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The influence of hedge structure, management and landscape context on the value of hedgerows to birds: A review

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In this review, we discuss the value of hedgerows as bird habitat in lowland-farming landscapes to provide a background against which decisions concerning hedgerow management might be evaluated. The two most important factors positively associated with species richness and abundance of breeding birds in hedgerows are hedge size (height/width/volume) and the presence/abundance of trees. The provision of cover and the botanical and structural complexity of the vegetation are also important. However, large hedges do not suit all species; birds tend to prefer hedgerow types which most closely resemble their usual non-hedgerow breeding habitat. The value of hedgerows to birds can be increased by combining them with other features such as headlands (for game birds), verges, wildflower strips, game and wild-bird cover and well-vegetated banks and ditches. The presence of well-grown, dead or decaying trees is beneficial to many species, providing nest holes, foraging sites and perches. Increasing the structural complexity of a hedgerow and its associated habitat may also reduce the incidence of predation. Hedgerows also provide physical shelter and roost sites and are an important source of winter food supplies, especially berries and other fruits. Some bird species, usually those whose primary habitat is woodland, live mainly within the hedgerow itself, whereas others are more dependent on the surrounding landscape to a greater or lesser extent. However, even the presence of woodland bird species is influenced by the availability and characteristics of alternative habitats in the surroundings and therefore hedgerows and their bird populations do not function as isolated patches. As linear landscape elements, hedgerows also provide safe cover for both local and larger-scale movements and may facilitate access to resources or habitat which might otherwise be too risky or too remote for birds to use or colonise. A number of recommendations for improving hedgerow habitat for birds are reiterated from an extensive literature and include combining hedgerows with other semi-natural habitat, providing a variety of structural types, maintaining good cover in the hedge-base, e.g. by excluding stock and herbicide, and avoiding excessive cutting. However, good hedgerow management has costs and is unlikely to be applied widely in the absence of national policy and funding.

Keywords: agriculture, birds, farming, hedgerow, hedge, hedgerow management, hedgerow structure, landscape structure, shelterbelts.

Introduction

In lowland-farming landscapes in Britain, hedgerows comprise one of the most important surviving elements of semi-natural habitat for birds. In 1990, the amount of hedgerow in Britain was estimated at 464 000 km (Barr *et al*., 1993). It is generally acknowledged that protected sites, such as nature reserves, are liable to be inadequate to maintain long-term, viable populations of many species and that such protected areas are vulnerable to events occurring beyond their borders (Pienkowski and Bignal, 1993; Lavers and Haines-Young, 1996; Pienkowski *et al*., 1996). The bulk of most bird species populations will always reside in the wider countryside and thus conservation measures and good management must be applied at a similar scale. The expectation of the general public to experience a countryside rich in wildlife also demands large-scale action and has recently been acknowledged at governmental level in the UK by the inclusion of the status of bird populations as quality of life indicators

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(DETR, 1999). Here, we review the value of hedgerows as habitat for birds and how this varies according to the needs of individual bird species, hedgerow structure and the characteristics of the wider landscape. Against this background of how birds use hedgerows, some simple management guidelines are reiterated from an extensive literature and some of the difficulties inherent in good hedgerow management are discussed.

Hedgerows provide birds with nesting, roosting and foraging sites, provide cover for local movement and for some species, may also facilitate long distance movement through landscapes (e.g. Osborne, 1984; O'Connor, 1987; Johnson and Beck, 1988; Moles and Breen, 1995; Demers *et al*., 1995). The value of hedgerows for birds depends on a number of factors including hedge size and structure in relation to the habitat preferences of individual bird species, the density and spatial arrangement of hedgerows in the local landscape and the management of the hedgerows themselves and of their surroundings (e.g. Arnold, 1983; Yahner, 1983; O'Connor, 1984; Burel and Baudry, 1990; Green *et al*., 1994; Parish *et al*., 1995). Bird species typical of hedgerows are commonly those of woodland, woodland edge and scrub type habitats and although some species, such as Cirl Bunting *Emberiza cirlus*, are at present closely associated with hedgerows, few, if any, 'hedgerow' birds are confined to this habitat alone.

In many farming landscapes, semi-natural habitat other than hedgerows may be in short supply. The scale at which hedgerows and birds interact therefore ranges from local effects confined to the hedgerow itself to large-scale factors such as adjacent crop types and the availability of hedgerows and other habitats, such as gardens and woods, in the wider landscape. Bird/hedgerow interactions also depend on the resources obtained from a hedgerow by different bird species; some species may live almost entirely within a hedgerow whereas some may use it only as a song post (Johnson and Beck, 1988). In a landscape context, hedgerows may also have a negative influence on some bird species typical of open farmland, the most notable such species of lowland farmland in Britain being Northern Lapwing *Vanellus vanellus* and Skylark *Alauda arvensis*. Therefore, although these species are not hedgerow birds as such, their interactions with hedgerows are included in this review as appropriate in the landscape context. The variation between bird species in their requirements and use, or avoidance, of hedgerows means that no single prescription for hedgerow structure and management can meet the needs of all the birds of a given locality. However, it has been suggested that a large proportion of hedgerows are either under-managed or over-managed (MacDonald and Johnson, 1995), indicating considerable potential for improving the quality of hedgerows for birds and other wildlife via the application of suitable management. The nomenclature used for British birds in this review is that of the British Ornithologists' Union (1999).

Hedgerows as bird breeding habitat

Many studies have shown that bird species richness and overall abundance increase with increasing hedge size (e.g. height and width, Figures 1 and 2) and hence it is not surprising that larger hedges have more birds (Arnold, 1983; Osborne, 1984; Shalaway, 1985; Green *et al*., 1994; Lakhani, 1994; Parish *et al*., 1994; MacDonald and Johnson, 1995; Sparks *et al*., 1996). Studies differ in how 'size' is measured (Table 1). Hinsley *et al*. (1999) found that bird species richness and abundance showed a better relationship with hedge width than with height (Figures 1 and 2), but other studies (such as those mentioned above) have found height and/or volume to be more significant. Variables such as height and width, amongst others, are often highly correlated making it difficult to disentangle their separate influences (e.g. MacDonald and Johnson, 1995), but in practical terms, short, narrow hedges are generally unfavourable to most birds, probably due to a combination of lack of resources and exposure to both weather and predators.

