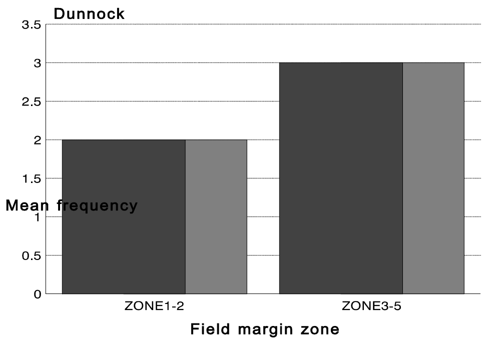
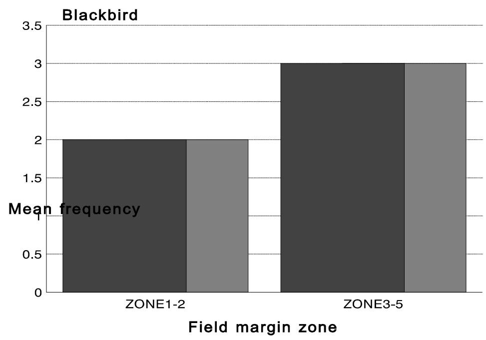
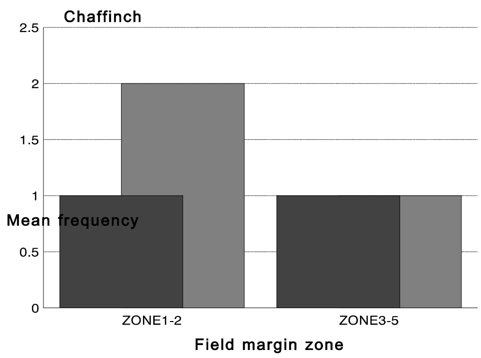

All species
20
15
10
Mean frequency
5
0
ZONE1-2
ZONE3-5
Field margin zone

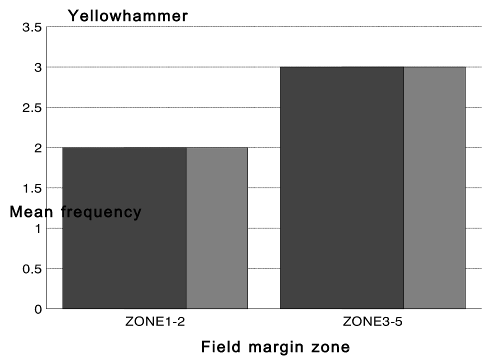
Figure 3.3 The mean frequency of Dunnock, Blackbird, Chaffinch, Yellowhammer and all bird species combined (averaged over the number of observation visits) on five field margin zones adjacent to sprayed (black bars) and unsprayed (grey bars) crops. There was no significant association between spray treatment and margin zone use in any species. (Fisher exact tests). Data are from Manydown Farm (see Section 3.3.2 (ii))


Dunnock
3.5
3
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone


Blackbird
3.5
3
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone

(B)


