Hedgerow Management for Breeding Birds

A comparison of the effects of wildlife hedgelaying and other management techniques on hedgerow bird populations during the breeding season at two grassland nature reserves in Oxfordshire

Andrew James Halcro-Johnston

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Oxford Brookes University
School of Life Sciences

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Declaration of Individual Authorship

The author confirms that this research project contains no unacknowledged work or ideas from any publication or work by any other author.

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Abstract

This study investigates the relationship between hedgerow management and passerine bird populations during the breeding season in order to determine which management techniques are most beneficial to breeding hedgerow birds. Four types of hedgerow were sampled at two sites being restored to wet grassland in the catchment of the River Ray in Oxfordshire; Otmoor and Upper Ray Nature Reserves. The primary research aim was to establish whether hedgerows that were left unmanaged, trimmed by mechanical flailing, layed using traditional methods or layed using a new technique called 'wildlife hedgelaying' supported different numbers of breeding birds (measured as total abundance counts) and breeding bird species (measured using species richness estimates). Weekly bird surveys were conducted along 40 m hedgerow line transects during April–June 2008 to cover the main part of the breeding season and bird song was used as an indicator of possible breeding. Hedgerow surveys were conducted in June–July 2008 to measure the main structural and botanical characteristics of the sample hedgerows linked to the type of management used on them. The results revealed significant trends of bird distribution and management type, with unmanaged hedges supporting the highest total bird abundance and richness of breeding species and layed hedges the lowest. These trends were strongest for measures of bird abundance; not all measures of species richness varied with management. Bird abundance and species richness were positively correlated with hedgerow size (height, width and volume) and the number of mature hedgerow trees but not with the number of woody shrub species. Hedgerow size and tree number varied with the type of management; unmanaged hedgerows were the largest and had the most trees on average. Significantly more birds were found in wildlife-layed hedgerows than in traditionally-layed hedgerows when the hedgelaying had been conducted within the previous three years. This suggests that the new method of hedgerow restoration is beneficial to breeding bird populations, at least in the short term, due to the larger hedge structure and greater cover provided. These findings are discussed with reference to the large body of literature on hedgerow bird habitat preferences and this study reinforces the importance of hedgerow management underpinned by scientific evidence in the light of recent widespread declines in farmland bird populations.

Table of Abbreviations

BAP	Biodiversity Action Plan
BBOWT	Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust
BBS	Breeding Bird Survey
BTCV	British Trust for Conservation Volunteers
BTO	British Trust for Ornithology
CBC	Common Birds Census
CEH	Centre for Ecology and Hydrology
CPRE	Campaign to Protect Rural England
DEFRA	Department for Environment, Food and Rural Affairs
ELS	Entry Level Stewardship
FWAG	Farming and Wildlife Advisory Group
HLS	Higher Level Stewardship
JNCC	Joint Nature Conservation Committee
LPA	Local Planning Authority
MOD	Ministry of Defence
NFU	National Farmers' Union
OS	Ordinance Survey
PCA	Principle Component Analysis
RSPB	Royal Society for the Protection of Birds
SMR	Stepwise Multiple Regression
SSSI	Site of Special Scientific Interest
UK	United Kingdom
UTTESA	Upper Thames Tributaries Environmentally Sensitive Area

Chapter 1: Introduction

1.1 Managing hedgerows for wildlife

Hedgerows are an important and valued feature of the British countryside. Their historical and landscape significance has long been recognised, however our understanding of their critical role in supporting farmland wildlife is a relatively recent development (Clements & Tofts, 1992). The New Naturalist volume *Hedges* by Pollard *et al.* (1974) was the first major work to present a detailed account of the value of this habitat to native plants and animals. A large amount of ecological research effort has since been directed at this topic and this expanding body of knowledge has helped to inform national policy on the way hedgerows are managed, for example through Environmental Stewardship programmes funded by the Department for Environment, Food and Rural Affairs (DEFRA) to promote environmentally-sensitive farming practices. Driving this research is a growing awareness of the importance of hedgerows for sustaining biodiversity during a period when rapid agricultural intensification has led to large-scale habitat degradation and put increasing pressure on the resilience of the countryside. The historic under-valuing of hedgerows as a wildlife habitat may be one reason why they did not receive special legal protection, under the Hedgerow Regulations, before 1997 (Anon, 1997).

More than 600 species of plant, 1500 insects, 65 birds and 20 mammals have been associated with hedgerows in the United Kingdom (UK) (Winspear & Davies, 2005). Hedgerows are important to many rare and threatened species including several UK Biodiversity Action Plan (BAP) Priority Species (JNCC, 2007). Some of those that benefit from good hedgerow management include the tree sparrow (*Passer montanus*), linnet (*Carduelis cannabina*), greater horseshoe bat (*Rhinolophus ferrumequinum*), dormouse (*Muscardinus avellanarius*) and several species of butterfly (FWAG, 2004). The hedgerow plant community resembles one of open woodland and hedgerows essentially provide the closest alternative to this type of habitat in a countryside largely stripped of its native forest cover, particularly across the lowlands of Southern and Eastern Britain. Hedgerows have a valuable ecological function because they provide a wide range of essential resources to a variety of species. For example, hedgerows provide breeding birds with song posts, nest sites, cover from predators and invertebrates to feed nestlings, while in winter they act as roost sites and produce a berry crop that can sustain many foraging birds (Winspear & Davies, 2005).

Hedgerows are transitional semi-natural features that loose their barrier function and wildlife value if left unmanaged for long periods of time. Hedgerow shrubs tend to become leggy at the base as herbaceous ground flora are shaded out and eventually the compact shrub layer will turn into a line of individual bushes or trees with large gaps. Such relict hedges are unable to provide the cover and food sources that nesting birds and other fauna require (Barr et *al*., 2005). Although most are now protected from deliberate removal, hedgerows continue to be threatened with deterioration due to neglect and is it estimated that only 25% of the UK's hedgerow stock is currently in favourable condition for wildlife (Natural England, 2008). Over-management from intensive annual trimming also remains a problem, depriving birds of perches, berries and cover (Winspear & Davies, 2005).

Various studies have shown that breeding birds in general prefer taller, broader hedges with a wide herbaceous or grassy buffer (Hinsley & Bellamy, 2000) but with steeply rising grain prices, the spread of biofuels and other economic incentives to put land back into production, the pressure to plough up field margins and trim hedges back to reduce crop shading looks set to intensify. There remains a pressing need for research that explicitly links hedgerow management and wildlife value; indeed the first scientific review of this subject was published as recently as 1995 and it has been identified as a priority research area by DEFRA (Barr *et al*., 2005). Most studies have focussed on relationships between the structural and botanical features of hedgerows and the organisms which they support, rather than on hedgerow management *per se*. Effective habitat management must be underpinned by high quality scientific research that provides a solid evidence base; too often management decisions for conservation are based on conjecture rather than scientifically proven fact (Sutherland *et al*., 2004). This project aims to provide data that will help fill that gap.

1.2 Project aims and objectives

This project sets out to answer two main questions: do hedgerows managed in different ways support different numbers of breeding passerine (perching) birds, and if so, what factors explain this? Passerines are a useful group to study because many species are known to breed in hedgerows and a large body of data already exists on the preferences of individual species for particular types of hedge (e.g. Lack, 1992). Furthermore, many passerines in Britain are songbirds, which helps with their identification and provides clear evidence of breeding behaviour (BTO, 2008) (Figure 1.1, next page). As a major breeding resource, hedgerows are possibly the most important single feature for birds on farmland (Lack, 1992).

This project originated as a research idea proposed by the Royal Society for the Protection of Birds (RSPB) at Otmoor Nature Reserve in Oxfordshire. The Reserve Warden and his team use a variety of techniques to manage the hedgerows there. These include leaving some hedges unmanaged and overgrown, flail-cutting some on three year rotation and restoring others by hedgelaying (Wilding, 2007, pers. comm.). While hedgerows in the surrounding farmland have been layed by hand using

Figure 1.1 A robin (*Erithacus rubecula*) sings from the upper branches of a hedgerow.
Source: http://www.moorhen.demon.co.uk

traditional methods (e.g. in the Midland style) a new mechanical hedgelaying technique is being trialled on the Reserve. This is known as wildlife hedgelaying, and it involves laying a hedge over without cutting out the woody growth, a necessary part of the manual method. The objective is to leave a larger volume of woody material in the layed hedge, providing better potential nesting cover and foraging resources for birds and other wildlife (Dodds, 2005). This may help to counteract any short-term loss of habitat while the woody shrubs grow back into a dense, rejuvenated hedgerow.

Wildlife hedgelaying is a perfect example of how hedgerow management, structure and composition and value to birdlife are intimately connected (Hinsley & Bellamy, 2000) yet the proposed benefits of the technique remain scientifically untested. This provides an exciting opportunity for a comparative study that can help deliver an evidenced-based approach to hedgerow management for wildlife. The RSPB is a major landowner of sites for nature conservation and so any outcomes generated by this study have the potential to be applied on a much wider scale.

The specific aims of the study are as follows:

1. To determine the distribution of breeding birds across four different hedgerow management treatments (unmanaged, flailed, traditionally-layed, wildlife-layed) using total abundance and species richness as the main measures of bird incidence.

2. To determine whether wildlife-layed hedges and traditionally-layed hedges support the same numbers and richness of breeding birds.

3. To identify the major hedgerow structural and botanical characteristics that explain any observed differences in bird distribution (e.g. hedgerow size and number of trees).

The null hypotheses are:

1. Birds are evenly distributed between the hedgerow management treatments.

2. Bird incidence is not related to structural or botanical characteristics of the hedgerows.

The alternative hypotheses are that bird distribution does vary with management treatment (e.g. wildlife-layed and traditionally-layed hedges are found to support significantly different numbers of birds in total) and that significant relationships exist between hedgerow attributes and the abundance and richness of birds in the hedgerows sampled.

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The following chapter elaborates further on the ideas introduced above and gives a detailed background and context to the research. Chapter 3 outlines the methodology used in the study and the data analysis and results are presented in Chapter 4. These results are discussed in Chapter 5, which summarises the main outcomes of the study and concludes with some management recommendations and suggestions for further work. Summary raw data can be found in the Appendices and a full list of References is presented on the final pages.

Chapter 2: The Importance of Hedgerows

This chapter begins by defining a hedgerow for the purpose of this study and goes on to look at the historic loss of hedgerows from the British countryside and their current status and legal protection. The decline of lowland farmland birds is considered and the importance of hedgerows to bird populations is discussed in this context. The chapter closes with a summary of the management methods available to maintain and restore hedgerows and their effects on birdlife.

2.1 Defining a hedgerow

There are many ways of defining the term ‘hedgerow’ but at its simplest a hedgerow comprises a field boundary that contains a line of shrubs and/or trees. There are several regional variations on this theme: in Cornwall, for example, hedgerows are known as hedge banks, which comprise a stone-faced earthen bank with a shrubby hedge on top (Pollard *et al*., 1974). Lines of trees planted as windbreaks in the flat agricultural landscapes of East Anglia also come under the definition. The major woody plant component varies regionally, from the beech (*Fagus sylvatica*) hedges of Exmoor to the Scots pine (*Pinus sylvestris*) hedges of the East Anglian Brecklands. Many factors underlie these variations, including climate, geology, the age of the hedge and cultural management practices (Lack, 1992).

The hedgerows considered in this study are typical of the lowland farmland of Southern Britain, comprising mainly hawthorn (*Crataegus monogyna*) and blackthorn (*Prunus spinosa*) and associated features including trees (mainly oak, *Quercus* spp.), post and wire fencing and wet or dry ditches. It is worth noting that the terms ‘hedge’ and ‘hedgerow’ are often used interchangeably, and no attempt has been made here to distinguish between them, following the convention of Pollard *et al*. (1974). Both terms are used to describe the whole complex of shrubs, trees and herbaceous plants of the hedge bottom.

For the purposes of standardising the type of hedges selected when designing a hedgerow bird survey methodology, the following summary definition from DEFRA’s *Hedgerow Survey Handbook* is used (DEFRA, 2007, p.10):

‘Any boundary line of trees or shrubs over 20 m long and less than 5 m wide between major woody stems at the base.’

Although the figures used are slightly arbitrary, the definition is useful in distinguishing a hedgerow from a scrub belt or remnant woodland of greater than 5 m width, and in establishing a minimum continuous length for an individual hedge, including small gaps. The end point, or node, of an individual hedgerow is defined where there is a gap of more than 20 m length or where one hedgerow joins to another at an intersection or to another landscape feature, e.g. a pond. A field boundary that changes direction or turns a sharp corner is classified as one hedgerow.

2.2 The state of Britain's hedgerows

Hedgerow loss

Hedgerows are still a common sight in lowland landscapes. However along with many other natural and semi-natural habitats in Britain they have suffered greatly from agricultural and developmental pressures on the countryside, which increased substantially with post-war economic expansion in the latter half of the twentieth century. In the nine years between 1984 and 1993 there was a net loss of 158 000 km of hedgerows in England, which is equivalent to about one third of the total that existed in 1984 (Anon, 1999 cited in McCollin, 2000). This alarming rate of loss, combined with a growing understanding of their ecological, historical and landscape amenity value, has led to action to protect and enhance the quality of the UK's remaining hedgerow stock. In 2008 a new cross-sector partnership called Hedgelink has been established, which brings together key stakeholders including Natural England, the National Farmers' Union (NFU), the Farming and Wildlife Advisory Group (FWAG), Campaign to Protect Rural England (CPRE) and the RSPB. The partnership's aim is to share information and provide management advice to support farmers and organisations interested in the preservation of the UK's hedgerow heritage (Anon, 2008).

Farmers and landowners have traditionally been viewed as the custodians of the countryside and historically the management of land was left to them with little outside intervention (Lack, 1992). Growing awareness of the need to balance food production with environmental and social concerns has led to an increasing provision of advice and funding to promote best practice in land stewardship. Hedgelink appears to be the latest response to the need to include farmers and landowners in the decision-making process and to work with them to look after their hedgerows for the benefit of the environment and wider society. The vast majority of hedgerows are on farmland, which comprises about 75% of the land area of Britain. It is estimated that as much as 50% of the UK's entire hedgerow stock has been lost due to increases in farm mechanisation, the origins of which lie in the 1947 Agriculture Act and the promotion of self-sufficiency in British food production (Robinson & Sutherland, 2002). These losses have been greatest in the open, planned countryside of the Midlands and Southern England (Pollard *et al*., 1974).

Agricultural intensification backed by substantial government incentives has required larger fields to maximise yields at lower costs. Economic factors have driven the decline of mixed farming, increased specialisation of arable crops and a widespread adoption of modern wire fencing. This has dramatically reduced the agricultural need for hedgerows, whose primary function was to provide a stock proof barrier between fields of pasture (Joyce *et al*., 1988; McCollin, 2000). Considered a hindrance to modern farming, up until the 1980s many hedgerows were still being grubbed out with the backing of government grants. The situation has markedly improved since then; Countryside Survey 2000 data reveal that there was no net loss of hedgerows in the UK between 1990 and 1998 as rates of loss and new planting balanced out (Haines-Young *et al*., 2000 cited in Barr *et al*., 2005). However the main driver of hedgerow deterioration today is lack of appropriate management and simple neglect, resulting in hedgerows that are so thin and gappy that they no longer function as an effective barrier or provide adequate shelter for stock. Hedgerows may also be damaged by over-management through intensive trimming, or through over-grazing, spray drift from herbicides and root damage resulting from cultivation right up to the hedge base (Winspear & Davies, 2005). The net result is a continuing decline in the wildlife value of the hedgerows that remain today.