Hedge size and the presence and/or abundance of trees were the two factors most commonly recorded as having a positive influence on bird species richness and abundance in hedgerows in the UK (Table 1). Tall hedges with many trees are probably attractive to many woodland-breeding bird species

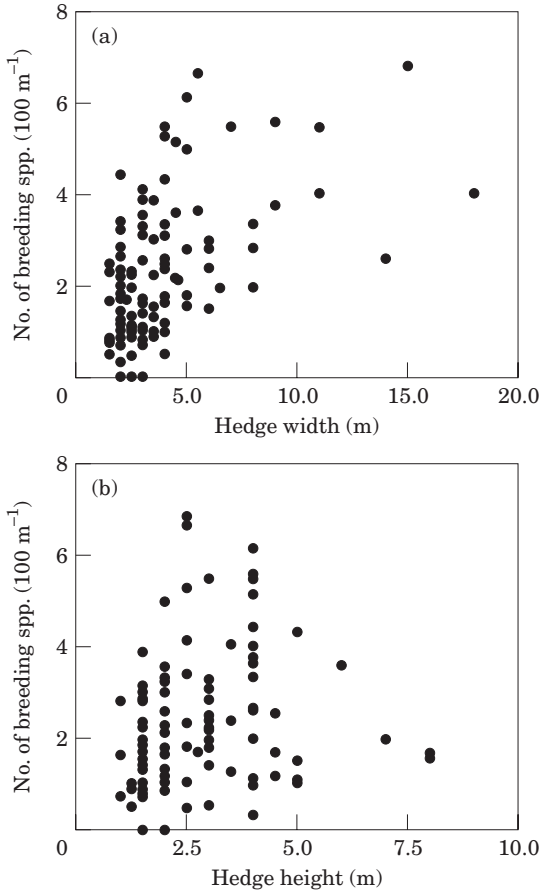

Figure 1. Relationship between breeding bird species richness (excluding game birds and owls except Little Owl, *Athene noctua*) per 100-m length and (a) hedge width (average lateral extent of the woody vegetation) and (b) hedge height. Both relationships are significant, but hedge height in this particular data set explains little of the variation in breeding species numbers. Equations describing the best fit to the data are (a) Species richness= 0·234+3·90 $\log_{10}$ Hedge width, $P<0·001$, $R^2=33\%$, N=106, and (b) Species richness=1·36+2·34 $\log_{10}$ Hedge height, $P=0·002$, $R^2=8\%$, N=106, but note that relationships are drawn using the untransformed data. Data are from a study of birds and hedgerows at 22 sites across the UK (Hinsley *et al*., 1999). Assessment of species richness and bird abundance were based on territory mapping which avoided duplication of records for hedges within sites, but any effects of management at the site level were not controlled for in this illustration.

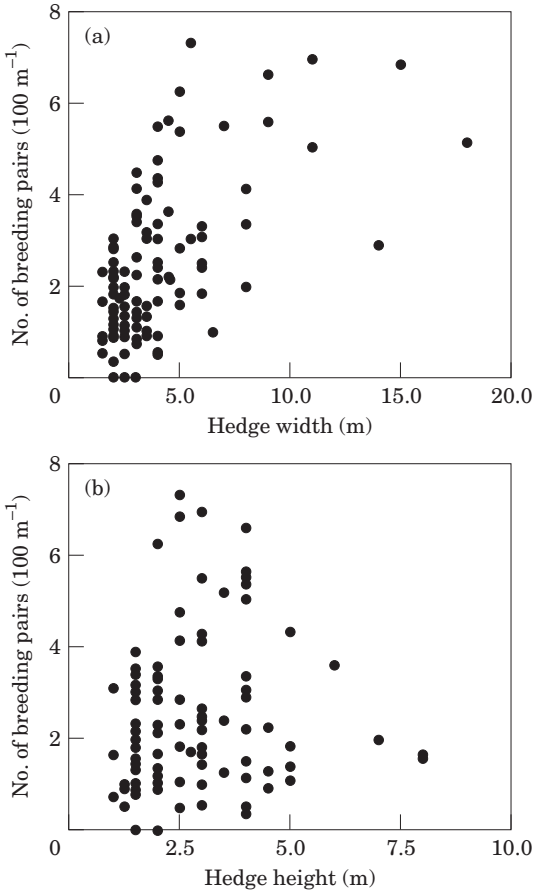

Figure 2. Relationship between breeding bird abundance (number of pairs, excluding game birds, Common Wood Pigeons *Columba palumbus* and owls except Little Owl) per 100-m length and (a) hedge width and (b) hedge height. Both relationships are significant, but hedge height in this particular data set explains little of the variation in bird abundance. Equations describing the best fit to the data are (a) Bird abundance=−0·137+4·74 $\log_{10}$ Hedge width, $P<0·001$, $R^2=41\%$, N=106, and (b) Bird abundance=1·45+2·25 $\log_{10}$ Hedge height, $P=0·006$, $R^2=6\%$, N=106, but note that relationships are drawn using the untransformed data. Data are from a study of birds and hedgerows at 22 sites across the UK (Hinsley *et al*., 1999) as in Figure 1.

because of the resemblence of this type of structure to woodland edge. Dense vegetation cover in and around the hedgerow base increases bird species richness and abundance and is important in nest site selection and success for a number of species (Rands, 1986a; Stoate and Szczur, 1994). The botanical composition of a hedgerow may also influence its bird fauna (Best, 1983; O'Connor, 1987; Green *et al*., 1994; MacDonald and Johnson, 1995); bird species richness and abundance both increased with the number of woody plant species present (Figure 3), which was as expected given the implicit increase in habitat diversity (Best, 1983). High botanical diversity may increase the variety and year-round availability of food supplies; shrub-rich hedgerows may also be older which could in turn influence their value as sources of seed, fruit and