Chaffinch
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone


Yellowhammer
3.5
3
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone

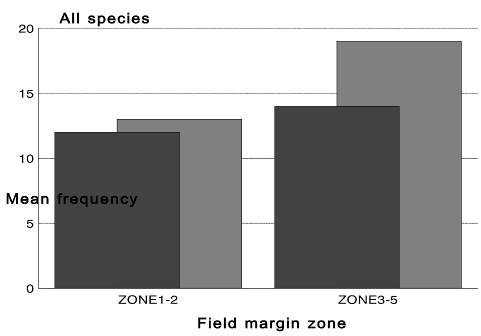
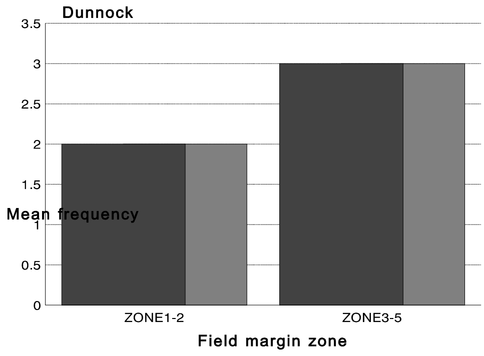
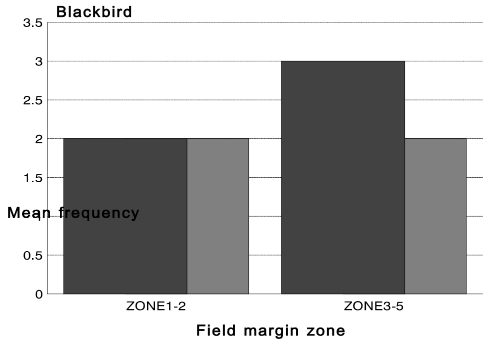
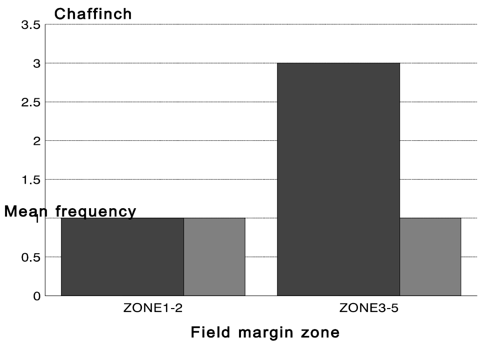

All species
20
15
10
5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone

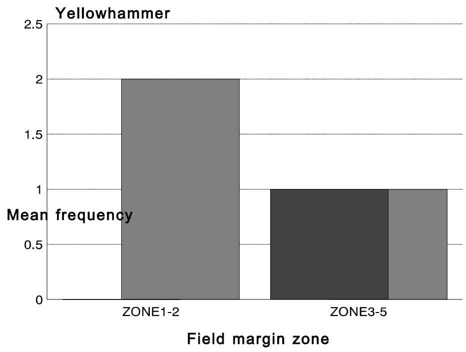
Figure 3.3 continued

(A)


Dunnock
3.5
3
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone


Blackbird
3.5
3
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone


Chaffinch
3.5
3
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone


Yellowhammer
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone

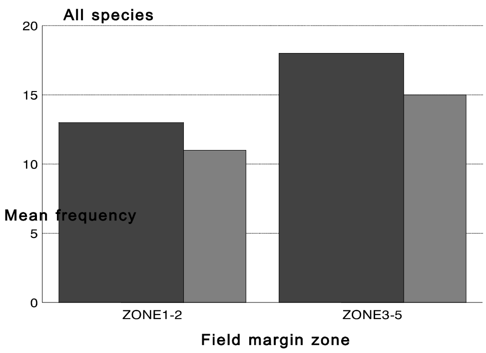
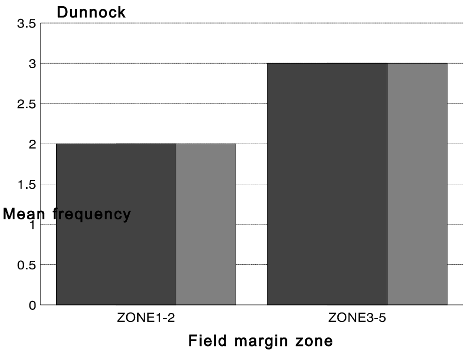
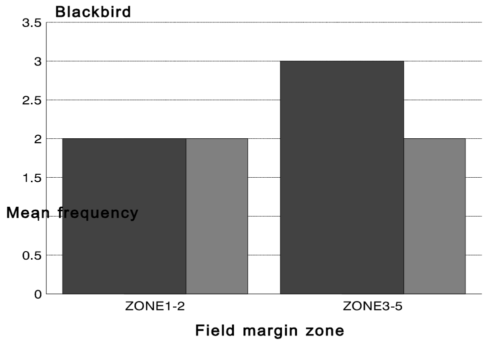
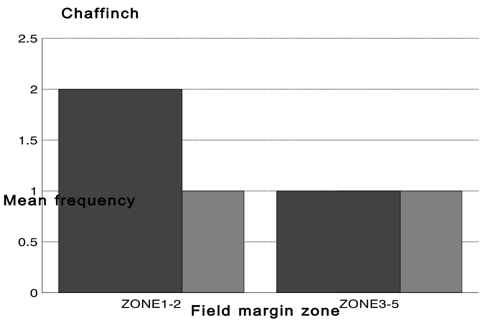