The intensification of farming and the accompanying loss of hedgerows have contributed to a widespread reduction in habitat heterogeneity at the landscape scale (Robinson & Sutherland, 2002; Benton *et al*., 2003). This has put further pressure on the ability of the countryside to support viable long-term populations of native plants and animals, including many rare and endangered species. For example the cirl bunting (*Emberiza cirlus*) is on the Red list of birds of high conservation concern, having experienced a rapid and severe population decline since the 1970s mainly due to changes in grassland management (RSPB, 2007, 2008a). At the northern limit of its European range, this bird relies on hedgerows and shrubs for breeding at a few sites on the South Devon coast (Lack, 1992). Targeted scientific research, appropriate management and adequate legal protection are all essential requirements if we are to maintain and improve the quality of the UK's hedgerow stock for endangered species such as the cirl bunting.

Legal protection

The importance of hedgerows was only statutorily recognised in 1997, after previous attempts to introduce legal protection through Parliamentary private members' bills in 1982 and 1992 failed (Joyce *et al*., 1988; Clements & Tofts, 1992). Despite their continuing loss from the countryside, the Government had previously favoured a voluntary approach towards hedgerow conservation. The Environment Act 1995 provides the legal framework for protection of 'important' hedgerows in

England and Wales under the Hedgerow Regulations 1997 (DEFRA, 2007). To be 'important', a hedgerow must be over 30 years old and satisfy at least one of a set of criteria relating to its archaeological, historical, landscape or wildlife value (Anon, 1997). It is unlawful to remove such hedgerows without the prior approval of the Local Planning Authority (LPA), who will assess the importance of the hedgerow and may order it to be retained. While the Regulations do cover most hedgerows in the British countryside, they fall short of providing full protection and leave the way open for the destruction of hedgerows that have yet to be surveyed for the LPA or do not meet the criteria. This loophole may lead to the potentially valuable, species-rich hedgerows of the future being removed with little foresight today. The Government is in the process of reviewing the Regulations (DEFRA, 1997).

Fortunately other policy mechanisms exist to help protect hedgerows either directly or indirectly. For example LPA consent is required to cut hedgerow trees subject to a Tree Preservation Order under the Town and Country Planning Act 1990 (Anon, 1990). Hedgerows may also be protected because they are on a designated site for nature conservation, provide habitat for a legally protected species or form part of a Scheduled Ancient Monument (DEFRA, 2007).

Economic incentives

Funding is available to farmers and landowners to protect and manage hedgerows. Under Environmental Stewardship, an agri-environment scheme designed to deliver effective environmental land management, hedge maintenance through appropriate rotational trimming is funded through Entry Level Stewardship (ELS). Higher Level Stewardship (HLS) includes additional payments for maintaining and restoring hedgerows of high environmental value that support birds, insects and mammals of conservation concern. All farmers receiving subsidy under the Single Farm Payment scheme are required to keep their hedgerows in good condition and avoid trimming them between March and July to prevent disturbance to nesting birds (DEFRA, 2008).

Given the tight margins under which most farmers operate today, and a growing desire to take environmental considerations into their land management decisions, these economic instruments may prove more effective at preserving the UK's hedgerows in the long term than the inadequate protection offered through the legislation.

2.3 Hedgerows and farmland birds

Habitat resources for birds

Hedgerows are considered to be an important habitat for birds of lowland farmland because they provide a variety of essential resources that may be lacking in the wider landscape (Lack, 1992; Winspear & Davies, 2005). Hedgerows provide a valuable food source over the course of the year. The woody shrubs and plants of the herbaceous margin support many insects and other invertebrates during the spring and summer months and provide a wealth of seeds and berries over the autumn and winter. This food diversity helps to meet the dietary needs of a wide range of bird species. Resident species, for example the robin (*Erithacus rubecula*) whose diet includes seeds, fruits and insects, are catered for throughout the year. Winter visitors such as the fieldfare (*Turdus pilaris*) and summer migrants including the chiffchaff (*Phylloscopus collybita*) can exploit the fruit and insect resources available during those times of year. Mature and dead trees in hedgerows provide a further source of seeds, nuts and insects. As well as a direct food supply, thick hedgerows can provide birds with cover from weather and predators, which enables them to forage more efficiently with less risk.

In the winter, many resident species and visiting thrushes such as redwing (*Turdus iliacus*) will use hedgerow shrubs and trees as roost sites. It is during the breeding season, however, that the true value of hedgerows to farmland birds becomes clear. Hedgerows can probably support a higher abundance of breeding birds than any other semi-natural habitat in lowland farmland (Lack, 1992). Thus farmland breeding bird populations may be influenced by the availability and quality of hedgerows more than any other feature. This is particularly true in the open landscape of the southern and eastern counties of the UK, which are characterised by a fairly homogenous countryside with large fields and few other semi-natural features such as woodland (Clements & Tofts, 1992). In open landscapes hedgerows may provide the only suitable nesting habitat for woodland birds such as the robin. Hedgerow shrubs are used by many nesting species and the cover of the hedge base flora is important to breeding game birds such as partridges (Rands, 1986). Mature hedgerow trees can provide breeding habitat for hole-nesting birds such as the great spotted woodpecker (*Dendrocopos major*) and the endangered lesser spotted woodpecker (*Dendrocopos minor*) (Winspear & Davies, 2005). As well as nest sites, hedgerow plants provide perches and song posts from which male songbirds (oscines) can sing to attract mates and defend their territories.

The importance of hedgerows to breeding birds is highly significant in light of the well-documented declines of lowland farmland birds since the 1970s (Fuller *et al.*, 1995). Sharp contractions in the range and abundance of many species have been linked to changing agricultural practices including a loss of winter stubbles, increased use of agro-chemicals, more intensive grassland management and the removal of hedgerows. While British breeding birds as a whole have shown a slight population increase since 1970, farmland bird populations fell by 42% between 1970 and 2002 (Figure 2.1); woodland bird populations fell by 15% over the same period (Anon, 2004). Recent conservation measures such as agri-environment schemes may be starting to reverse this long-term trend; between 1998 and 2002 farmland bird populations increased by 5%.

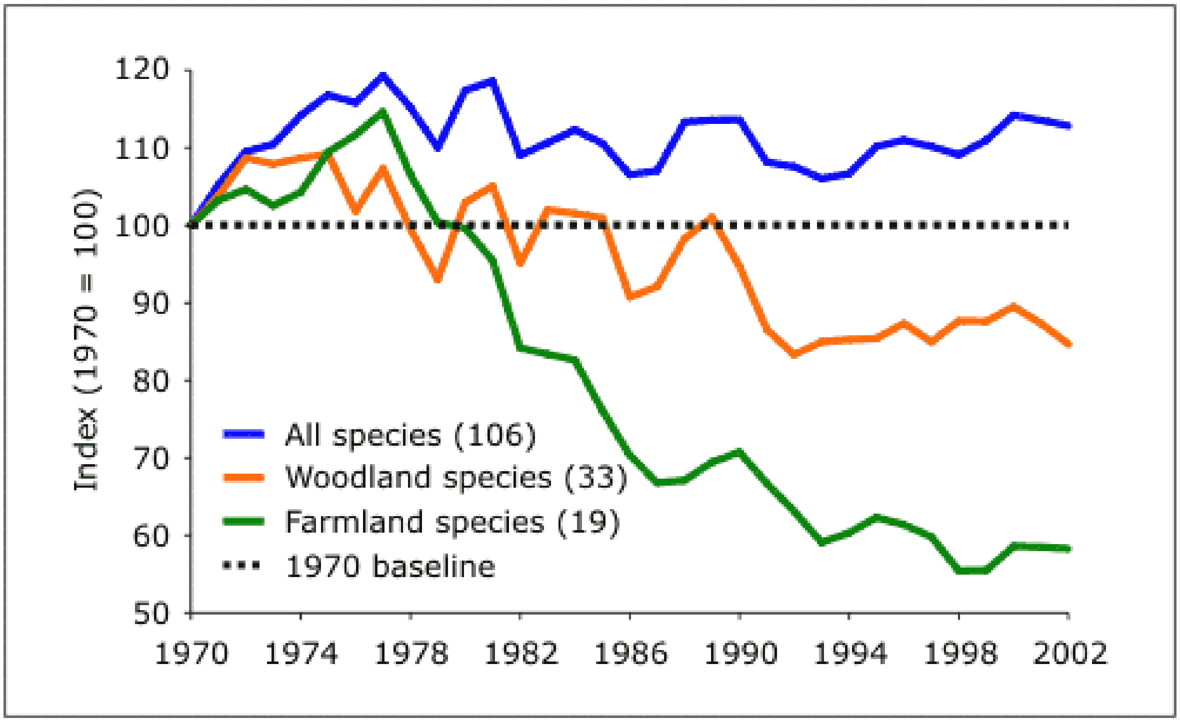


Figure 2.1 Changes in British wild bird populations between 1970 and 2002.

Source: Based on DEFRA, BTO & RSPB data from http://www.sustainable-development.gov.uk

Many farmland birds use hedgerows to some degree. Of 55 common species found on farmland (based on Common Birds Census [CBC] data, which measures numbers of territories held), Lack (1992) lists 27 species that routinely use hedgerows for nesting and feeding during the breeding season. These are mostly birds of woodland and woodland edge habitats that utilise field boundaries for breeding. These hedgerow birds are listed in Table 2.1 (next page) along with a summary of their population trends since the late 1960s and a recent estimate of population size based on British Trust for Ornithology (BTO) combined CBC and Breeding Bird Survey (BBS) data. The birds are grouped by their UK conservation status. The four species on the Amber list of medium conservation concern have typically suffered declines of over 25% in the last 25 years; those that have typically suffered more than 50% declines are on the Red list of high concern (RSPB, 2007). The yellowhammer (*Emberiza citronella*) is a new addition to the Red list, the other five species having been there since 1996 (Baillie *et al.*, 2007). It is clear that hedgerows support several species of conservation interest, including some formerly common and widespread birds like the tree sparrow (*Passer montanus*) that have undergone severe declines with agricultural intensification.

Table 2.1 Population trends of 27 common hedgerow birds based on CBC/BBS UK data.

		UK % population change 1967–2005	UK population size in 2000 (territories)
Introduced			
Little owl	*Athene noctua*	-41	5800–11,600[c]
Red-legged partridge	*Alectoris rufa*	-16	72,000–200,000
Green status			
Blackbird	*Turdus merula*	-17	4,935,000
Blackcap	*Sylvia atricapilla*	144	932,000
Blue tit	*Parus caeruleus*	44	3,535,000
Carrion crow	*Corvus corone*	116[b]	987,500[c]
Chaffinch	*Fringilla coelebs*	30	5,974,000
Goldfinch	*Carduelis carduelis*	16[a]	313,000
Great tit	*Parus major*	100	2,074,000
Greenfinch	*Carduelis chloris*	30	734,000
Lesser whitethroat	*Sylvia curruca*	-15	64,000
Long-tailed tit	*Aegithalos caudatus*	73[a]	273,000
Magpie	*Pica pica*	102	650,000
Robin	*Erithacus rubecula*	38	5,895,000
Whitethroat	*Sylvia communis*	-62	945,000
Woodpigeon	*Columba palumbus*	143	2,570,000–3,160,000
Wren	*Troglodytes troglodytes*	95	8,512,000
Amber status			
Dunnock	*Prunella modularis*	-34	2,163,000
Kestrel	*Falco tinnunculus*	10	36,800[c]
Mistle thrush	*Turdus viscivorus*	-41	222,500
Willow warbler	*Phylloscopus trochilus*	-60[a]	2,125,000
Red status			
Corn bunting	*Miliaria calandra*	-86	8,500–12,200
Grey partridge	*Perdix perdix*	-87	70,000–75,000[c]
Linnet	*Carduelis cannabina*	-71[a]	556,000
Song thrush	*Turdus philomelos*	-50	1,144,000
Tree sparrow	*Passer montanus*	-97[a]	68,000
Yellowhammer	*Emberiza citrinella*	-55	792,000

Notes
[a]Based on CBC/BBS data for England only [b]Includes hooded crow (*Corvus cornix*) [c]Unit is breeding pairs

Source: Lack, 1992 and Baillie *et al.*, 2007

Lack (1992) lists a further 16 common birds that use hedgerows as a secondary breeding habitat if their populations are high, including the Red-listed turtle dove (*Streptopelia turtur*), spotted flycatcher (*Muscicapa striata*) and bullfinch (*Pyrrhula pyrrhula*). Thus hedgerows are vitally important to the long-term conservation of farmland birds and their management and upkeep needs to be targeted accordingly. For example, in recognition of their value to wildlife, hedgerows are the subject of a UK BAP which aims to protect their biodiversity value and achieve ‘favourable condition’ status for 50% of the hedgerow network by 2015 (DEFRA, 2007). Enhancing the value of hedgerows for wildlife and providing suitable breeding habitat for farmland birds should go hand in hand.

The value of individual hedgerows to breeding birds depends on a number of factors. These include the size, structure and botanical composition of the hedge, the density of hedgerows in the landscape, their location in relation to other features such as woodland and the habitat preferences of individual birds (Lack, 1992; Hinsley & Bellamy, 2000). Birds that use hedgerows are typically those associated with woodland, woodland edge and scrub habitats and the degree to which they can exploit hedges in the breeding season depends on the population densities of different species and the quality of resources this habitat provides in relation to the wider countryside. It is important to understand what makes a hedgerow valuable for birds in order to manage it effectively for conservation. It is clear that no single hedgerow type or structure can meet the needs of all the birds that might be encountered on farmland and that diversity in structure and management is important in order to support the greatest range of species (Barr *et al*., 2005). However some general conclusions can be drawn from the wealth of studies that have investigated relationships between bird distributions and particular hedgerow attributes.

Hedgerow size and structure, woody species composition and hedgerow trees are the attributes that are probably most directly affected by hedge management and therefore of relevance to this study. These are discussed below.

Hedgerow structure

Several studies have demonstrated the relationship between hedgerow size (height and width) and bird numbers on lowland farms; in general species richness and total abundance are greater in taller, wider hedgerows (Arnold, 1983; Osborne, 1984; Green *et al.*, 1994; Parish *et al.*, 1994, 1995; Macdonald & Johnson, 1995; Sparks *et al*., 1996; Hinsley *et al.*, 1999 cited in Hinsley & Bellamy, 2000). Woodland birds such as blue tit (*Parus caeruleus*), blackbird (*Turdus merula*) and chaffinch (*Fringilla coelebs*) require greater vertical structure in their breeding habitat and tend to prefer height and width in hedgerows (Lack, 1992; Sparks *et al*., 1996). Large hedges better mimic a woodland habitat than short ones and generally provide greater cover for nesting, more woody shrubs and food abundance. This is not a universal trend, however. Species associated with woodland edges and scrub, e.g. linnet and dunnock (*Prunella modularis*) tend to prefer shorter hedges (under 2 m tall) with wide bases to provide good nesting cover at the hedge bottom. Open field species, e.g. grey partridge (*Perdix perdix*) and other game birds will tolerate short, gappy hedges but not tall ones with trees which may increase their risk of predation (Rands, 1986; Hinsley & Bellamy, 2000). Nest site selection is probably the dominant factor determining these distributions (e.g. Sparks *et al.*, 1996). It is interesting to note that the species generally associated with short hedges – dunnock, linnet, yellowhammer, whitethroat (*Sylvia communis*), grey partridge and corn bunting (*Miliaria calandra*) – are nearly all birds of conservation concern (Table 2.1) and where hedgerow management objectives are targeted at such species then tall hedges may not be the most appropriate outcome.