Table 1. Summary of factors influencing bird species richness and bird abundance in hedgerows in the UK

A. ***Species richness and abundance increased with hedge 'size', where size was measured or defined as:***	
Height	Arnold, 1983 (winter and summer); Lack, 1987, 1992; Parish *et al*., 1994 (winter and summer); Green *et al*., 1994; Moles and Breen, 1995[a]; MacDonald and Johnson, 1995
Width	O'Connor, 1987; Shaw, 1988
Height and width	Arnold, 1983; Lack, 1992; Green *et al*., 1994; Moles and Breen, 1995
Area	Osborne, 1984
Volume	O'Connor, 1987; Parish *et al*., 1994 (winter and summer)
Overgrown	Pollard *et al*., 1974; O'Connor and Shubb, 1986; O'Connor, 1987
B. ***Species richness and abundance were positively influenced by trees, where trees were recorded as***:	
Presence and/or no. of trees	Williamson, 1971; Wyllie, 1976; Arnold, 1983 (winter); O'Connor, 1984; O'Connor and Shrubb, 1986; O'Connor, 1987; MacDonald and Johnson, 1995; Lack, 1992; Moles and Breen, 1995
Tree height	Parish *et al*., 1994 (winter and breeding); Parish *et al*., 1995 (winter and summer)
Tree height × tree no.	Parish *et al*., 1994; Parish *et al*., 1995 (winter and summer)
Tree spp. diversity (no. spp. × no. trees)	Osborne, 1984
No. of dead trees	Osborne, 1982, 1984; Lack, 1992
C. ***Other factors intrinsic to the hedgerow related to species richness and abundance:***[b]	
No. of shrub species	Osborne, 1984; O'Connor, 1987; MacDonald and Johnson, 1995; Parish *et al*., 1994 (winter and breeding)
Cover in hedgerow	Moore *et al*., 1967; Rands, 1987; O'Connor, 1987; Lack, 1992; Arnold, 1983
Shrub spp. identity	Influences abundance, Moore *et al*., 1967; Lack, 1992
Gaps	−ve for hedge-dwelling bird abundance, MacDonald and Johnson, 1995; −ve for bird abundance, Moles and Breen, 1995[c] (winter), +ve for open-field birds, Lack, 1992
D. ***Influence of adjacent landscape features, surrounding land-use and the wider landscape:***	
Verge width	+ve for species richness, Parish *et al*., 1994 (breeding)
Ditch width	+ve for species richness, Parish *et al*., 1994 (winter), Osborne, 1984; +ve for abundance, O'Connor, 1987
Wet ditches	+ve for species richness, Moles and Breen, 1995 (winter)
Adjacent scrub	+ve for species richness, Osborne, 1984
Adjacent woodland	+ve for abundance, Lack, 1992[d] −ve for abundance, O'Connor, 1987[d]
Conservation headlands	+ve for game birds, Rands, 1985, 1986b; unresolved/indifferent for other species, Fuller, 1984; Cracknell, 1986; Lack, 1992; Green *et al*., 1994
Grass, espec. permanent pasture	+ve for species richness compared to arable, Arnold, 1983; Parish *et al*., 1994 (winter, summer and breeding), +ve for abundance, Moles and Breen, 1995 (winter)
Area of open field	−ve for abundance, Osborne, 1984
Hedgerow intersections	+ve for abundance, Lack, 1988, 1992

(*Continued overleaf*)

Table 1. (*Continued*)

Amount of hedgerow and other boundaries in landscape	+ve for species richness, O'Connor and Shrubb, 1986; Lack, 1992; +ve for abundance, O'Connor and Shrubb, 1986; Moles and Breen, 1995
Gardens in landscape	+ve for abundance, MacDonald and Johnson, 1995
Woodland in landscape	−ve for species richness, Arnold, 1983[e]

Information is for birds censused in spring and summer (and therefore likely to be breeding) unless otherwise indicated. The two factors most commonly recorded as important were hedge size and trees.
[a]Tall cover noted as important for breeding birds, but coefficient for 'tall, wide hedge' was −ve in regression describing total no. of species and that for 'short narrow hedge' was +ve in the regression describing total no. of individuals.
[b]Relationships are +ve unless otherwise indicated.
[c]The effect of gaps is inferred from the classification of 'tall scrub' given in the appendix.
[d]Difference in findings may depend in part on differences between study areas and years in population sizes of the birds examined and their predators.
[e]Concerns woodland in the wider landscape rather than that immediately adjacent to or adjoining hedgerows.

invertebrates (Pollard *et al*., 1974; O'Connor, 1987). However, how the presence and/or stage of growth of particular woody plant species, in relation to hedgerow age, structure and overall plant species diversity, influences bird species richness is unclear, but is discussed further below in relation to individual bird species preferences.

Despite the general rule-of-thumb 'bigger hedges, more birds', large hedges do not suit all species (Table 2). In general, birds prefer hedgerows which most closely resemble their usual non-hedgerow breeding habitat. Therefore, woodland species (e.g. Common Blackbird *Turdus merula*) prefer tall, wide hedgerows with lots of trees, woodland edge and scrub species (e.g. Common Linnet *Carduelis cannabina*) prefer lower, but wide and often dense hedgerows, and open-country species (e.g. Corn Bunting *Miliaria calandra*) prefer, or at least tolerate, short, possibly gappy hedgerows or even just clumps of bushes (Figure 4). Corn Buntings usually nest on or near the ground in cover provided by crops, rank vegetation and low bushes; in Figure 4, their rarity in boundaries without hedges was due to the poor cover provided by such features in this particular study area. Some scrub and open-country species like a few trees for perches, song posts and nest holes, whereas other open-country species, such as Skylark and Northern Lapwing (both ground nesters), avoid hedgerows, but will tolerate the proximity of short ones to some extent (O'Connor, 1984; Green *et al*., 1994; MacDonald and Johnson, 1995; Moles and Breen, 1995; Sparks *et al*., 1996). In Figure 4, the presence of Skylarks in some transects with hedgerows was due to the inclusion of 10 m of cropland on either side of the field boundary transects. Trees and other features providing perches for potential predators of eggs and young may also be avoided by some open-country species (Redfern, 1982; Tucker *et al*., 1994). Hole-nesting birds, particularly medium and large-bodied species (e.g. woodpeckers and owls), are most dependent in their use of hedgerows as nesting habitat on the presence of well-grown, decayed or dead trees (Osborne, 1984).