All species
20
15
10
5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone

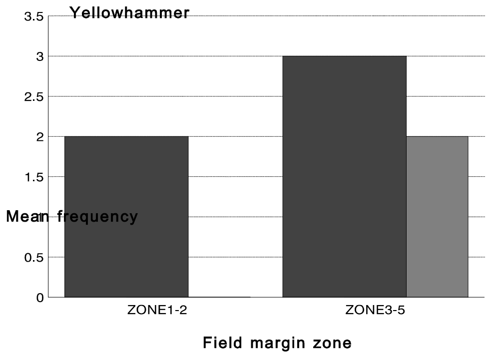
Figure 3.4 The mean frequency of Dunnock, Blackbird, Chaffinch, Yellowhammer and all bird species combined (averaged over the number of observation visits) on five field margin zones adjacent to good (grey bars) or poor (black bars) quality hedgerows. There was no significant association between hedgerow quality and margin zone use in any species in (a) 1984 or (b) 1985. These data are from Manydown Farm, Hampshire. Zones are defined in Table 3.1 (Fisher exact tests)

(B)


Dunnock
3.5
3
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone


Blackbird
3.5
3
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone


Chaffinch
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone


Yellowhammer
3.5
3
2.5
2
1.5
1
0.5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone

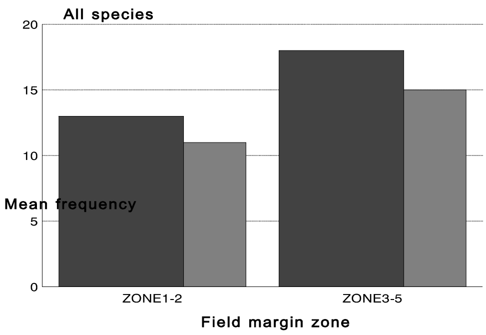

All species
20
15
10
5
0
Mean frequency
ZONE1-2
ZONE3-5
Field margin zone

Figure 3.4 continued

APPENDIX 1

NAMES OF PLANTS AND ANIMALS MENTIONED IN THE TEXT

Plant Species
Acorns *Quercus*
Amaranths (Amaranthaceae)
Aphids (Aphididae)
Barren Brome *Bromus sterilis*
Beech Mast (Fagacea)
Bilberry *Vaccimium* (Ericaceae)
Bistorts (Polygonaceae)
Black Bryony *Tamus communis*
Black Grass *Alopecurus myosuroides*
Black Knapweed *Centaurea nigra*
Blackthorn ***Prunus spinosa***
Bramble ***Rubus fruticosus*** (Rosaceae)
Buckthorn *Rhamnus*
Burdocks *Arctium*
Buttercup (Ranunculaceae)
Charlock *Sinapis arvensis* (Cruciferae)
Chickweed *Stellaria*
Cleavers *Galium aparine*
Cocksfoot *Dactylis glomerata*
Cockspur *Echinochloa*
Common Bent *Agrostis capillaris*
Common Mallow *Malva sylvestris*
Cornflower *Centurea cyanus*
Couch Grass *Elymus repens*
Cow Parsley *Anthriscus sylvestris*
Cranesbills *Geranium* (Geraniacee)
Crested Dog's Tail *Cynosurus cristatus*
Dandelion *Taraxacum*
Docks (Polygonaceae)
Dog Rose *Rosa canina*
Dog's Mercury *Mercurialis perenne*
Dogwood *Thelycrania sanguinea*
Elder *Sambucus* (Caprifoliaceae)