Hedgerow height and width are highly correlated and it can be difficult to separate their effects on bird distributions (Macdonald & Johnson, 1995). It appears that, irrespective of height, a wide and thick hedge base is important for many nesting species. Hedges that have become thin and leggy at the base are more likely to be accessible to foxes (*Vulpes vulpes*) and other ground predators (Winspear & Davies, 2005) and wider hedges may provide better cover for species like whitethroat that prefer to nest in the herbaceous flora of the hedge base (e.g. Stoate & Szczur, 2001). Very short (less than 2 m) and thin hedges offer little cover and foraging opportunities and are of limited value to breeding birds. In contrast, tall hedges have been linked to better breeding success; Fuller (1984) cited in Barr *et al*. (2005) reported twice as many songbird territories in tall hedges compared to short ones. However the advantage of height may diminish above a certain level so that very tall hedges actually deter breeding birds; another study found that both nest density and species richness were greatest within hedges of medium height (2–3 m), possibly because nesting near the top of the canopy increases the risks of attack from birds of prey and exposure to the weather (Macdonald & Johnson, 1995).

Closely correlated to hedgerow size is canopy volume, a function of the height and width of the shrub layer and the length of the hedgerow without gaps. Large gaps, particularly at the base, may deter breeding birds because there is less woody growth in which to nest and the shrub layer is more accessible to predators (Lack, 1992). A larger volume of woody material should be able to hold a greater richness of birds. This simple linear relationship has been demonstrated by Parish *et al.* (1994) on a study of farmland birds in Cambridgeshire. Hedge volume was the most important variable explaining variations in bird distribution at one of the two sites studied. Using the length of woody vegetation in a 50 m transect as a measure of volume, Green *et al*. (1994) found a significant relationship with the incidence of five of the eighteen species recorded: dunnock, robin, blackbird, chaffinch and blackcap (*Sylvia atricapilla*).

Other structural attributes such as hedgerow length and shape in cross section are not considered to be particularly important in terms of breeding bird value (Lack, 1992). The A-shape hedge has often been favoured aesthetically and may promote a thicker shrub base but there is little evidence of its quality as a bird habitat (Barr *et al.,* 2005). Hedgerows that are heavily stock-grazed may loose their basal vegetation and develop a tree-shaped profile accessible to ground predators, but again there is little evidence to support a significant effect on breeding birds (Lack, 1992).

Hedgerow trees

Along with hedgerow size, the presence and/or number of hedgerow trees is one of the most frequently recorded positive influences on bird species richness and abundance (Arnold, 1983; Green *et al*., 1994; Macdonald & Johnson, 1995; Sparks *et al*., 1996; Hinsley & Bellamy, 2000). Tree height (Parish *et al.*, 1994, 1995) and species diversity (Osborne, 1984) can also be important factors. This is of relevance to hedgerow management because the growth of tree saplings will be determined by the frequency of the hedge trimming regime and any additional tree planting. Mature trees may be left unmanaged or they may be felled if believed to harbour avian predators of ground-nesting birds such as lapwing (*Vanellus vanellus*) in adjacent fields (Winspear & Davies, 2005).

Green *et al.* (1994) found significant relationships between the number of trees and birds in sections of hedgerow for 11 of the 18 species recorded. As expected, woodland birds showed positive correlations with the number of trees and birds of scrub tended to be lacking in sections with trees. The density of mature trees was a significant predictor of bird abundance and nest density in Macdonald & Johnson's (1995) study. Mature trees are thought to provide some hedgerow species with increased shelter, foraging opportunities and nest sites. They also provide song posts and this may be the most important attraction to oscines during the breeding season. Trees with a shrub layer below appear to be more beneficial than a line of trees on its own and breeding birds including chaffinch, song thrush (*Turdus philomelos*) and wren (*Troglodytes troglodytes*) have been found nesting significantly more often in hedge sections within 25 m of a tree (Lack, 1992). Cutting trees down is likely to significantly reduce the numbers of birds in a hedgerow.

Tree height and number explained a large percentage of the variation in bird distributions observed at both sites studied by Parish *et al.* (1994, 1995). Larger trees provide a larger volume of woody growth and so probably create greater habitat diversity for breeding birds, although smaller trees and shrubs are just as useful as song posts (Lack, 1992). The diversity of tree species (measured as number of trees x number of species) can also positively bird numbers (Osborne, 1984). Native deciduous trees such as oak and willow (*Salix* spp.) hold the highest numbers of insects; the native oaks *Quercus robur* and *Quercus petraea* hold over 400 species (Kennedy & Southwood, 1984). The bark of old and dead trees is a valuable source of invertebrates and provides nest sites for cavity-nesting birds such as blue tits, as does the ivy (*Hedera helix*) growing on such trees (Osborne, 1984; Lack, 1992). Hedgerow trees are clearly a useful resource to many breeding birds.

Botanical composition

Several studies have shown bird abundance and species richness to increase linearly with the number of woody shrub species in a hedgerow (Arnold, 1983; Osborne, 1984; Green *et al.*, 1994; Parish *et al.*, 1994, 1995; Macdonald & Johnson, 1995; Hinsley *et al.*, 1999 cited in Hinsley & Bellamy, 2000). A richer shrub layer should hold more host plant-specific invertebrates and produce a wider variety of berries, as well as providing greater structural diversity for nesting birds. These factors may also be a function of hedgerow age because older hedges have longer to develop a rich woody flora (Lack, 1992; Macdonald & Johnson, 1995). The underlying bird–plant relationships might be complex and Green *et al.* (1994) suggests that birds may prefer hedges with particular shrubs over woody species-rich hedgerows *per se* so that hedges with many shrubs will tend to have more birds per unit length.

Green's study reported that the dominant woody species in a hedgerow was a significant predictor for two birds, whitethroat and lesser whitethroat (*Sylvia curruca*), and that elder (*Sambucus nigra*) was the least preferred hedgerow plant for these species. Elm (*Ulmus* spp.) hedges are generally considered to hold few breeding birds compared to hawthorn hedges, which may be due to the density of foliage provided by the latter (Clements & Tofts, 1992; Lack, 1992). The large berry crops produced by hawthorn and ivy are also important to wintering hedgerow birds.

2.4 Hedgerow management

Why manage hedgerows?

A hedgerow is a transitional semi-natural habitat that, left unmanaged, will naturally grow into a line of trees. As this happens the hedge becomes gappy and straggly, losing the dense shrub base that provides cover, nesting and foraging resources for birds and other wildlife. The value of the hedge both as a habitat and stock barrier deteriorates as the hedgerow develops larger gaps and eventually turns into a relict of isolated shrubs and trees (Barr *et al.*, 2005). Therefore ongoing maintenance by mechanical trimming is an essential part of hedgerow management, as is the restoration of relict hedgerows by laying and coppicing. An extensive literature on the management of hedgerows for wildlife (and birds in particular) has been produced by the scientific community (e.g. Hinsley & Bellamy, 2000), DEFRA (Barr *et al.*, 2005) and conservation organisations including British Trust for Conservation Volunteers (BTCV) (Brooks & Agate, 1998), the RSPB (Winspear & Davies, 2005) and the Game Conservancy Trust (Sotherton & Page, 1998).

Lack (1992) makes the point that it is generally more efficient and cost effective to manage existing habitat features on farmland for the benefit of birds than to create new ones, because existing features usually have the characteristics, such as foraging resources, that make them valuable to birds. For example, an ancient hedgerow that has become neglected and in need of restoration is likely to contain a higher number of woody plant species and insects than a newly-planted, species poor hedgerow. As any hedgerow management will change its size and shape (and possibly its woody species composition) in the years immediately following the work, it is important to assess the effect this is likely to have on bird species that are known to prefer certain hedge structures. A further consideration is striking the right balance of management to maximise the wildlife benefit: an unmanaged tall, wide hedgerow with plenty of deadwood can provide a valuable nesting and foraging habitat for birds and should be left unmanaged unless there is a risk of it deteriorating into a relict hedge (Winspear & Davies, 2005). Getting this balance right at the farm scale can be difficult, but in general it is better to under-manage hedgerows than to intensively trim them every year to produce small, boxy hedges that look neat but are of little value to breeding birds (Hinsley & Bellamy, 2000). Most farmland birds are not restricted to individual hedgerows but use them as part of the wider landscape, so hedge maintenance should form part of a larger management regime at the farm scale (Bignal & McCracken, 1996).

The management method used, its timing and frequency can all affect the value of hedgerows to bird populations (Lack, 1992). In each case clear management objectives are needed because no single type of hedgerow size and composition will be beneficial to all the birds present (Hinsley & Bellamy, 2000). If the aim is to increase overall bird species richness and abundance then providing a heterogeneous mix of hedgerow types should be the main consideration. Alternatively, if management is targeted at a particular species, a detailed knowledge of that species' requirements is necessary. For example, yellowhammers and whitethroats have shown better breeding success on fields bounded by short hedges and a perennial herbaceous margin, which provides the ground nesting cover these species require (Stoate & Szczur, 2001). Information on species-specific management is lacking in most management guides, as they tend to focus on managing hedgerow growth rather than relationships with birds (Hinsley & Bellamy, 2000). However some general recommendations for managing hedgerows for birds have emerged in the literature, based on the results of studies investigating bird–habitat preferences (Hooper, 1992 cited in Barr *et al.*, 2005;

Lack, 1992; Parish *et al.*, 1994; Hinsley & Bellamy, 2000). These are targeted at birds in general rather than individual species and can be summarised as:

1. Aim to produce as large a volume of woody growth as possible within agricultural constraints, to provide the maximum habitat for birds. Hedgerows should be at least 2 m wide for birds that nest in the hedge base and tall hedges will suit most woodland species.
2. Combine hedgerows with other landscape features such as ditches, ponds and grassy field margins at least 2 m wide and manage these sympathetically to provide the best cover, herbaceous plant diversity and seed, berry and invertebrate food sources for birds.
3. Trim hedgerows in rotation every two or three years and allow the growth of some tree saplings and woody shrubs to stimulate berry production and invertebrate abundance.
4. A heterogeneous mix of hedge types (in terms of size, plant composition and timing of management) will meet the needs of bird species with different resource requirements.

The hedgerow management methods most relevant to this study are discussed below.

Trimming

Hedge trimming using a tractor-mounted flail cutter (also known as flailing) is the most common form of hedgerow maintenance on farmland (Lack, 1992) (Figure 2.2, next page). Regular trimming along the top and sides of a hedgerow helps to stimulate new woody growth, keeping the structure dense and preventing the development of straggly growth and gaps. The RSPB recommend allowing the hedge to grow a few centimetres in height and width between cuts so that thicker cover develops as side branches grow out from behind the cut stems (Winspear & Davies, 2005). Over-trimming hedges into neat, boxy shapes is discouraged from a conservation perspective because birds generally prefer outgrowths for perching and a good volume of habitat. Over time this intensive management can reduce the vigour of the shrubs and lead to premature death, accelerating the deterioration of the hedge (Brooks & Agate, 1998). In contrast, normal regular trimming is unlikely to be very detrimental to either breeding birds or the woody shrubs (Lack, 1992).

The timing of the cut is crucial. Trimming during the peak nesting season (March to July) is strongly discouraged to avoid disturbance to breeding birds. Post-harvest autumn trimming, while the land is still dry enough to drive over, is common amongst arable farmers. The problem with this is that the autumn berry crop, an important food source for wintering birds, is removed because woody plants like hawthorn, blackthorn and dog rose (*Rosa canina* agg.) produce the most berries on the outermost twigs, including outgrowths from the hedge. Therefore trimming is best

Figure 2.2 Flail cutting a hedgerow in winter.
Source: BH Tree Services

undertaken in January or February after the berries have been eaten but before the main breeding season begins (Croxton & Sparks, 2004; Winspear & Davies, 2005).

Another critical factor for birds is the frequency of the cut. On many shrubs berries are produced on the second year's growth, so annual trimming will remove much of the potential berry crop (Marshall *et al.*, 2001a). The RSPB recommend annual trimming only where necessary to control fast-growing plants like ash (*Fraxinus excelsior*) or on road-side hedges; otherwise a two or ideally three year cutting rotation is best for birds (Winspear & Davies, 2005). Cutting a few hedges on rotation each year to produce a variety of hedge sizes also provides better opportunities to increase bird populations than if all the hedges on a farm are cut at the same time in a uniform manner (Lack, 1992; Hinsley & Bellamy, 2000).

A further consideration is the height and provision of trees in a hedgerow. It may be advantageous to avoid trimming saplings and allow the hedgerow to grow tall in areas near to woodland, to provide edge habitat for woodland bird species (Hinsley & Bellamy, 2000). However, in open landscapes a more severe trimming regime to maintain shorter hedges with occasional trees may be more appropriate; open field birds such as lapwing and corn bunting tend to avoid nesting near to tall field boundaries due to the increased risk of predation from corvids and birds of prey (Winspear & Davies, 2005). Dead trees should be left in hedgerows to provide a valuable invertebrate food source and nest holes for specialists like the great spotted woodpecker (Lack, 1992).

Copping and hedgelaying

A hedgerow that has become too gappy or leggy at the base will most likely require restoration if it is not to deteriorate further and cease to provide good cover for nesting birds. This can be done by coppicing or laying the hedge. In contrast to mechanical trimming, these methods tend to be labour intensive and slow because the work is done by hand.

Coppicing involves cutting woody stems at ground level and allowing them to regrow, which should eventually produce a denser, rejuvenated hedge structure. Gaps in the hedge can be planted up with new shrubs. Coppicing is typically carried out on a 10–20 year rotation and is best suited to very gappy hedges or where the stems are too thick to be laid (Winspear & Davies, 2005).

Hedgelaying was traditionally practised to restore the hedge to a stock proof barrier and remains a popular restoration technique today. A recent report on attitudes to hedgerow management found that more than half of the farmers surveyed had laid hedges in the previous five years, compared to a fifth who had undertaken coppicing (Britt *et al*., 2000 cited in Barr *et al*., 2005). Hedgelaying involves cutting partway through the base of the woody stems and laying them over at an angle of about 35 degrees (Blissett, 2007). The layed stems (pleachers) are pinned with vertical stakes and the hedge top is horizontally bound to hold the woody growth together (Figure 2.3, next page). Laying works best for younger hedges with stems up to 10 cm diameter. The hedge may then be trimmed on a two or three year rotation to maintain its shape and re-layed every 10–20 years (Winspear & Davies, 2005).

In their review of hedgerow management, Barr *et al*. (2005) report relatively few studies on the effects of restoration techniques on wildlife. It is clear that coppicing and laying have considerable short-term effects on the structure of the hedge, as a large volume of woody growth is removed for the first two or three years after management. Traditional laying necessitates the removal of side branches to gain access to the hedge base and to allow the pleachers to be lowered. Species such as elder, which do not respond well to laying, might have to be removed completely (Winspear & Davies, 2005). The immediate result is a thin, narrow hedge with no outgrowths, which is of little use for nesting or foraging. Coppicing can have even more drastic effects on breeding birds in the

Figure 2.3 A newly-layed elm hedgerow with stakes and binding.
Source: Natural England

short term; in a study where 3–4 m high neglected hedges were coppiced on a plot in Hertfordshire, the number of territories was more than halved, taking about ten years to return to pre-coppicing levels (Lack, 1987).