The 10 most frequently recorded bird species breeding in hedgerows in a number of studies in the UK are shown in Table 2. Of these, seven are common species of woodland and, in more recent times, of gardens. For a detailed description of the hedgerow characteristics preferred by a number of individual bird species see Green *et al*. (1994). Despite differences between species in their preferences for a number of factors including height, width and the number of trees present, the incidence of most species increases linearly with increasing numbers of woody plant species per unit length (Figure 3). As mentioned above, relationships between bird species and plant species are liable to be complex. For example, American Robins *Turdus migratorius* nesting in shelterbelts in Minnesota, USA, preferred spruce (*Picea* spp.) trees for nest sites, but site selection was also influenced by the growth form of the tree and the proximity of foraging areas outside the shelterbelt (Yahner, 1982a). In a similar way, elm (*Ulmus* spp.) in shelterbelts was the preferred foraging substrate of half the bird species studied, a result attributed to the management of these trees which had sprouted dense shrubby growth following cutting to control the spread of Dutch elm disease (Yahner, 1982b). One to

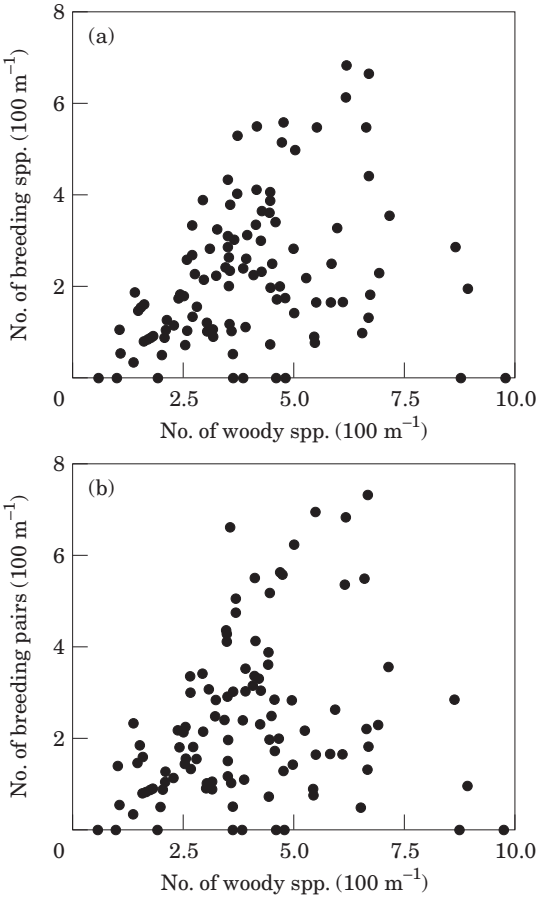

Figure 3. Relationship between (a) breeding bird species richness and (b) breeding bird abundance and the number of woody plant species in a hedge. All values are expressed as numbers per 100-m length of hedge. Both relationships are significant, but are heavily influenced by the four points corresponding to the highest numbers of woody species (values >7·5 m). Of these four particular hedges, two were short-trimmed and two were tall with many trees, but thin at the base. Equations for the relationships without these four hedges are (a) Species richness=0·448+0·488 Number of woody spp., $P<0·001$, $R^2=22\%$, N=102 (with the four hedges, $P=001$, $R^2=9\%$, N=106), and (b) Bird abundance=0·706+0·439 Number of woody spp., $P<0·001$, $R^2=15\%$, N=102 (with the four hedges, $P=016$, $R^2=5\%$, N=106). Data are from a study of birds and hedgerows at 22 sites across the UK (Hinsley *et al*., 1999) as in Figure 1.

one relationships between plant species and bird species in hedges are unlikely because particular bird requirements, e.g. nest cover, can be provided by several plant species, e.g. many conifers and dense growing thorny shrubs, and the resources provided by a particular plant species are likely to be exploited in different ways by several bird species, e.g. a dead elm can provide perches, nest holes and foraging opportunities.

Land use adjacent to a hedgerow can also influence its bird fauna. Most species are more abundant in hedgerows and other field boundaries surrounded by pasture than in similar boundaries in arable crops, which may be due to differences in land management as well as to the land use *per se* (Parish *et al*., 1995; Sparks *et al*., 1996; Fuller *et al*., 1997). However, there are some important exceptions including Yellowhammer *Emberiza citrinella* and game birds, which are more abundant in arable-crop boundaries, especially cereals (Green *et al*., 1994; Parish *et al*., 1995). For the species showing lower abundance in hedgerows adjacent to arable crops, oil-seed rape *Brassica napus* appeared to be the most favourable crop (Lack, 1992; Green *et al*., 1994), probably because it provides food (leaves, seed and invertebrates), cover and access to the ground. It can be difficult to assess the relationship between the bird fauna of a particular hedgerow and its immediately adjacent land use (including management practices such as conservation headlands) because the mobility of birds allows them to use the available habitat on a larger-scale than that which might be assumed when looking for such associations (Fuller, 1984; Sotherton, 1991; Green *et al*., 1994). It is also possible that effects might take several years to become apparent (Lack, 1992) and be further confounded by crop rotations. Despite these difficulties, there is little doubt that combining hedgerows with conservation headlands and with additional semi-natural habitat such as grass verges, wildflower strips, game and wild-bird cover and well-vegetated banks and ditches can greatly increase the value of a hedgerow to birds as both nesting and foraging habitat (although the value of conservation headlands has so far only been demonstrated for game birds, Rands, 1985; Rands, 1986b). At the simplest level, bird species richness and abundance should increase as the amount and diversity of habitat increases. Long-term, detailed studies of the Grey Partridge *Perdix perdix* have stressed the importance of verge width, topography and vegetation characteristics for both nest success and chick rearing (Potts, 1986; Rands, 1986b, 1987, 1988; Potts and Aebischer, 1995). More recent studies have reached similar conclusions about