Eyebright *Euphrasia* (Scrophulariaceae)
Fescues *Festuca* (Gramineae)
Field Marigold *Calendula officinalis*
Field Scabious *Knautia arvensis*
Finger-grass *Digitaria* (Gramineae)
Forget-me-nots *Myosotis* (Borginaceae)
Fumitories *Fumaria* (Fumariaceae)
Goosefoots (Chenopodiaceae)
Greater Knapweed *Centaura scabiosa*
Groundsel *Senecio vulgaris*
Guelder Rose (Caprifoliaceae)
Hawthorn ***Crataegus monogyna***
Hazel *Corylus avellana*
Hemp-nettle *Galeopsis spp*
Hogweed *Heracleum sphondylium*
Holly *Ilex* (Aquifoliaceae)
Honeysuckle *Lonicera* (Caprifoliaceae)
Ivy ***Hedera helix*** (Araliaceae)
Knapweed *Centaurea* sp
Knotgrass *Polygonum spp*
Lady's Mantle *Alchemilla*
Late Perennial Ryegrass *Lolium perenne*
Lupins *Lupinus*
Meadow grass *Poa*
Meadowsweet *Filipendula*
Medicks *Medicago* (Leguminosae)
Millet *Setaria*
Mistletoe *Viscum* (Loranthaceae)
Mouse-ears (Caryophyllaceae)
Mugworts *Artemesia*
Nettles (Urticaceae)
Purslanes *Portulacca* (Portulacaceae)
Oilseed Rape *Brassica napus* (Cruciferae)
Oraches (Chenopodiaceae)
Ox-eye Daisy *Chrysanthemum leucanthemum*
Pennycresses *Thlaspi*
Perennial Ryegrass *Lolium perenne*
Pheasant's Eye *Adonis annua*
Privet *Ligustrum* (Oleaceae)
Psyllids (Psyllidae)
Ragwort *Senecio*
Red Fescue *Festuca rubra*
Ribwort Plantain *Plantago lanceolata*
Rowan *Sorbus aucuparia* (Rosaceae)
Rye-grass *Lolium*
Saltworts *Salsola* (Chenopodiaceae)
Scentless Mayweed *Tripleurospermum maritimum*
Sheeps' Fescue *Festuca ovina*
Shepherd's-purse *Capsella* (Cruciferae)
Smooth Meadow Grass *Poa pratensis*
Sorrel *Rumex acetosa*
Sow Thistles *Sonchus* (Compositae)
Spear Thistle *Cirsium vulgare*
Speedwells *Veronica*
Spurges *Euphorbia* (Euphorbiaceae)
Spurreys (Caryophyllaceae)
Sterile Brome *Bromus sterilis*
Stinging Nettle *Urtica dioica*
Sunflowers (Compositae)
Teasel *Dipsacus* (Dipsacaceae)
Thistles *Cirsium*
Violet *Viola* (Violaceae)
Wayfaring tree *Viburnum* spp
Whitebeam *Sorbus aria* (Rosaceae)
White Bryony *Bryonia dioica*
White Mustard *Sinapsis alba*
Yarrow *Achillea millefolium*
Yorkshire Fog *Holcus lanatus*