In the longer term, a thicker, rejuvenated hedge providing more cover and a better habitat for nesting birds can be produced (Lack, 1992) although there is little empirical evidence to demonstrate this. Other studies have indicated that coppicing can result in rapid hedge regeneration where blackthorn, which spreads via suckers, is a significant component (Britt *et al*., 1996 cited in Barr *et al*., 2005) and that hedgelaying can lead to significant increases in insect abundance (Marshall *et al.*, 2001b cited in Barr *et al.*, 2005) which should provide a better food resource for birds. In any case, to avoid unnecessary pressure on existing breeding populations, restoration techniques should only be carried out in winter and only on small sections in rotation to allow displaced birds to move into other hedgerows on the farm (Winspear & Davies, 2005).

A new type of restoration management called wildlife hedgelaying has been reported by Dodds (2005) (Figure 2.4, next page). This mechanical laying method, pioneered by a Buckinghamshire

Figure 2.4 Wildlife hedgelaying. A tall, straggly hedge before laying (top). The layed hedge has a dense structure and retains its berry crop (bottom).

Source: Matthew Dodds, AVDC

farmer and trialled by Aylesbury Vale District Council Countryside Service, involves cutting part way through the woody stems with a pruning saw (a chainsaw on a pole). This method allows access to the hedge base without the need to cut away many pleacher side branches so little woody material needs to be removed from the hedge. The whole of the woody growth is layed over in short sections and pressed into place with a tractor-mounted telescopic handler. The weight of material holds the structure together and removes the need to stake and bind the hedge. If necessary the hedge is fenced at least one metre either side of the base to provide an effective stock barrier. The laying can also be done manually using a chainsaw to coppice out excess stems. This is slower but allows the hedge to be laid over without having to compact it and any cut material can be used to fill gaps. The mechanical technique seems better suited to young, tall, thin and leggy hedges (Scott, 2005).

This new technique may offer significant wildlife benefits over traditional hedgelaying, particularly in the years immediately following the work (Dodds, 2005). The retention of most side branches and small trees means the layed hedgerow has a larger volume and denser structure, which may help to counteract the loss of habitat that usually accompanies hedgerow restoration. The autumn berry crop is retained, the woody shrubs flower the following year and the hedge contains deadwood for invertebrates, providing essential foraging and nesting resources for birds. Wildlife-layed hedges have also shown more vigorous growth, possibly because the woody plants are less stressed from cutting and retain their ability to shade out aggressive competitors like cleavers (*Galium aparine*) and nettles (*Urtica dioica*). An additional benefit is that the issue of field margin nutrient enrichment from burning cut material is avoided.

Time and cost savings over traditional hedgelaying, which is done by hand and requires specialist skilled labour, may be substantial. Dodds (2005) reports that up to 250 m of hedge per day could be layed mechanically compared to 20 m using traditional methods. There is no need to buy stakes and binders and the costs can be based on daily labour and equipment hire rather than the rate per metre charged by professional hedgelayers. The financial aspects of hedgerow management were a major consideration for the farmers surveyed by Britt *et al.* (2000) and the (often false) perception that managing hedgerows for wildlife was expensive and impractical was one of the main reasons cited for not following official advice on best practice, such as rotational trimming. Wildlife hedgelaying is not intended to replace the traditional method, which is culturally and economically important and does improve the wildlife value of a restored hedge over the longer term (Scott, 2005). However it may prove an attractive option for farmers and nature conservation site managers concerned about the short-term effects of hedgerow restoration, or where time and budgets for this type of management are limited and the aesthetic aspects of hedgelaying are not so important.

Chapter 3: Methodology

The methods used to survey hedgerow birds and hedgerow structural characteristics are outlined in this chapter, along with an introduction to the Otmoor and Upper Ray study sites, why they were chosen and a description of how the data collected there were analysed. Issues of data accuracy and precision are discussed where these arose.

3.1 The study area

The study area comprises two lowland sites in Oxfordshire, Southern England. The main site, Otmoor, lies approximately 5 km to the north-east of Oxford at Ordinance Survey (OS) grid reference SP5713. The second site, Upper Ray, is situated on the Oxfordshire/Buckinghamshire border approximately 3 km south of the village of Marsh Gibbon at SP6519. Upper Ray lies about 10 km to the north-east of Otmoor (Figure 3.1). Separating the two sites are the M40 motorway, a main line railway and Ministry of Defence (MOD) land at Bicester Garrison.

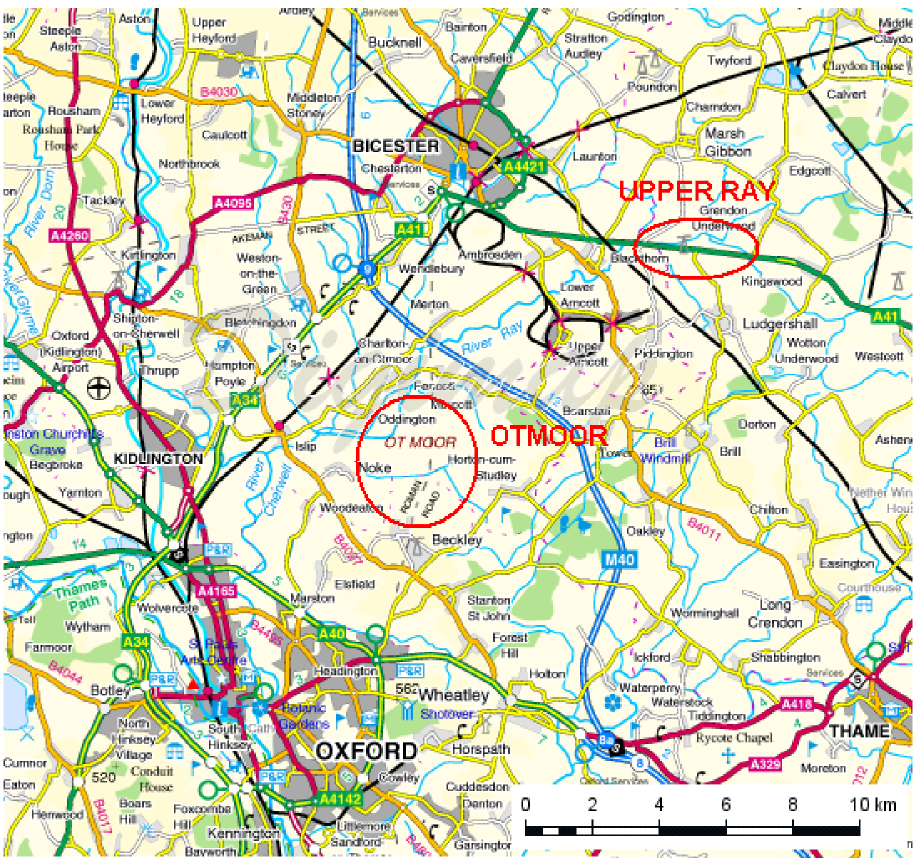


Figure 3.1 Map of study area showing the location of Otmoor and Upper Ray.

Source: EDINA Digimap

The study area sits within the floodplain of the River Ray, a tributary of the Thames. Both sites are characterised by damp grassland, parts of which are subject to periodic inundation, on neutral alluvial soils overlying Oxford clay. The wildlife and landscape importance of this wetland habitat was recognised in 1994 with the inclusion of the Ray catchment in the Upper Thames Tributaries Environmentally Sensitive Area (UTTESA) which covers approximately 27,000 hectares of the Thames Valley, including the lower reaches of five of its tributaries (DEFRA, 2002). The majority of the UTTESA lies within Oxfordshire. The remnant wet pastures and semi-natural hay meadows which characterise this area support several rare and scarce plant species, a high diversity of invertebrates and regionally important populations of breeding wading birds, including lapwing (*Vanellus vanellus*), redshank (*Tringa totanus*), curlew (*Numenius arquata*) and snipe (*Gallinago gallinago*). Farmers and landowners that have entered into management agreements receive funding to maintain the character and conservation interest of the ESA through, among other things, reverting arable to wet grassland and restoring and planting hedgerows (DEFRA, 2004).

The importance of the Ray catchment at the landscape scale has been recognised by the launch in March 2008 of the Ray Valley Restoration Project, a partnership between BBOWT and the RSPB that aims to create new wetlands, improve water quality and involve the farming community in nature conservation across the whole catchment area (RSPB, 2008b). This ambitious project links up several existing sites of conservation interest with the wider landscape, including the RSPB's Otmoor Reserve in the south and BBOWT's Upper Ray Meadows Reserve in the north (Figure 3.2, next page). The wetland conservation work undertaken by the two organisations around the River Ray is already recognised nationally, and much of this centres on enhancing the value of the floodplain to birdlife. This makes the Ray catchment an ideal place in which to conduct a study of the effects of habitat management on breeding birds.

Otmoor

Otmoor is a flat, open wetland basin of about 1400 ha (RSPB, undated). Traditionally the area flooded in winter and was grazed by commoners in summer. The Ray flowed through the middle of the moor until it was diverted to the north-west in 1830 in an attempt to drain the area for agriculture, which was not entirely successful. Enclosure took place between 1815 and 1837 and most of the hedgerows surviving today date from that period. The moor was extensively drained in the 1970s to create arable farmland and improved pasture and many of the hedgerows were removed at that time. The mesotrophic alluvial soils are moderately fertile but the area has never been very productive for crops, the marshy land being better suited to grazing. In addition to agricultural use, 212 ha of the southern part of the moor are designated as a SSSI which comprises a

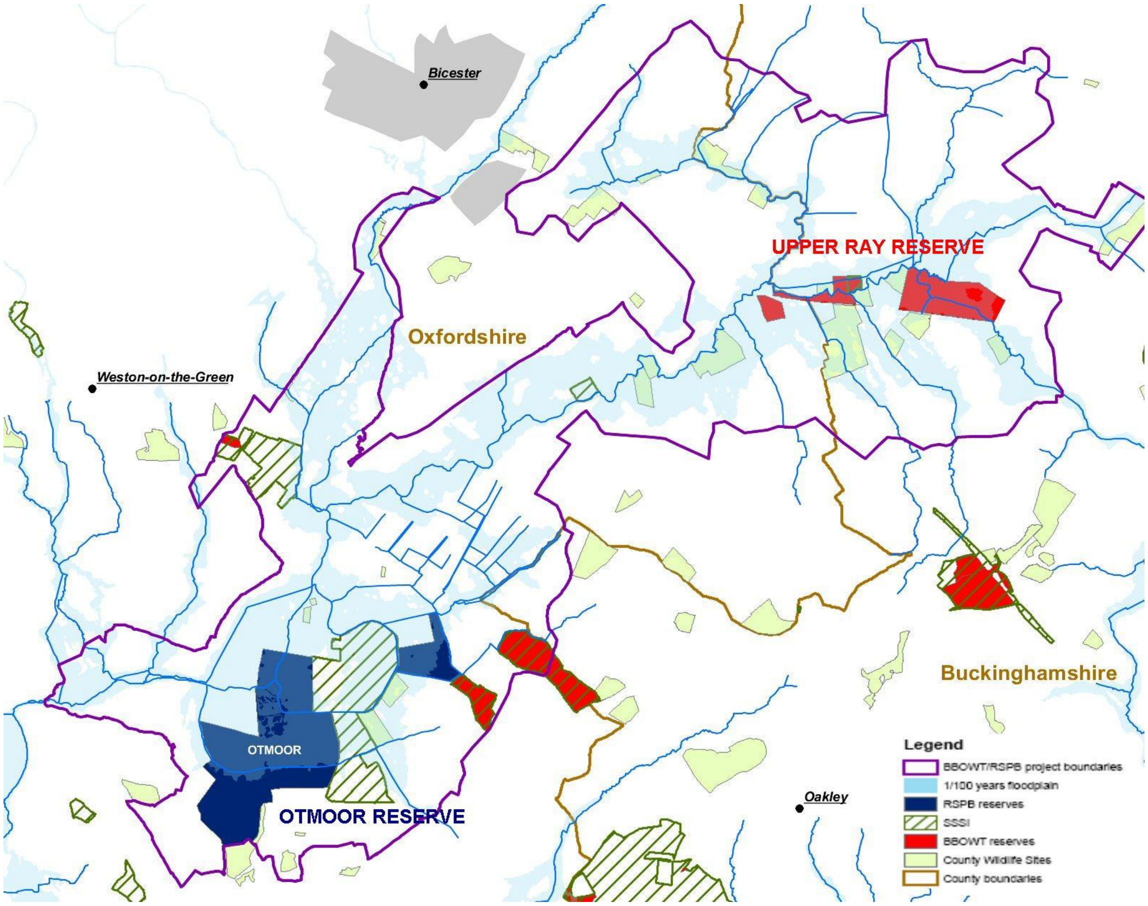


Figure 3.2 Location of the study sites within the Ray Valley Restoration Project area. Source: BBOWT

mosaic of herb-rich neutral unimproved grassland, coarser grassland and wet sedges (Natural England, undated). Much of the SSSI is part of an MOD firing range.

In 1997 the RSPB started to buy land adjacent to the SSSI to create Otmoor Reserve, which now extends to 370 ha. With the aid of an extensive system of reservoirs and ditches, the area is being restored to wet grassland and grazing marsh to provide a breeding habitat for waders of conservation concern including the four Amber-listed birds mentioned above. A 22 ha reed bed has been created to attract birds such as bittern (*Botaurus stellaris*) and marsh harrier (*Circus aeruginosus*). The blackthorn hedgerows on the reserve are managed for wildlife and as well as providing a breeding habitat for a large diversity of resident and summer migrant passerines, they are known to support colonies of the nationally restricted brown hairstreak (*Thecla betulae*) and black hairstreak (*Satyrium pruni*) butterflies (RSPB, undated).

Otmoor was chosen as the primary study site because the hedgerows there are managed using a variety of methods (including flail cutting on a three year rotation and wildlife hedgelaying) giving an opportunity to compare the effects of different treatments on bird usage at one site. As an area well known for its birdlife, with good records of the breeding species using the reserve and a lack of alternative nesting habitat in the open landscape, there was a high chance of finding enough birds to make meaningful comparisons between the different hedgerow treatments. Furthermore, the RSPB are interested in how their hedgerow management strategy is affecting the bird use of the Otmoor hedgerows during the breeding season, particularly with regard to wildlife hedgelaying which is a relatively new and untested technique. Alongside hedgerow restoration, one objective of laying the hedges on the more open parts of the reserve is to reduce their height in an effort to deter avian predators, particularly corvids, from preying on lapwing and other ground-nesting waders in adjacent fields (Wilding, 2007, pers. comm.). This presents a potential conflict between the management of hedgerows for common breeding passerines and to reduce the predation pressure on wetland birds of conservation concern, which this study may be able to help resolve.

Upper Ray

BBOWT's Upper Ray Meadows Reserve comprises several blocks of hay meadow and former arable farmland and pasture in the upper floodplain of the Ray. Much of the reserve is spread out along a narrow belt of flat land bordered by the river to the north and the busy A41(T) to the south. BBOWT first acquired Long Herdon Meadow, a species-rich unimproved hay meadow designated as a SSSI, in 1981. It continues to expand the reserve, doubling its size to 110 ha in December 2007 with the purchase of Gallows Bridge Farm at the eastern end of the site (BBOWT, 2008). The land acquisitions are a core part of BBOWT's Living Landscapes Project, which is a 30 year strategy for landscape-scale conservation that aims to engage landowners in wetland restoration for wildlife across the Upper Ray catchment. The vision is to create a wetland corridor all along the Ray Valley from the BBOWT reserve south to the Otmoor basin. The hydrology and vegetation characteristics of the site are broadly similar to Otmoor; accordingly the management objectives for the reserve echo those of the RSPB, which are to restore agricultural land to hay meadows, wet grassland and grazing marsh, all target habitats of the Oxfordshire local BAP. One of the primary aims, as at Otmoor, is to provide suitable habitat for breeding waders (Phillips *et al.*, 2007).