Table 2. Factors influencing the presence of individual bird species in hedges in the UK

Species	Hedge height	Hedge width	Trees in hedge	Number of woody spp.	Adjacent verge	Adjacent ditch	Presence/abundance of other features in surrounding landscape				
							Ditches	Gardens	Woods	Hedges	Grass/arable
A Common Blackbird 1,2,3,4,5,6,7,8,9	+ve	+ve	+ve	+ve	—	sum. +ve win. +ve	sum. wet +ve	+ve	sum. −ve win. −ve	sum. −ve[a]	grass +ve
B Hedge Accentor 1,2,3,4,5,6,8	+ve but pref. med.	+ve	−ve or indiff.	—	—	+ve	—	+ve	—	—[a]	—
B Yellowhammer 2,4,5,6,7,8	+ve/−ve pref. short	+ve	−ve or indiff.	+ve	+ve[h]	+ve[h]	—	win. +ve	+ve[h]	win. +ve sum. −ve[i]	arable +ve
C Chaffinch 1,2,4,5,6,8,9	+ve	—	+ve	win. −ve	+ve[f]	—	win. dry −ve	—	—	sum. +ve win. +ve/−ve[g]	—
D European Robin 2,3,4,5,6,9	sum. +ve win. +ve	+ve	+ve	+ve	—	—	sum. wet +ve	—	—	sum. +ve win. +ve	—
D Great Tit 1,2,4,5,6,7,8,9	+ve	—	+ve	+ve	—	—	+ve	—	win. −ve[e]	win. +ve[a]	grass +ve
D Common Wood Pigeon 1,2,3,4	+ve	—	+ve	—	−ve	—	win. dry +ve	sum. +ve	—	win. −ve	arable +ve
D Winter Wren 1,3,4,5,6,7	+ve	+ve	+ve	+ve	—	+ve	sum. dry −ve sum. +ve	+ve	—	—[a]	—
E Song Thrush 1,2,3,4,6,7,8,10	+ve	+ve	+ve	+ve[b]	—	—	+ve and win. dry −ve	+ve	sum. −ve[c]	win. −ve[d]	grass +ve

(*Continued overleaf*)

Table 2. (*Continued*)

Species	Hedge height	Hedge width	Trees in hedge	Number of woody spp.	Adjacent verge	Adjacent ditch	Presence/abundance of other features in surrounding landscape				
							Ditches	Gardens	Woods	Hedges	Grass/arable
E Blue Tit 1,4,5,6,7,8	+ve	+ve	+ve	+ve	+ve	+ve	—	+ve	win. −ve[e]	+ve[a]	grass +ve
Common Whitethroat 1,2,5,6,11	+ve/−ve pref. med.	+ve	−ve	+ve	+ve	—	—	—	—	—	—
Linnet 1,2,3,4,5,6,7	−ve pref. short	—	−ve	—	+ve[f]	—	sum. wet +ve	sum. +ve win. +ve[f]	—	—	—
Skylark 1,2,4,6,7,12	−ve	−ve	−ve	—	win. +ve	—	+ve	—	sum. +ve	sum. +ve	arable +ve
Corn Bunting 2,4,7,8,12	−ve	—	−ve	—	+ve[h]	+ve[h]	—	—	sum. +ve[h] win. −ve[h]	—	arable +ve

Species were selected to demonstrate a range of responses to hedgerows and landscape attributes. The first 10 species in the table were those most frequently recorded in the studies cited. They are listed in order of their approximate relative ranking (most commonly encountered first) as indicated by the capital letters. Factors shown are some of those most commonly reported as important to birds in hedgerows. Factors generally favourable for the presence and/or abundance of a species are shown by +ve, generally unfavourable factors by −ve and mixed findings by +ve/−ve. Information is for birds censused in spring and summer (and therefore likely to be breeding) unless otherwise indicated. Sum., summer, win., winter, dry, dry ditch, wet, wet ditch, pref., prefer, med., medium, indiff., indifferent. Numbers under species refer to key references: 1. MacDonald and Johnson, 1995; 2. Sparks *et al*., 1996; 3. Moles and Breen, 1995; 4. Arnold, 1983; 5. Fuller, 1984; 6. Green *et al*., 1994; 7. Parish *et al*., 1995; 8. Lack, 1992; 9. Osborne, 1984; 10. Mason, 1998; 11. Stoate and Szczur, 1994; 12. O'Connor, 1987.

[a]The presence of scrub/bushes, distinct from hedgerows, was +ve, Osborne (1984) and/or Moles and Breen (1995).

[b]Findings of Arnold (1983), where Song Thrushes in summer preferred hedgerows with few shrub species, differed from the general trend.

[c]The −ve effect recorded for numbers of thrushes (nests and territories) as a group, Arnold (1983).

[d]The −ve effect recorded for short, narrow hedgerows, Moles and Breen (1995).

[e]The −ve effect recorded for tits as a group, Arnold (1983).

[f]The +ve effect recorded for finches as a group, Parish *et al*. (1995) and/or Arnold (1983).

[g]Medium height, wide hedgerows +ve in winter, short, wide hedgerows −ve in winter, Moles and Breen (1995).

[h]The +ve effect recorded for buntings as a group, Parish *et al*. (1995) and/or Arnold (1983).

[i]Short hedgerows −ve in winter, Arnold (1983).