Invertebrates
Ants (Formicidae)
Aphids (Aphididae)
Beetles (Coleoptera)
Blow flies (Calliphoridae)
Bush Crickets (Tettigoniidae)
caddisflies (Trichoptera)
Carabid Beetle
Caterpillars (Lepidoptera)
Chafers (Coleoptera)
Crane flies (Tipulidae)
Crickets (Gryllidae)
Damselflies (Odonata)
Dragonflies (Odonata)
Dung Flies (Coleoptera)
Earthworms (Annelida)
Earwigs (Dermaptera)
Elaterid Beetle
Fly Larvae (Diptera)
Fruit Flies (Drosophilidae)
Grasshopper (Acrodidae)
Ground Beetles (Carabidae)
Harvestman (Opiliones)
Ichneumon Wasps (Ichneumonidae, Braconidae)
Leaf Beetles (Chrysomelidae)
Leatherjackets (Tipulidae)
March Flies (Bibionidae)
Mayflies (Ephemeroptera)
Midges (Chironomidae)
Rove Beetles (Staphylinidae)
Sawflies (Symphyta)
Snails / Slugs (Mollusca)
Snipe Flies (Rhagionidae)
Spiders (Araneae)
Springtails (Collembola)
Weevils (Curculionidae)
Wireworms (Elateroidea)

Bird Species
Barn Owl *Tyto alba*
Blackbird *Turdus merula*
Blue-headed Wagtail *Motacilla flava flava*
Blue Tit *Parus caeruleus*
Bullfinch *Pyrrhula pyrrhula*
Carrion Crow *Corvus corone*
Chaffinch *Fringilla coelebs*
Cirl Bunting *Emberiza cirlus*
Corn Bunting *Miliaria calandra*
Crossbills *Loxia curvirostra*
Dunnock *Prunella modularis*
Fieldfare *Turdus pilaris*
Goldfinch *Cardeulis cardeulis*
Great Tit *Parus major*
Greenfinch.*Cardeulis chloris*
Grey Partridge *Perdix perdix*
Hobby *Falco subbuteo*
House Sparrow *Passer domesticus*
Jackdaws *Corvus monedula*
Kestrel *Falco tinnunculus*
Lapwing *Vanellus vanellus*
Linnet *Cardeulis cannabina*
Long-tailed Tit *Aegithalos caudatus*
Magpies *Pica pica*
Mallard *Anas platyrhynchos*
Meadow Pipit *Anthus pratensis*
Mistle Thrush *Turdus viscivorus*
Oystercatcher *Haematopus ostralegus*
Pheasant *Phasianus colchicus*
Pied Wagtail *Motacilla alba*
Red-legged Partridge *Alectoris rufa*
Redwing *Turdus iliacus*
Reed Bunting *Emberiza schoeniclus*
Ringed Plover *Charadrius hiaticula*
Robin *Erithacus rubecula*
Rook *Corvus frugilegus*
Skylark *Alauda arvensis*
Snipe *Gallinago gallinago*
Song Thrush *Turdus philomelos*
Sparrowhawk *Accipiter nisus*
Starling *Sturnus vulgaris*
Stone Curlew *Burhinus oedicnemus*
Tree Sparrow *Passer montanus*
Turtle Dove *Streptopelia turtur*
Twite *Cardeulis Flavirostris*
Whitethroat *Sylvia communis*
White Wagtail *Motacilla alba alba*
Willow Warbler *Phylloscopus trochilus*
Woodpigeon *Columba palumbus*
Wren *Troglodytes troglodytes*
Yellowhammer *Emberiza citrinella*

Tree Species

Alder *Alnus* (Betulaceae)

Ash *Fraxinus* (Oleaceae)
Birch *Betula* (Betulaceae)
Elm *Ulmus* (Ulmaceae)
Maple *Acer* (Aceraceae)
Oak (Fagaceae)
Pine *Pinus*
Spruce (Pinaceae)
Willow *Salix* (Salicaceae)
Yew *Taxus* (Taxaceae)

Butterfly Species
Gatekeeper *Pyronia tithomas*
Meadow Brown *Maniola jurtina*

Mammal species
Wood Mouse *Apodemus sylvaticus*
Bank Vole *Clethrionomys glareolus*
Field Vole *Microtus agrestis*
Common Shrew *Sorex araneus*
Harvest Mouse *Micromys minutus*