Upper Ray was chosen for several reasons. As well as allowing a greater geographical spread of data to be gathered, using this site allowed for comparisons of the effect of hedgerow management age to be made with Otmoor, because much of the hedgelaying at Upper Ray had been carried out some years previously. Thus it was possible to test whether the perceived benefits of wildlife hedgelaying compared to traditional laying (in terms of numbers of breeding birds and species supported) were short-term. The site is managed for wildlife in a similar way to Otmoor and, as at that site, the fields adjacent to the hedgerows are predominantly neutral damp grassland, which should minimise any effects of surrounding land use on the distribution of hedgerow birds. A further advantage is that both sites were farmland only a few years previously so the results of this study should hopefully have some application to the wider agricultural landscape.

3.2 Sampling method

Selecting hedgerows

The purpose of this study was to investigate relationships between hedgerow management and breeding bird distribution. A complete census of hedgerow birdlife was not possible in the time available so sample hedges representing each management treatment were selected for survey from information provided by the RSPB, BBOWT, CPRE and local farmers and landowners. The four treatments were unmanaged, flail cut, traditionally-layed and wildlife-layed hedges. 'Unmanaged' hedges had a large and overgrown shrub layer that showed no signs of significant management within the last three years. (In fact, being semi-natural features, most hedgerows are subject to *some* form of management even if this is only periodic.) The other management methods are as described in Chapter 2. The selection of sample hedges was not random but was driven by a logistical requirement to find sufficient lengths of hedgerow typical of the four treatments at each site and to follow a logical survey route that would allow each site to be covered in a morning's survey.

A key consideration in selecting sample hedges was the desire to control factors not related to hedgerow management that could affect the survey results. Hedges were selected as much as possible next to fields of semi-improved neutral grassland and away from other landscape features such as woodland and gardens; variations in the nature and quality of the surrounding habitat are known to influence the distribution of birds in hedges (e.g. Green *et al*., 1994; Macdonald & Johnson, 1995). However it would have been impractical, if not impossible, to try to control the presence or absence of associated features such as ditches and banks, trees or the hedgerow's orientation, so the approach taken was to record these variables during the hedgerow structural surveys and factor them as necessary into the data analysis. Beyond these considerations the sample hedges within each treatment were selected to represent a range of structures (in terms of height, width, etc) that were indicative of the type of management used on those hedgerows.

The amount of time since hedgerow management was carried out might be expected to affect bird distribution; hedges that were layed five years ago would on balance provide a considerably bigger habitat than those layed in the last year or two and have not had time to regrow. This factor was standardised at Otmoor by selecting only sample hedgerows where the management had been carried out within the last three years, i.e. since winter 2005/06. At Upper Ray all the flailing and wildlife laying had been carried out within the last three years but the traditional laying was older, dating from between winter 2002/03 and winter 2004/05 (three to six years ago). This allowed a direct comparison of the effects of time since management on the birdlife of the differently-layed hedges at Upper Ray.

Marking out transects

A number of standard bird census techniques were considered for this study as described in Bibby *et al*. (1992). Territory mapping, which may have yielded precise data on the number of territories being held by breeding birds in each hedgerow, was rejected on the basis of the large amount of time needed to observe individual birds and the high skill level required. A variation on the line transect method, in which the observer walks along a fixed route noting any bird contacts, was considered to be a more efficient way to gather sufficient data in the time available for the study. The transect method is a relatively quick technique that can be picked up easily, is better suited to comparative studies like this one and forms the basis of the BTO's annual Breeding Bird Survey (BTO, 2007). 50 m line transects were used in Green *et al.*'s (1994) hedgerow bird surveys and the methodology used there was adapted for this study. 40 m hedgerow transects were chosen to enable ten transects per management treatment at each site to be surveyed on weekly visits (there being only 400 m of wildlife-layed hedge at Otmoor available to survey). Thus each site had 40 transects totalling 1600 m in length.

The ends of the 40 m transects were marked out with red tape to allow precise relocation on subsequent visits. Transects were mostly located in straight sections of hedge to aid visual bird detection and at least 5 m away from nodes (end points) and intersections which are known to harbour more breeding birds than straight sections (Lack, 1988 cited in Lack, 1992), possibly because invertebrates cluster in these parts of hedges (Pollard & Holland, 2006). At each site the transects were split over at least two separate hedgerows per treatment to reduce any potential bias attached to particular hedgerows (e.g. near to a water body). At Otmoor, traditional hedgelaying is not practised on the reserve so hedges for this treatment were selected in damp pasture fields of similar vegetation character (many of them managed for wildlife under Environmental Stewardship) about 1.5 km to the north of the reserve. These fields are located near to the village of Charlton-on-Otmoor on the northern part of the moor at OS grid reference SP5615.

3.3 Bird surveys

All bird surveys were carried out between 16 April and 18 June 2008. This period was chosen to cover the main breeding season for resident and summer migrant passerines that use hedgerows as a breeding resource. Ten weekly visits were made to Otmoor and six alternating weekly visits were made to Upper Ray. Six visits were considered sufficient to gather enough data for comparison with the main site (see e.g. Macdonald & Johnson, 1995). Weekly visits were chosen over visits at the start and end of the breeding season for two reasons: to provide sufficient replicates for statistical analysis (given the relatively small amount of habitat being surveyed) and to maximise the number of species encountered. Weekly visits increased the chance of duplicate counts of the same individual holding a territory in a particular transect over time but this trade off was deemed necessary to provide enough data. Furthermore, any bias would operate in the same direction, i.e. favouring better quality hedges which could support territories over a longer time period.

The author and a fellow recorder (Barry Oxley or Philip Barnett, both experienced birdwatchers) conducted all surveys in the morning between 7 am and 12 pm. The presence of two recorders on each visit ensured consistency in the detection and identification of birds. Surveys were not conducted in wet or windy conditions when birds tend to be less active, as per standard BTO breeding survey instructions (BTO, 2007). The start and end points of the route changed on each visit to reduce bias caused by visiting particular transects at particular times of day. The protocol was to pause briefly at the end of each transect, noting any birds ahead, then walk slowly along the transect about 2–5 m from the line of the hedge, recording all visual and aural (song and call) registrations of adult birds on a standard form (Appendix 1). Birds were recorded in the transect in which they were first detected and great care was taken not to double count individuals that were flushed along the hedge by the recorders. Fledgling and juvenile birds were noted but not recorded. Birds that could not be identified to species level were recorded as ‘unidentified’. Due to time and access restrictions only one side of each hedgerow was surveyed. Birds detected on the other side of the shrub canopy were recorded.

For each registration the location within the transect was noted: ‘hedge’ being the shrub layer; ‘margin’ the perennial herbaceous or grassy margin extending to 5 m from the hedge base; ‘tree’ a mature tree within the hedgerow over 10 m tall. Registrations of birds outside these locations (e.g. skylark [*Alauda arvensis*] singing in an adjacent field or crow flying overhead) were excluded. Birds flying into or out of the hedgerow were recorded. The sex of each individual, if known, was recorded to give an estimation of numbers of breeding pairs. Singing males were recorded as a sign of possible breeding, singing behaviour indicating defence of a territory against other males or mate attraction. Nests counts were not attempted due to limitations of time and expertise; however any occupied nests encountered in hedgerows were noted. Foraging behaviour was not recorded due to difficulties in determining whether individual birds were using the hedgerow for this purpose.

3.4 Hedgerow surveys

Between 25 June and 5 July 2008 the hedgerow transects were surveyed by the author to measure their structural and botanical characteristics. The aim was to gather sufficient data to produce a set of independent variables that could be correlated to variance in the bird distributions. In other words, how was the management treatment affecting the hedgerow's structure and composition and hence its value as a breeding bird habitat? June and July are the best months for hedgerow survey as several woody species are in flower, aiding their identification (DEFRA, 2007). Furthermore, nesting wild birds are protected under the Wildlife and Countryside Act (1981) and minimal disturbance would be caused by measuring the hedge after the main part of the breeding season (Anon, 1981). Most surveys were carried out in good weather, avoiding where possible wet and windy conditions that would affect the survey efficiency. Due to the time and access restrictions mentioned earlier, only one side of each hedgerow was surveyed. All data were recorded on a standard form (Appendix 2).

The attributes recorded for each transect are summarised in Table 3.1 on the next page. In addition to the physical dimensions and botanical characteristics of the hedgerows, data were collected on orientation (Lack, 1992), adjacent features such as ditches (Parish *et al.*, 1994) and surrounding land use (Green *et al.*, 1994) which have been shown to affect hedgerow bird distributions. Only the shrub and tree layers were measured because many transects lacked an obvious herbaceous ground flora (the pasture often extending right up to the hedge base) and time constraints would not permit a detailed botanical survey of this layer in any case. Standard guidelines were followed for hedgerow survey methodology as per the *Hedgerow Survey Handbook 2nd Edn.* (DEFRA, 2007). Hedgerow dimensions were estimated to the nearest metre using an extendable 3 m measuring pole.

Once the data were collected, the following structural attributes were calculated for each transect:

Hedge width	An average of top width and base width.
Hedge volume	An estimate of the volume of the shrub layer: (CSA x 40) - (CSA x 40 x (GAP/100)) where cross sectional area (CSA) = height x width and GAP = % gaps in canopy.

Table 3.1 A summary of hedgerow attributes recorded for each 40 m transect.

Attribute	**Definition**
Average height	A mean of three height measures made at 10 m intervals.
Average top width	A mean of three width measures made at 10 m intervals at approximately 0.5 m below the top of the shrub canopy.
Average base width	A mean of three width measures made at 10 m intervals at approximately 0.5 m above the ground.
% gaps in canopy	A visual estimation of the extent of gaps in the shrub layer, to the nearest 10%.
Tree number	Number of mature trees over 10 m in height.
Tree species	The tree species (ash *Fraxinus excelsior*) or genus (oak *Quercus* spp. and willow *Salix* spp.).
Tree height	Tree height estimated to the nearest 5 m.
Woody species number	Number of woody species in the shrub layer, determined using Rose (1981). The following were determined to genus level and each counted as one 'species': bramble *Rubus* spp., elm *Ulmus* spp., hawthorn *Crataegus* spp., oak *Quercus* spp., willow *Salix* spp.
Dominant woody species	The dominant structural component of the shrub layer.
Orientation	The orientation of the side surveyed: north, east, south or west.
Adjacent features	Present/absent within 10 m: ditch (wet or dry), earth bank, path or track, fence, separate hedgerow. Present/absent within 30 m: woodland, open water, reed bed.
Adjacent land use	Main land use to Phase 1 survey level (JNCC, 2003) recorded on both sides of the hedgerow.

3.5 Data analysis

The bird survey data across all visits were summed to give a total count of individual birds (abundance) and number of species (richness) for each of the 40 transects at each site. Records of unidentified birds contributed to the abundance counts but were excluded from the richness counts because the species was unknown. These data were then pooled by management treatment to give total bird abundance and richness figures for each treatment. Data from Otmoor and Upper Ray were not pooled because, although broadly similar in terms of habitat characteristics and birdlife, other undetected variance in, e.g. food availability or predation pressure might have introduced bias into the dataset. Keeping the data separate also allowed for simple comparisons of trends in bird distribution to be made across the two sites, providing a greater geographic spread to the results.

The total abundance figures were used in subsequent statistical analysis. The raw richness data were first transformed into species richness estimates using Jacknife methods. This was necessary to deal with problems of data inaccuracy arising from the fact that birds in larger hedgerows (i.e. the unmanaged and flailed treatments) were generally harder to detect, leading to probable undercounting of those hedges. Jacknife methods help to correct bias from unequal richness estimation between treatments. In addition to abundance and richness, a diversity measure was calculated for each treatment to investigate whether the relative proportions of different bird species (species evenness) also varied with hedgerow management. The Shannon Index of diversity, which measures the amount of order within a sample, was used (Krebs, 1999).

There were a number of ways to show evidence of breeding using the bird data. Any individual found in suitable nesting habitat during the breeding season is a possible breeder (BTO, 2008) and this was true of the majority of hedgerow birds recorded in the surveys. However it was desirable to select a breeding indicator that closely linked breeding behaviour to the particular hedgerows surveyed. One way to do this would be to identify pairs of birds in hedgerow nesting habitat, which would indicate probable breeding. Pair matching was attempted using the sex data to identify male and female birds of the same species in the same transect, however this proved to be an unreliable method, particularly for species such as blue tit that do not have sexually dimorphic plumage. To determine breeding pairs reliably would have involved long periods of observation on the same individuals (e.g. territory mapping) which was beyond the scope of this study. Occupied nest records could not be used because nest searching was not a standard part of the survey protocol.

In contrast, singing males were easy to detect with accuracy and this behaviour could be clearly linked to the hedgerows because the birds had used the woody shrubs and trees as song posts. Thus singing birds were chosen as a subset of the main data to indicate evidence of possible breeding. Only using song as a sign of breeding would inevitably underestimate the total breeding use of the hedgerows and favour detection of the more conspicuous songbirds (such as the wren) but because the study was designed to compare management treatments rather than determine absolute bird densities any detection bias would tend to operate in the same direction across treatments and therefore should have little impact on the final results.

Birds which were registered in the shrub layer or margin were selected as a second subset to test the effect of excluding records from trees on the distribution data. The presence of trees in a hedge is known to exert a large influence on bird distribution (see Chapter 2, section 2.3) so it was desirable to test whether any relationships between hedge management and bird distribution still held when tree data were excluded from the analysis.

Hedgerow survey data were pooled for each treatment so that differences in the values of hedgerow attributes linked to management could be statistically tested. The Otmoor data and Upper Ray data were kept as separate datasets. For each treatment a mean value across the ten transects was calculated for continuous variables (e.g. height) and frequency data was summed (e.g. number of trees). Following a visual analysis of the data, the attributes most clearly linked to management treatment were selected for further statistical analysis. These were: hedgerow height, width, volume, tree number and woody species number. The other variables listed in Table 3.1 were excluded on the basis that they showed very little variance (e.g. % gaps, dominant woody species), could not be easily correlated to patterns in the bird data (e.g. tree species, adjacent features) or proved difficult to record accurately (e.g. adjacent land use to Phase 1 level, tree height estimates). In any case these attributes were of less interest to the study than those directly affected by hedgerow management and as they were unlikely to significantly influence the observed bird distributions they were not deemed worth investigating further.

For all statistical tests a significance level of $P < 0.05$ was adopted for rejection of the null hypothesis. Fit to normal distribution was checked using StatSoft Statistica to verify the use of parametric tests where appropriate. All tests were carried out in Microsoft Excel using the Data Analysis tools. G-tests were used to compare observed differences in total bird abundance and species richness against an expected even distribution across all treatments and between wildlife and traditionally-layed hedges. This test is similar to Chi-square goodness of fit but is recommended as theoretically superior (Dytham, 2003). For the hedgerow data G-tests were used to compare differences in the number of mature trees and woody plant species between treatments (i.e. where frequency data were involved). Differences in continuous variables (hedgerow height, width and volume) were tested across treatments and between laying methods using one-way ANOVA (analysis of variance) and two sample t-tests respectively. One-tailed t-tests were used to determine the direction of significant differences between the laying methods.