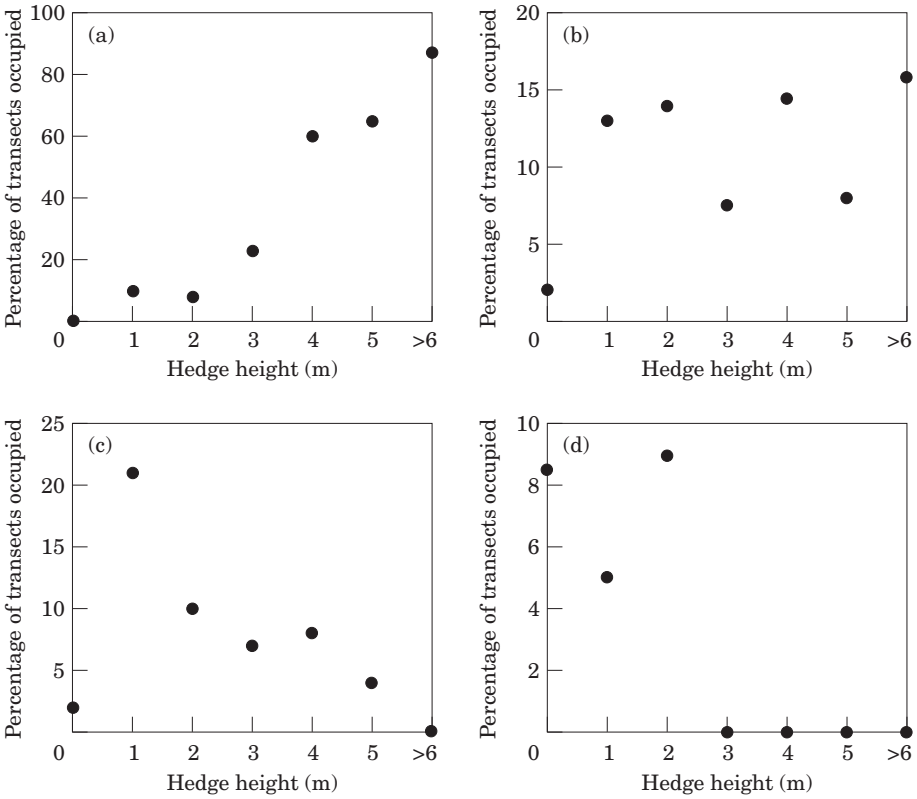

Figure 4. Examples of different species responses to hedge height. The information was derived from records of breeding birds in 117 200-m field boundary transects, including 10 m into the crop on either side. Species showing a similar response to that of Common Blackbird included Common Wood Pigeon, European Turtle Dove *Streptopelia turtur*, Winter Wren *Troglodytes troglodytes*, European Robin, Song Thrush, Common Whitethroat, Blue Tit, Great Tit and Chaffinch *Fringilla coelebs*. Species with a similar response to Linnet included Eurasian Reed Warbler *Acrocephalus scirpaceus*, Hedge Accentor and Yellowhammer. Sedge Warbler *A. schoenobaenus* showed a response similar to that of Skylark and Corn Bunting. See Green *et al*. (1994) for further details of individual species preferences for hedge height. Note the differences in the vertical scales. (a) Blackbird; (b) Linnet; (c) Corn Bunting; (d) Skylark. The information in this figure is redrawn from *Agriculture, Ecosystems & Environment* **60**, Sparks *et al*. (1996), Breeding birds in field boundaries in an agricultural landscape, pp. 1–8, © (1996), with permission from Elsevier Science.

the value of such habitat for other species including Yellowhammer (granivorous, but feeds young on invertebrates) (Stoate *et al*., 1998), and Common Whitethroat *Sylvia communis* (summer migrant insectivore) (Stoate and Szczur, 1994) and for seed eating birds in general (Parish *et al*., 1995). The abundance of some seed eaters, including Common Linnet, Reed Bunting *Emberiza schoeniclus* and European Goldfinch *Carduelis carduelis*, and of certain insectivores/omnivores, including Song Thrush *Turdus philomelos*, is also influenced by the presence and size of ditches (Parish *et al*., 1994, 1995). Additional habitat adjacent to hedgerows may also increase the quality of hedgerow territories by increasing local food supplies and hence reducing the time and energy required for foraging trips by parent birds feeding young in the nest. In Common Linnets (granivorous, feeding young on seeds), increased foraging distances following hedgerow loss and conversion of meadows and fallows to cropland, resulted in longer absence of parents from the nest, and were associated with nestling loss (Eybert *et al*., 1995). Additional habitat such as verges and ditches also offer added value in a landscape context by provide nesting and foraging sites for open-country species such as Corn Bunting (Donald *et al*., 1997; Sotherton, 1998).

Increasing the structural complexity of hedgerow boundaries by increasing the width and/or height of the hedge (without losing good cover) and adding additional habitat may also help reduce the incidence of predation. Thin, narrow hedgerows with little or no verge offer few options for nest

concealment and are easily searched by predators (Arnold, 1983; Grajetzky, 1993; Chamberlain *et al*., 1995; Newton, 1998). Agricultural, and other man-modified, landscapes may be beneficial to certain predators such as corvids by supplying year-round food in the form of carrion, animal feed and garbage. Such populations may then achieve high densities and increase the predation pressure on their natural prey. In studies using both artificial and natural nests (e.g. Gates and Gysel, 1978; Andrén *et al*., 1985; Sandström, 1991; Bayne and Hobson, 1997; Keyser *et al*., 1998) higher predation rates in habitat edges, usually of woodland in agricultural landscapes, have often (but not always, Paton, 1994) been recorded, indicating that the birds breeding in edge-type habitats such as hedgerows may be especially vulnerable to nest predators (Chamberlain *et al*., 1995).

Use of hedgerows by birds other than as breeding habitat

Hedgerows can provide cover for birds, increasing the safety with which they can exploit nearby resources and allowing them access to locations which might otherwise be too risky to use at all (Cracknell, 1986; Suhonen, 1993; Andrews and Rebane, 1994). In the 1960s, when Eurasian Sparrowhawks *Accipiter nisus* were rare or absent in much of England due to the effects of organochlorine pesticides, Common Bullfinches *Pyrrhula pyrrhula* were noted to have become more common and widespread in the open countryside (Newton, 1967). In the absence of their major predator, they were able to exploit seed sources far from cover—a situation now reversed by the recovery of the Sparrowhawk population (Newton, pers. comm.). A similar situation may also have occurred for the Eurasian Tree Sparrow *Passer montanus* (Summers-Smith, 1995). Although birds are highly mobile, in many landscapes hedgerows comprise a major source of cover and thus may provide the safest option as travel routes for both short and long-distance movements. The presence of some breeding woodland birds (including European Robin *Erithacus rubecula*, Blue Tit *Parus caeruleus*, Great Tit *Pares major*, and Long-tailed Tit *Aegithalos caudatus*) in particular woods was found to be influenced by characteristics of the landscape outside the woods, including the number of hedgerows connected to a wood and the total amount of hedgerow in the surrounding landscape (Opdam *et al*., 1985; Hinsley *et al*., 1995). This relationship may have arisen in part because the hedgerows, particularly those directly connected to a wood, provided additional habitat, but given the tendency of many species, e.g. Long-tailed Tit, to travel along hedgerows, additional use as corridors seems likely. In a study of Short-toed Treecreepers *Certhia brachydactyla* in the Netherlands, the birds' abilities to colonise new, linear habitat (rows of trees) was found to depend on a high degree of connectivity between the source of colonists, an established landscape of small fields and woods with an extensive hedgerow network, and the new trees (Clergeau and Burel, 1997; see also Spellerberg and Gaywood, 1993; Dawson, 1994; Kirby, 1995). In the Great Plains in North America, shelterbelts are thought to aid the movement of birds between otherwise isolated woodlands, and to have extended the ranges of several bird species, e.g. Mississippi Kite *Ictinia mississippiensis*, into the Great Plains by providing both travel routes and habitat (Johnson and Beck, 1988; Haas, 1995). In a similar way, in Australia (and elsewhere) linear strips of native vegetation preserved or reinstated, for example along roadsides, serve as both habitat and access routes for birds and other wildlife (Saunders and Hobbs, 1991; Bennett, 1999).

In winter, hedgerows provide physical shelter and are an important source of food for both resident and wintering birds (Arnold, 1983; Johnson and Beck, 1988; Snow and Snow, 1988; Moles and Breen, 1995; Sparks and Martin, 1999). Some studies have indicated that relationships between bird occurrence and hedgerow characteristics differ between summer and winter, factors associated with certain food supplies being more important in winter and those associated with the provision of cover more important in the breeding season (Arnold, 1983; Moles and Breen, 1995). There is also evidence of habitat selection by birds on passage; Duckworth (1994) recorded a preference for tall, mature hedgerows by Common Redstarts *Phoenicurus phoenicurus*, whereas Whinchats *Saxicola rubetra* within the same locality, preferred short, dense hedgerows.

With respect to the provision of winter food, urban and suburban hedges may comprise an under-estimated resource, especially during periods of severe weather when species, such as Redwing *Turdus iliacus* and Fieldfare *Turdus pilaris* (winter visitors to Britain), may enter towns and cities in large numbers to feed on the berries of ornamental and other shrubs. Given the primary purpose of ornamental, berry-bearing shrubs, a large difference between rural and urban hedges (including roadsides and gardens) may lie in the timing of cutting and hence a greater retention of fruit during the winter on the latter (Snow and Snow, 1988).

Hedgerow management for birds: farm-scale to landscape-scale

Combining a hedgerow with other types of semi-natural habitat was discussed above as one means of increasing local habitat diversity and the same principle applies at the landscape-scale. Again at the simplest level, more hedgerow habitat in a given locality should result in more hedgerow birds, and combining hedgerows into networks in conjunction with other semi-natural features such as ponds and copses will serve to increase habitat diversity which in turn correlates with increased bird diversity and abundance (O'Connor and Shrubb, 1986; Lentner and Landmann, 1994; Shrubb *et al*., 1997). One of the major problems of intensive agriculture, both arable and pastoral, is the loss of habitat diversity and the concomitant creation of monoculture.

The different preferences of bird species for certain types of hedgerow arise from the differences in the relationships between the birds and the habitat provided by the hedgerow. For most woodland birds, the hedgerow and its immediate adjacent habitat, such as a ditch or grass verge, provides all or most of the birds' requirements. There are exceptions to this generality, for example Common Blackbirds will forage extensively in certain crops and other species such as Hedge Accentor *Prunella modularis* (in the UK, a ubiquitous species of dense, low cover) will nest in some crops (e.g. oil-seed rape) once these are sufficiently well-grown. However, for many woodland birds, the hedgerow is a more or less discrete habitat patch or 'island' in the agricultural landscape. For other species, such as many finches, which forage widely in the landscape (Newton, 1972), the principal use of the hedgerow is to provide cover for the nest site and therefore the hedgerow is part of a network of resource patches rather than the principal island. For species such as Corn Bunting and Skylark, which rely mainly on the cropland rather than the surviving patches of semi-natural habitat, habitat use is even more diffuse and not restricted to well defined patches. For birds in shelterbelts in North Dakota, Johnson and Beck (1988) reviewed five categories of use depending on how each species partitioned the activities of nesting, singing and foraging between a shelterbelt and its surroundings. Thus management of the hedgerow itself may be of prime importance, at least on a local scale, for some species of woodland birds, but for most birds in agricultural landscapes, management needs to encompass the whole farm landscape (Bignal and McCracken, 1996).

On a larger scale, various studies have demonstrated that the bird populations of hedgerows do not function in isolation from other habitat in the surrounding landscape (Arnold, 1983; Hinsley *et al*., 1995; MacDonald and Johnson, 1995; Clergeau and Burel, 1997; Fuller *et al*., 1997; Lentner, 1998). For example, Arnold (1983) showed that the abundance of birds in hedgerows in summer was inversely related to the amount of woodland and garden in the surrounding 2·5 km^2, although the relationships for individual species were also influenced by characteristics of the hedgerows. The numbers of territories of breeding woodland birds in hedgerows declined as the area of woodland increased which was consistent with the view that hedgerows can be sub-optimal habitat for at least some woodland species (Krebs, 1971; O'Connor, 1984; Riddington and Gosler, 1995; Mason, 1998). However, even sub-optimal habitat is better than none at all and can play a vital role in population persistence (Pulliam and Danielson, 1991; Donovan *et al*., 1995a,b). Given the variation that exists in hedgerow structure and other characteristics it is also likely that optimality of hedgerow habitat will vary

in relation to locally or regionally available alternative habitats. Relationships between habitat type and availability and bird distributions and abundances are also influenced by bird regional population sizes, such that when populations are low suitable habitat may be unoccupied (Hinsley *et al*., 1996).