Having determined the significance of differences between treatments, tests of association were used to examine relationships between the hedgerow and bird data to reveal which hedge types (as a function of management) were favoured by breeding birds at the study sites. The nature and significance of relationships between the main hedgerow attributes and bird distribution (e.g. height and abundance) was investigated with linear regression. A correlation matrix was produced to show the nature of intercorrelations between the different variables. Relationships between the abundance of individual species and hedgerow attributes were not tested in this study because the number of birds recorded was for most species too low to make statistically-meaningful comparisons. Such relationships have been examined in detail elsewhere (e.g. Parish *et al*., 1995; Sparks *et al*., 1996).

Chapter 4: Results

This chapter opens with a brief consideration of the reliability of the survey data. The results of the bird surveys are presented as measures of total abundance, species richness and diversity for each of the management treatments. This is followed by the hedgerow data analysis, which tests variance in height, width, volume, tree number and woody species number between the management treatments and examines the relationships between these key variables and the observed bird distributions.

4.1 Data reliability

Bird–habitat studies can be prone to bias because the many different factors that determine bird densities in the countryside are often difficult to control. Some bias in the survey design is inevitable and its effect can be reduced by spreading the bias across replicates (Bibby *et al.*, 1992). This approach was adopted in this study and the survey methodology was carefully designed to minimise potential bias wherever possible. This is why, for example, all bird surveys were conducted at the same time of day during similar weather conditions and with two observers, so that bird detectability would not vary substantially between visits.

Despite the careful design, some minor problems arose during the bird surveys that could not be controlled. Noise disturbance from contractors in a nearby field and from verge mowing affected six transects at Otmoor on one visit. Additionally, heavy rain in early June led to localised flooding at both sites on one set of visits, particularly at Cow Leys at the western end of Upper Ray, which necessitated wading through water up to 0.5 m deep. One transect at Cow Leys was observed but not walked due to safety reasons. Both noise and flooding of adjacent fields might be expected to reduce the numbers of birds recorded on those visits, however the data gathered did not support this. It was concluded that these minor disturbances were not significant to the results.

The hedgerow surveys were also subject to some small difficulties, particularly around assigning adjacent land use into neutral grassland categories (umimproved, semi-improved or improved) due to lack of Phase 1 survey experience. Full coverage Phase 1 habitat maps could not be obtained for the sites. It was difficult to estimate the size of large unmanaged hedgerows with the same level of precision as the managed ones, so the dimensions of those hedges are likely to be slight underestimates. However the effects of variation in the quality of the surrounding grassland habitat and difficulties in measuring hedgerow size were considered to be small and therefore unlikely to significantly influence the results. For example, Green *et al.* (1994) and similar studies considered it sufficient to measure differences in land use at a much coarser scale, such as ‘arable’ or ‘pasture’.

4.2 Bird distributions

A total of 27 species were recorded at Otmoor and 22 species at Upper Ray (Appendix 3). Of these, 18 species showed evidence of breeding (recorded as singing males) at Otmoor and 10 species at Upper Ray. The ten most commonly-recorded species across both sites were, in order of decreasing abundance, chaffinch (91 individuals), blue tit (64), reed bunting (*Emberiza schoeniclus*) (54), wren (46), robin (36), whitethroat (32), sedge warbler (*Acrocephalus schoenobaenus*) (26), woodpigeon (*Columba palumbus*) (25), great tit (*Parus major*) (23) and blackbird (20). With the exception of reed bunting and sedge warbler these are all common birds of hedgerows (Lack, 1992; see Table 2.1, page 11). Reed bunting and sedge warbler are typically wetland birds while the other eight are usually associated with woods and woodland edge habitats.

With the exception of the winter visitor fieldfare all the birds recorded are resident or summer migrant species which are known to breed during the period surveyed. One third of all those recorded are birds of conservation concern. Cuckoo (*Cuculus canorus*), dunnock, fieldfare, meadow pipit (*Anthus pratensis*) and willow warbler (*Phylloscopus trochilus*) are Amber list species while bullfinch, linnet, reed bunting, song thrush, starling (*Sturnus vulgaris*) and yellowhammer are on the Red list (RSPB, 2007). All of these except fieldfare, meadow pipit and willow warbler are also UKBAP Priority Species (JNCC, 2007). Only reed bunting was recorded in significant numbers.

Abundance

The distribution of all birds recorded varied significantly between treatments at Otmoor ($G=127.68$, d.f.=3, $P<0.001$) (Figure 4.1A, next page). The highest numbers of birds were found in unmanaged hedgerows, which supported about seven times more than the least-preferred treatment, traditionally-layed. This pattern was repeated for breeding birds ($G=59.76$, d.f.=3, $P<0.001$). Wildlife-layed hedgerows had significantly more birds in total than traditionally-layed hedgerows ($G=27.37$, d.f.=1, $P<0.001$) and significantly more breeding birds ($G=18.74$, d.f.=1, $P<0.001$). The management age of these two treatments at Otmoor was broadly the same: less than three years old.

At Upper Ray there was a significant difference in the distribution of all birds between treatments ($G=13.97$, d.f.=3, $P=0.003$) but this trend was not repeated for breeding birds (Figure 4.1B). At this site the lowest abundance of birds was found in wildlife-layed hedgerow. Breeding birds at Upper Ray preferred traditionally-layed hedgerows to other treatments and significantly more were found in traditionally-layed than wildlife-layed hedges ($G=6.79$, d.f.=1, $P=0.009$). However traditionally-layed hedges did not have significantly more birds in total (all birds). The traditional hedgelaying at Upper Ray was 4–6 years old whereas the wildlife laying was less than three years old.

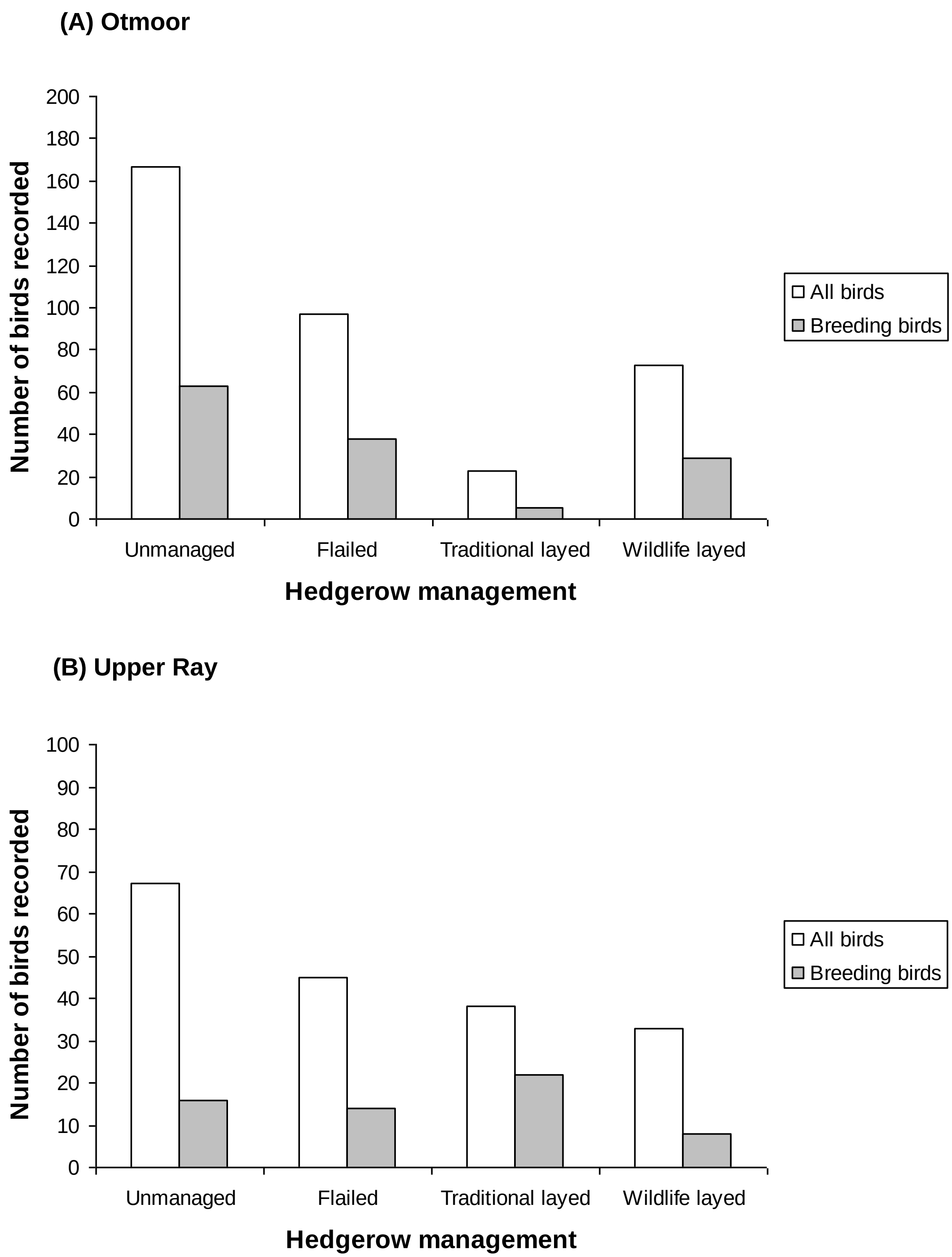


Figure 4.1 Bird abundance of each hedgerow treatment at Otmoor and Upper Ray. Note the scale of the y-axis differs.

When records of birds in mature hedgerow trees are excluded from the all birds datasets the distribution trends observed in Figure 4.1 are upheld at both sites (Figure 4.2). The difference between treatments is smaller but remains significant at Otmoor ($G=82.89$, d.f.$=3$, $P<0.001$). At

Upper Ray the significant difference between treatments is unchanged (G=14.27, d.f.=3, P=0.003). Wildlife-layed hedgerows still have significantly more birds than traditionally-layed hedgerows at Otmoor (G=27.37, d.f.=1, P<0.001) and vice-versa at Upper Ray (G=8.55, d.f.=1, P=0.003).

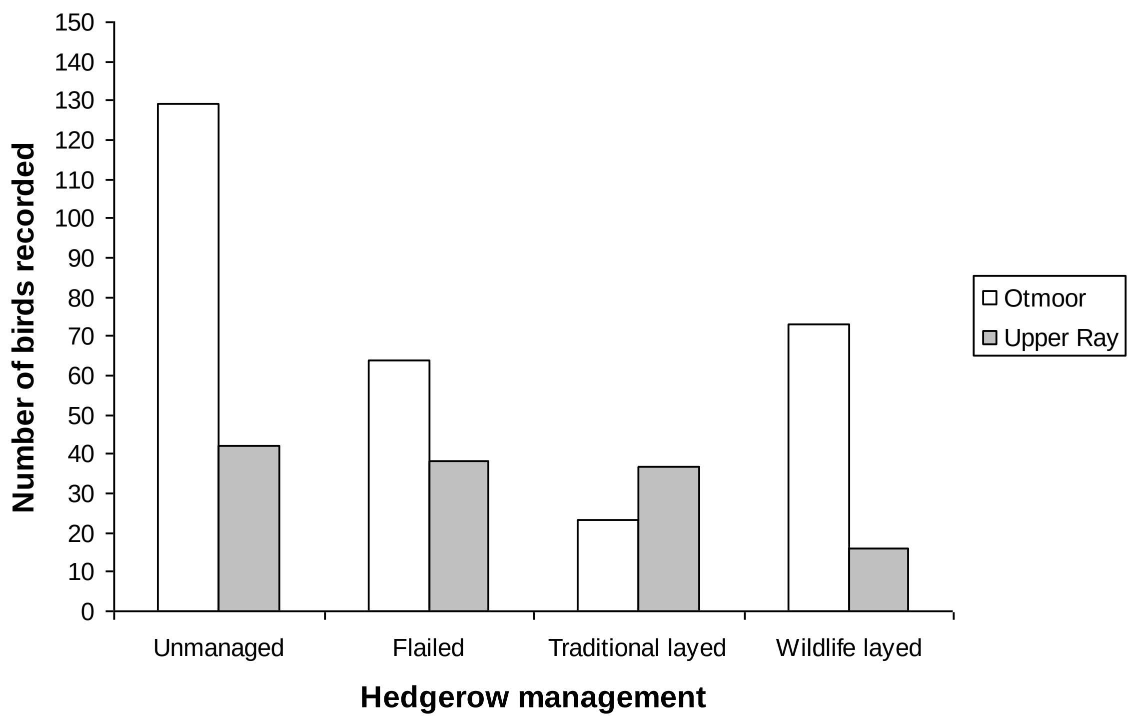
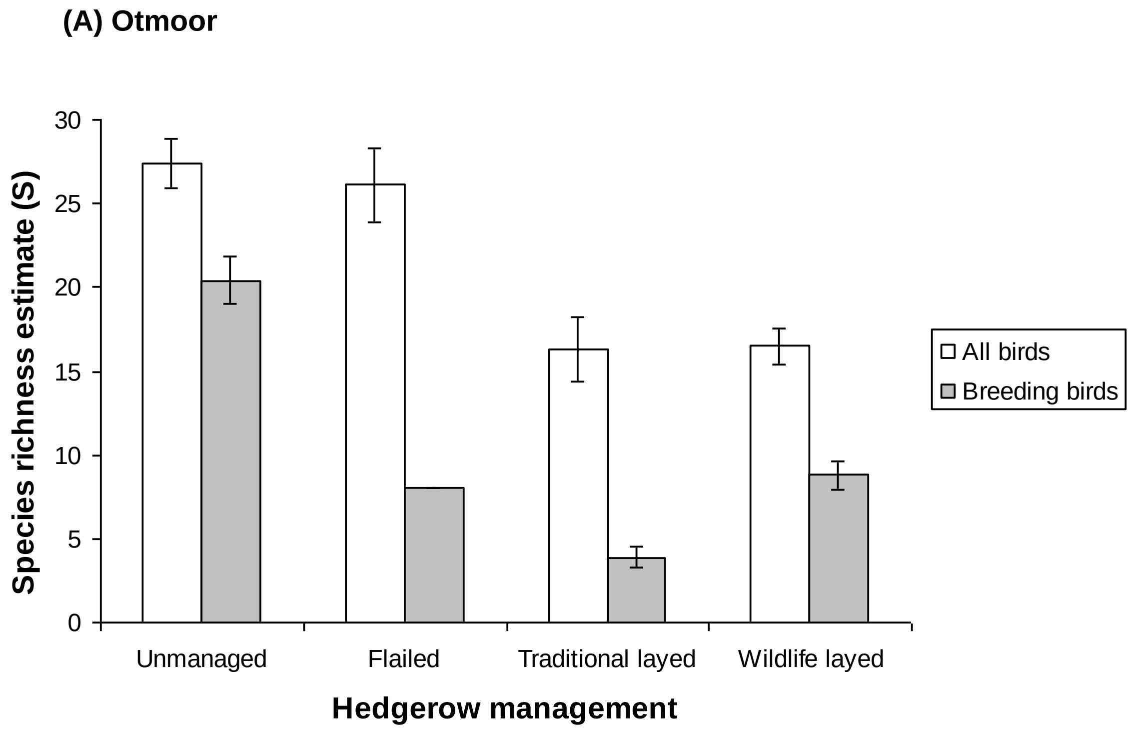


Figure 4.2 Total bird abundance at both sites with birds recorded in mature trees excluded.

Species richness

The distribution patterns of bird species at Otmoor show a similar trend to the abundance figures (Figure 4.3A, next page) with the highest Jacknife species richness estimates observed in unmanaged hedgerows (all birds S=27.4) and the lowest in traditionally-layed hedgerows (breeding birds S=3.9). However the degree of variance in bird species richness is much smaller than in bird abundance and only breeding species richness varied significantly between treatments (G=13.69, d.f.=3, P=0.003). At Otmoor unmanaged and flailed hedges appear to support approximately equal numbers of all bird species, as do the two types of layed hedge. Differences in estimated bird species richness of the two hedgelaying treatments were not significant.

At Upper Ray there is no clear trend in estimated species richness across the treatments (Figure 4.3B). Wildlife-layed hedgerow appears to support both the highest number of species in total (S=19.2) and the lowest number of breeding species (S=4.8). The differences between all treatments and between wildlife-layed and traditionally-layed hedgerow are not significant in any dataset.



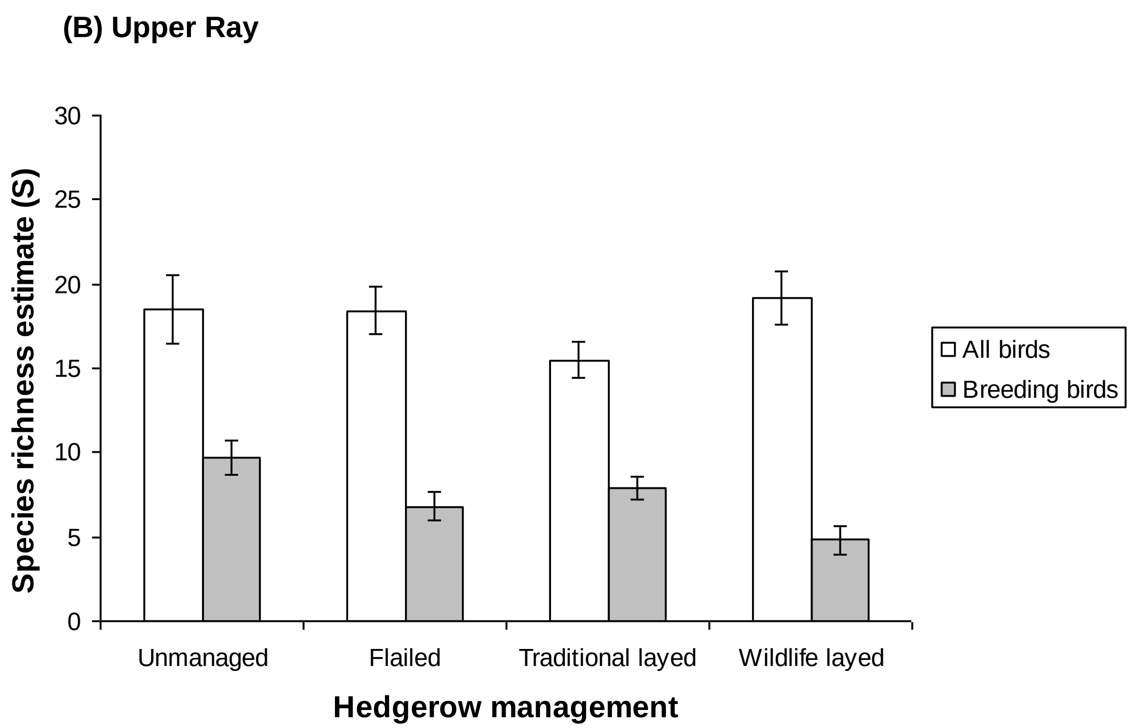


Figure 4.3 Jacknife species richness estimates for each hedgerow treatment at Otmoor and Upper Ray. Bars show 95% confidence intervals. No bars are displayed for breeding birds in flailed hedgerows at Otmoor because no variance was detected in that dataset.

Excluding records of birds in mature trees from the all birds dataset results in a drop in estimated species richness of flailed hedgerows at Otmoor (Figure 4.4). The overall distribution of species across treatments remains the same at this site but the differences between treatments are no longer significant. At Upper Ray wildlife-layed hedgerows change from supporting the most to the fewest species when trees are excluded; however again there is no significant difference across treatments.

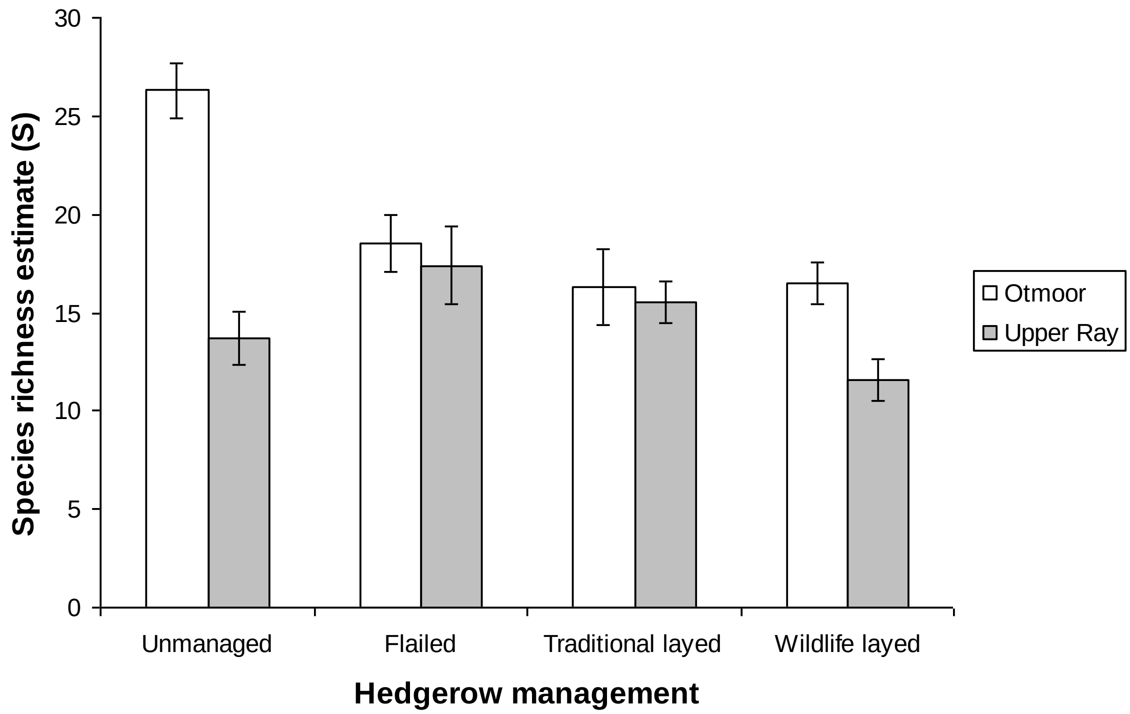


Figure 4.4 Jacknife species richness estimates at both sites with birds recorded in mature trees excluded. Bars show 95% confidence intervals.

Diversity

Calculated Shannon diversity (H') indices for each site are displayed in Table 4.1 on the next page. At both sites unmanaged hedgerows have the highest diversity and wildlife-layed hedgerows the lowest diversity when all birds are considered. The diversity of breeding birds is lower across all treatments. Wildlife-layed hedgerows have a higher breeding bird diversity than traditionally-layed hedgerows at Otmoor but the opposite is true at Upper Ray. There is no significant difference in the value of H' between treatments at either site.

Table 4.1 Shannon diversity indices and 95% confidence intervals for each hedgerow treatment at both sites.

	Unmanaged	Flailed	Traditional layed	Wildlife layed
Otmoor				
All birds	2.54 ± 0.08	2.46 ± 0.10	2.23 ± 0.17	2.15 ± 0.09
Breeding birds	2.20 ± 0.11	1.99 ± 0.11	1.05 ± 0.15	1.71 ± 0.12
Upper Ray				
All birds	2.37 ± 0.11	2.27 ± 0.13	2.10 ± 0.13	2.02 ± 0.14
Breeding birds	1.75 ± 0.16	1.47 ± 0.14	1.87 ± 0.14	0.74 ± 0.13

4.3 Hedgerow characteristics

The data collected on hedgerow structural and botanical characteristics at Otmoor and Upper Ray are given in Appendix 4 and summarised in Table 4.2 on the next page. The dimensions of the transects surveyed were broadly similar at the two sites, with Upper Ray having slightly wider hedges and a greater volume of woody material despite being more gappy. The main botanical distinction between the sites is that the Otmoor hedges are dominated by blackthorn whereas those at Upper Ray are mainly hawthorn. Semi-improved neutral grassland was the dominant land use at both sites, occurring adjacent to approximately three quarters of transects surveyed. The rest of the adjacent land use comprised improved or unimproved neutral grassland plus an area of scattered scrub at Otmoor. Also at this site, approximately one fifth of transects were within 30 m of open water or reed bed. The five key attributes used in subsequent data analysis were hedgerow height, width, volume, mature tree number and woody species number.

Table 4.3 (page 42) presents the results of a correlation analysis between the key hedgerow attributes and bird abundance and species richness data for each site. As expected there are significant positive correlations between the structural attributes at both sites, with stronger correlations of volume with height and width than between those attributes. The number of mature trees in Otmoor hedgerows is significantly positively correlated with their height and volume but this trend is not repeated at Upper Ray. The small but significant association between woody species richness and the other hedgerow attributes shows no clear trend across the sites.

Table 4.2 Summary of all habitat variables recorded at Otmoor and Upper Ray. Figures are means with ranges in parentheses. Descriptions are modal values for that variable. Italics denote the five key variables used in data analysis.

	Otmoor	Upper Ray
Height (m)	2.8 (1.0–7.0)	2.8 (1.0–6.0)
Top width (m)	2.0 (1.0–4.0)	2.2 (1.0–4.0)
Base width (m)	2.7 (1.0–7.0)	3.2 (1.0–5.0)
Average width (m)	2.3 (1.0–5.5)	2.6 (1.0–4.5)
Volume (m^3)	290 (40–1000)	315 (40–960)
Gaps in canopy (%)	1.3 (0–10)	2.3 (0–40)
Number of mature trees	0.8 (0–7)	0.3 (0–2)
Dominant tree species	Oak	Oak
Tree height (m)	12.8 (10–20)	12.7 (10–15)
Number of woody species	6.1 (3–12)	5.1 (3–8)
Dominant woody species	Blackthorn	Hawthorn
Orientation	West	East
Adjacent feature	Path/track	Ditch
Adjacent land use	Semi-improved neutral grassland	Semi-improved neutral grassland
N (transects)	40	40

The strongest positive correlations between habitat variables and bird distribution at Otmoor are clearly a function of hedgerow structure, with tree number additionally showing a small but significant association with species richness. Interestingly at Upper Ray hedgerow structure shows relatively little association with bird distribution; tree number on the other hand is strongly positively correlated with both bird abundance and richness. The strongest correlations at both sites are between the two bird distribution variables.

Table 4.3 Correlation matrices of key hedgerow characteristics and bird distribution at Otmoor and Upper Ray. Asterisks indicate significant correlations: * P<0.05 (R= 0.304), ** P<0.01 (R= 0.393), *** P<0.001 (R= 0.490).

(A) Otmoor

	Height	Width	Volume	Mature trees	Woody species	Bird abundance	Bird richness
Height							
Width	0.490 ***						
Volume	0.809 ***	0.871 ***					
Mature trees	0.523 ***	0.226	0.415 **				
Woody species	0.316 *	0.101	0.175	0.288			
Bird abundance	0.511 ***	0.772 ***	0.776 ***	0.203	0.011		
Bird richness	0.480 **	0.763 ***	0.733 ***	0.337 *	0.149	0.877 ***	

(B) Upper Ray

	Height	Width	Volume	Mature trees	Woody species	Bird abundance	Bird richness
Height							
Width	0.464 **						
Volume	0.895 ***	0.732 ***					
Mature trees	0.231	0.033	0.128				
Woody species	0.290	0.321 *	0.346 *	0.317 *			
Bird abundance	0.362 *	0.295	0.298	0.725 ***	0.236		
Bird richness	0.422 **	0.332 *	0.368 *	0.588 ***	0.264	0.902 ***	

Hedgerow height

The mean height of hedgerows across all transects varied significantly between treatments at Otmoor (F=27.62, d.f.=3, P<0.001) (Figure 4.5, next page). This height pattern follows the patterns observed for bird distribution at this site (Figures 4.1 and 4.2). Unmanaged hedgerows are the tallest with an average height of 5 m (though note the 1 m confidence intervals for this treatment) and traditionally-layed hedgerows the shortest, averaging approximately 1.5 m. Wildlife-layed hedges, at approximately 2 m tall, were significantly higher than traditionally-layed hedges (t=1.76, d.f.=18, P=0.048) and 0.5 m shorter than flailed hedges. A different pattern was observed at Upper Ray, where traditionally-layed hedgerows were only 0.5 m shorter than unmanaged hedgerows. The differences between treatments were significant at this site (F=23.94, d.f.=3, P<0.001) and wildlife-layed hedgerows, at approximately 1 m tall, were significantly shorter than their traditionally-layed counterparts (t=10.30, d.f.=18, P<0.001). Unmanaged hedgerows fall into the ‘tall’ category (>4 m), flailed and layed ‘medium’ height (2–4 m) except traditionally-layed hedges at Otmoor and wildlife-layed hedges at Upper Ray which can both be described as ‘short’ (<2 m).

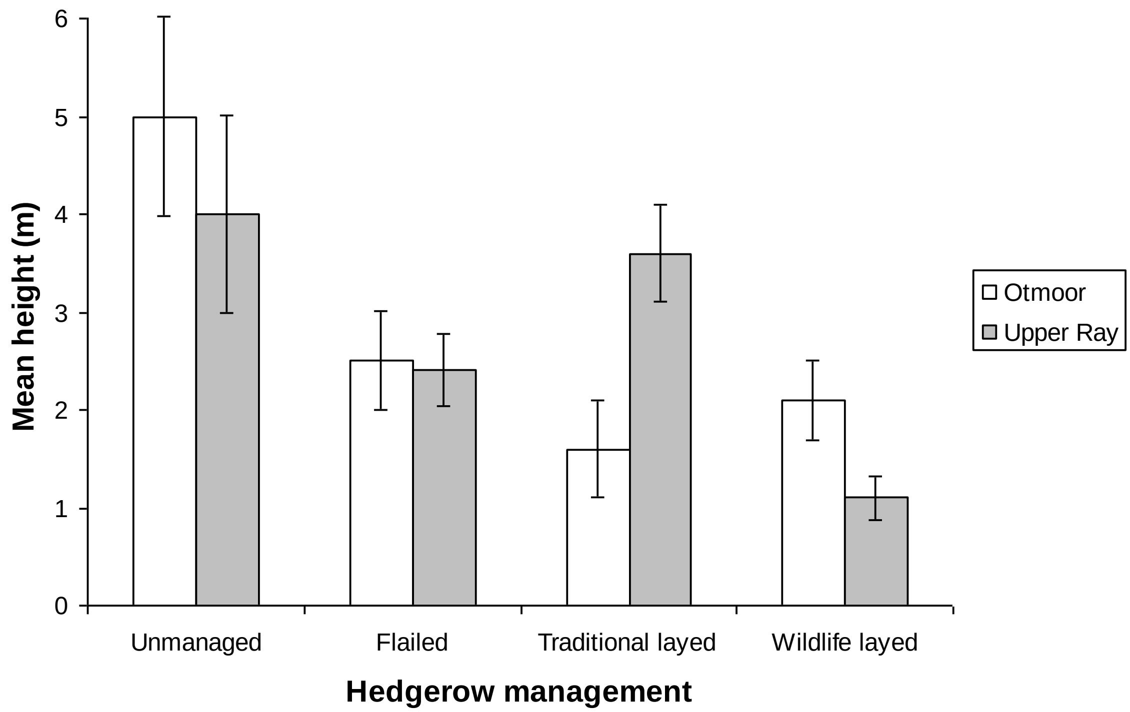


Figure 4.5 Mean heights of hedgerow treatments at both study sites. Bars show 95% confidence intervals.