Hedgerow management

Numerous books, management guides, leaflets and research papers have been concerned either in part or in whole with descriptions or recommendations for hedgerow management (e.g. Arnold, 1983; ADAS, 1986; Lack, 1992; Countryside Commission, 1992; Aebischer *et al*., 1994; Boatman, 1994; Green *et al*., 1994; Parish *et al*., 1994; Watt and Buckley, 1994; Barr *et al*., 1995; Dodds *et al*., 1995; MacDonald and Johnson, 1995; Sparks *et al*., 1996; Thomas and Lewis, 1997; MAFF, 1999a,b), although the primary concern of many of these is managing hedgerow growth and structure rather than the relationship between the hedgerow and its birds. No single type of hedgerow (in terms of size, structure, plant species composition, number and size of trees etc.) will be suitable for all bird species in a locality and therefore hedgerow management for the benefit of birds needs to target specified aims. These might be closely focused on the needs of a particular species or group of species or more broadly based in relation to increasing bird species richness and abundance in general. Where targeted management is not an option or is not required, a few simple rules based on the timing and frequency of cutting could be applied, combined with the avoidance of practices and events known to be detrimental, such as over-trimming, over-grazing by stock and the spread (both accidental and deliberate) of herbicide and fertilizer into the hedge-base (Hooper, 1992; Andrews and Rebane, 1994; McAdam *et al*., 1994; Barr *et al*., 1995). Completely unmanaged hedgerows eventually grow tall and become thin and gappy at the bottom as ground-cover is shaded out, reducing their suitability for some bird species. However, under-management is generally thought to be less damaging to hedgerow birds than over-management (O'Connor and Shrubb, 1986; Lack, 1987).

The following suggestions are not intended as a recipe for hedgerow management for birds, but merely repeat some of the most frequently encountered, and in some cases very simple, recommendations aimed at improving hedgerow habitat for birds in general, i.e. not targeted specifically at a particular species. (1) More habitat should mean more birds, therefore whenever possible, combine hedgerows with other semi-natural habitat such as ditches, grass verges, game or wild bird cover etc. Increase the width (to at least 1·2 m, preferably 2·0 m) and the vegetation density of narrow, thin hedgerows. (2) Go for a mixture of hedgerow structural types (i.e. variation in heights, numbers of trees etc. between, and not within, hedgerows) and try to encourage certain types according to their location. For example, large hedgerows with plenty of trees in areas near woodland, shorter hedgerows with fewer or occasional trees in more open areas. (3) Trim hedgerows in rotation so that not all hedgerows are cut each year—the exact timing, i.e. interval between cuts, and location of hedgerows cut would depend on what type of hedgerow was desired in the long-term, combined with the demands of crop production. This procedure, combined with (2) above should provide a range of hedgerow sizes and types within a given locality. If possible, leave cutting until late winter to avoid removing supplies of fruit and seed before the winter. Avoid all cutting, and clearance of associated ditches, in the breeding season (timing will depend on geographic location, the year and the species concerned, but is approximately from mid-March to mid-August in the UK). Avoid excessive use of flail cutters and the removal of too much material at a single cut when just trimming. (4) Maintain good cover in the hedge-bottom and especially prevent over-grazing/browsing by stock and the spread of herbicide into the hedge-base. (5) When restoring hedgerows or creating new hedgerows, consider the bird species liable to be present in the location concerned and tailor the design of the boundary to suit. In some cases, very gappy hedges might be best converted to rows of bushes interpersed with grass/flowers/seedy weeds, and sometimes a bank with grass, flowers and seed sources might be better than an actual woody hedgerow.

Conclusions

As shown above, knowledge concerning the management of hedgerows to maintain and enhance their value to birds and other wildlife is not in short supply. The difficulty appears to lie in its application in the countryside. Although many farmers and landowners are concerned to manage their hedgerows sympathetically there are problems with costs and the scale at which such work is carried out.

Good management of hedgerows may involve considerable expense in terms of planting, fencing for protection and trimming, laying or coppicing (Doubleday *et al*., 1994; Semple *et al*., 1994). There are also costs arising from land loss, shading of crops, reduced crop yields and the encouragement of weeds and pests such as Rabbits *Oryctolagus cuniculus* and Common Wood Pigeons (Deane, 1989; Doubleday *et al*., 1994; Inglis *et al*., 1994; Semple *et al*., 1994). Work by the Game Conservancy Trust at Loddington in Leicesterhire has shown that costs of effective conservation measures need not be excessive and can have substantial benefits for birds and other wildlife (Boatman *et al*., 1995; Boatman, 1996, 1998). In terms of crop foregone, the estimated cost of a metre wide grass strip against all hedgerows on the farm was £10·20 km^{-1}. For the arable land at Loddington (about 260 ha), the average cost of the conservation measures for the years 1993–1998, in terms of profit forgone, was £5·77 ha^{-1} (Boatman and Stoate, 1999).

As the major land-use in the UK, agriculture affects wildlife populations on a national scale, as shown by the national and long-term declines of farmland bird populations (Fuller *et al*., 1995). To halt and ultimately reverse these trends, changes in agricultural practices and the application of conservation measures also need to be applied at a national scale. Relatively small changes at the level of the individual farm can have substantial local benefits, but application at a national level would need to be policy-driven to ensure compliance and sufficient funding. Such changes are unlikely to occur without reform of the Common Agricultural Policy and a redistribution of funds into agri-environment schemes (Pienkowski and Bignal, 1993; Bartram *et al*., 1996; Pain and Pienkowski, 1997; McCracken and Bignal, 1998; Ovenden *et al*., 1998; Barclay, 1998; Boatman and Stoate, 1999).

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