Hedgerow height and all bird abundance show significant linear regression relationships (Figure 4.6); the number of birds generally increases in taller hedges. The relationship is stronger at Otmoor (R^2=0.26, d.f.=38, P=0.001) than Upper Ray (R^2=0.13, d.f.=38, P=0.022). At Otmoor the number of individuals recorded in individual transects is reduced above heights of about 4 m, suggesting that, at least at this site, the value of hedgerows to birds in the breeding season may deteriorate in hedges taller than 4 m. Similar regression relationships are observed between height and bird species richness (Otmoor R^2=0.23, d.f.=38, P=0.002; Upper Ray R^2=0.18, d.f.=38, P=0.007) (Figure 4.7).

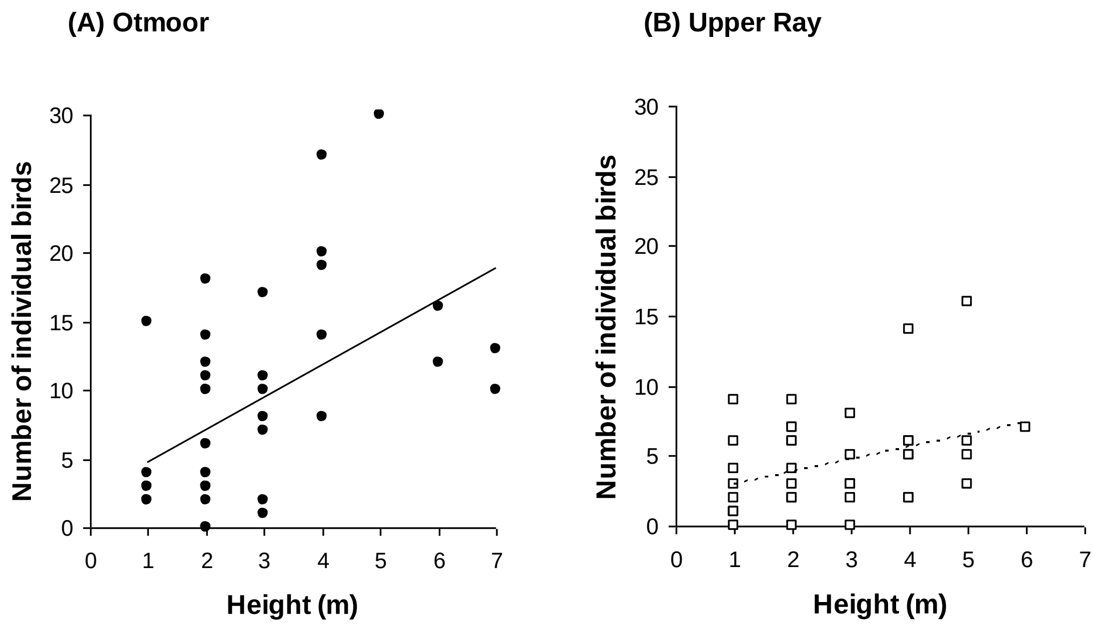


Figure 4.6 Relationship between hedgerow height and bird abundance at Otmoor and Upper Ray. Trend lines are displayed for significant relationships ($P<0.05$). Otmoor: $y = 2.36x + 2.40$, Upper Ray: $y = 0.89x + 2.12$.

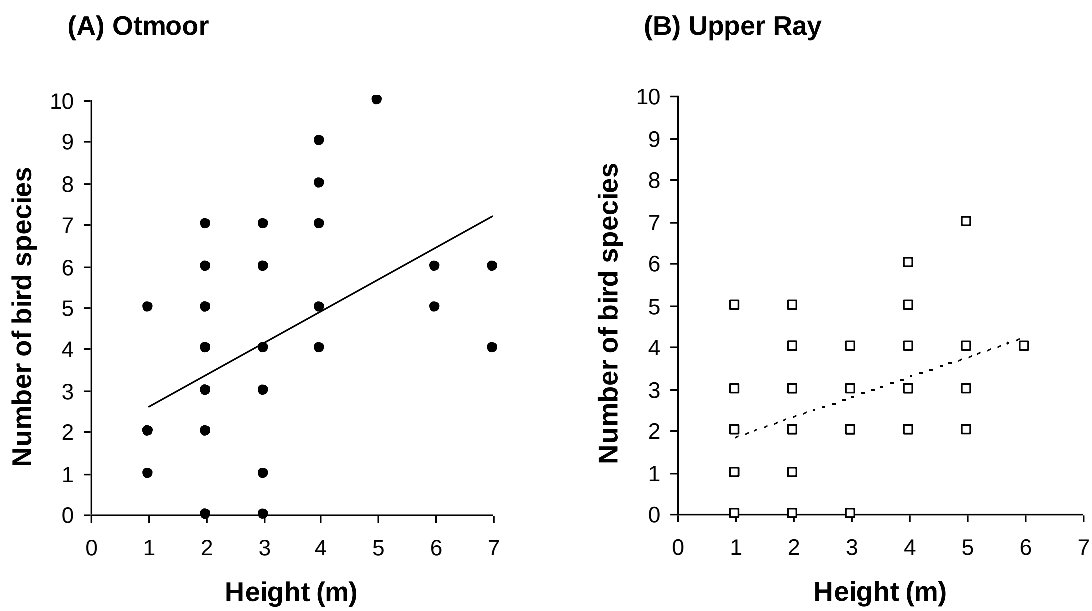


Figure 4.7 Relationship between hedgerow height and bird species richness at Otmoor and Upper Ray. Trend lines are displayed for significant relationships ($P<0.05$). Otmoor: $y = 0.76x + 1.87$, Upper Ray: $y = 0.48x + 1.32$.

Hedgerow width

Mean hedgerow width shows a similar pattern to height across treatments at Otmoor (Figure 4.8). The differences between treatments are significant with unmanaged hedgerows more than twice as wide as traditionally-layed hedgerows on average (F=14.20, d.f.=3, P<0.001) (again, note the 1 m confidence intervals for the former treatment). At Upper Ray the difference in width between treatments is also significant (F=26.12, d.f.=3, P<0.001) even though unmanaged and flailed hedges are equally wide at 3.5 m. Wildlife-layed hedgerows were significantly wider than traditionally-layed hedgerows at Otmoor (t=2.82, d.f.=18, P=0.006) and this pattern was reversed at Upper Ray (t=2.60, d.f.=18, P=0.009). Measures of shrub layer base width and top width (not shown), which were combined to form mean width, individually followed the same patterns across treatments, with hedges on average 0.5–1.0 m wider at the base than the top.

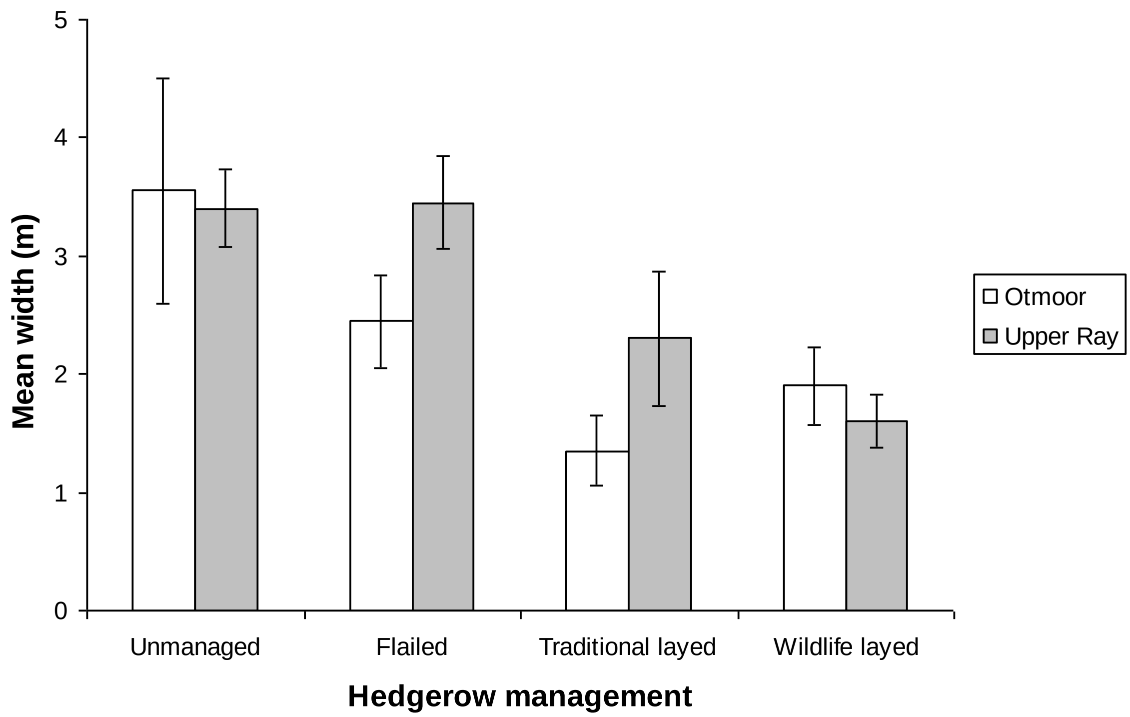


Figure 4.8 Mean widths of hedgerow treatments at both study sites. Bars show 95% confidence intervals.

At Otmoor hedgerow bird abundance was more strongly related to width than to height (R^2=0.60, d.f.=38, P<0.001) (Figure 4.9, next page). This may be explained by the fact that there was no drop off in abundance beyond a certain hedgerow width; the highest numbers of birds were found in the widest hedgerows of around 5 m. A very similar trend was observed between width and species richness at this site (R^2=0.58, d.f.=38, P<0.001) (Figure 4.10). A weaker by still significant linear relationship between these latter variables is evident at Upper Ray (R^2=0.11, d.f.=38, P=0.037). However there is no evidence of a significant relationship between width and abundance at this site.

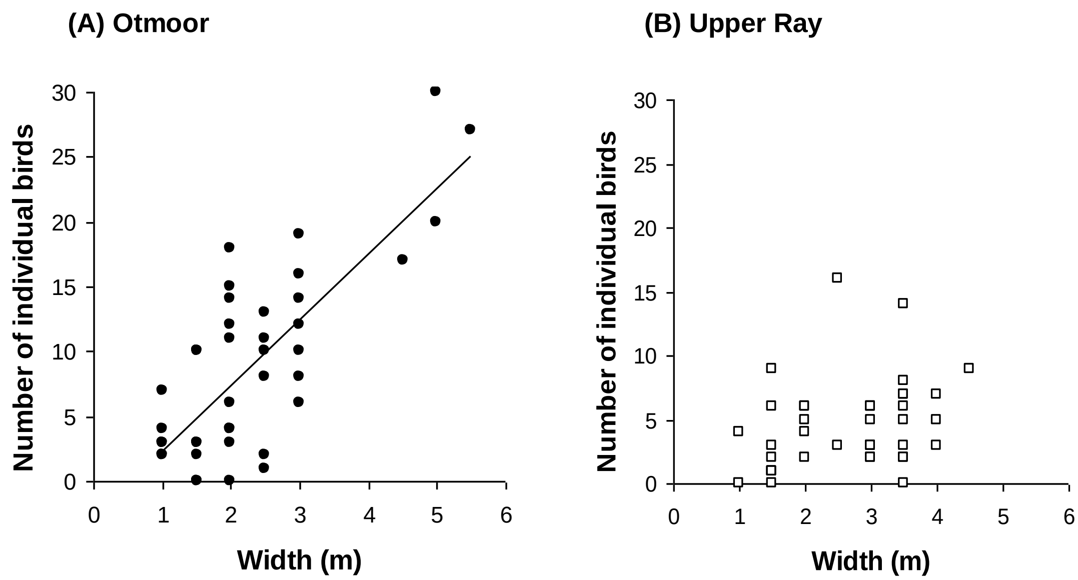


Figure 4.9 Relationship between hedgerow width and bird abundance at Otmoor and Upper Ray. Trend lines are displayed for significant relationships (P<0.05). Otmoor: y = 5.06x + 2.69.

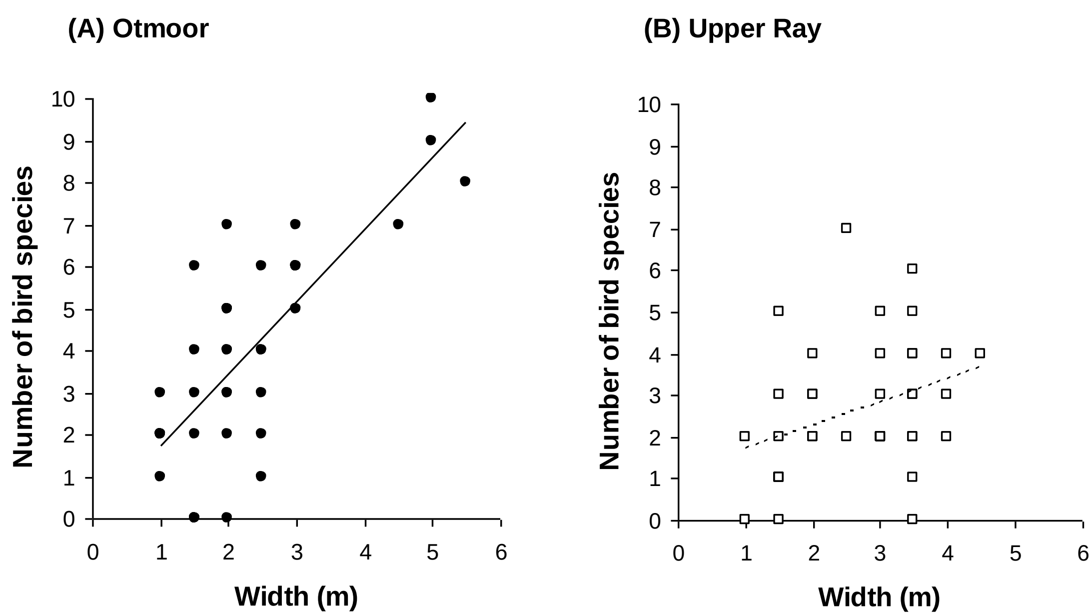


Figure 4.10 Relationship between hedgerow width and bird species richness at Otmoor and Upper Ray. Trend lines are displayed for significant relationships (P<0.05). Otmoor: y = 1.72x + 0.02, Upper Ray: y = 0.55x + 1.16.

Hedgerow volume

Estimated hedgerow volume is highly intercorrelated with height and width (see Table 4.3) and therefore follows a similar trend across hedgerow treatments to those variables (Figure 4.11). At both sites unmanaged hedges have the greatest volume of woody material and are more than seven times the size of the hedges with the smallest volumes, although note the unmanaged treatment figures have quite large confidence intervals. The differences between treatments are significant at Otmoor (F=41.94, d.f.=3, P<0.001) and Upper Ray (F=16.67, d.f.=3, P<0.001). The differences between the volumes of wildlife-layed and traditionally-layed hedgerows are also significant at both sites (Otmoor t=2.40, d.f.=18, P=0.014; Upper Ray t=5.39, d.f.=18, P<0.001).

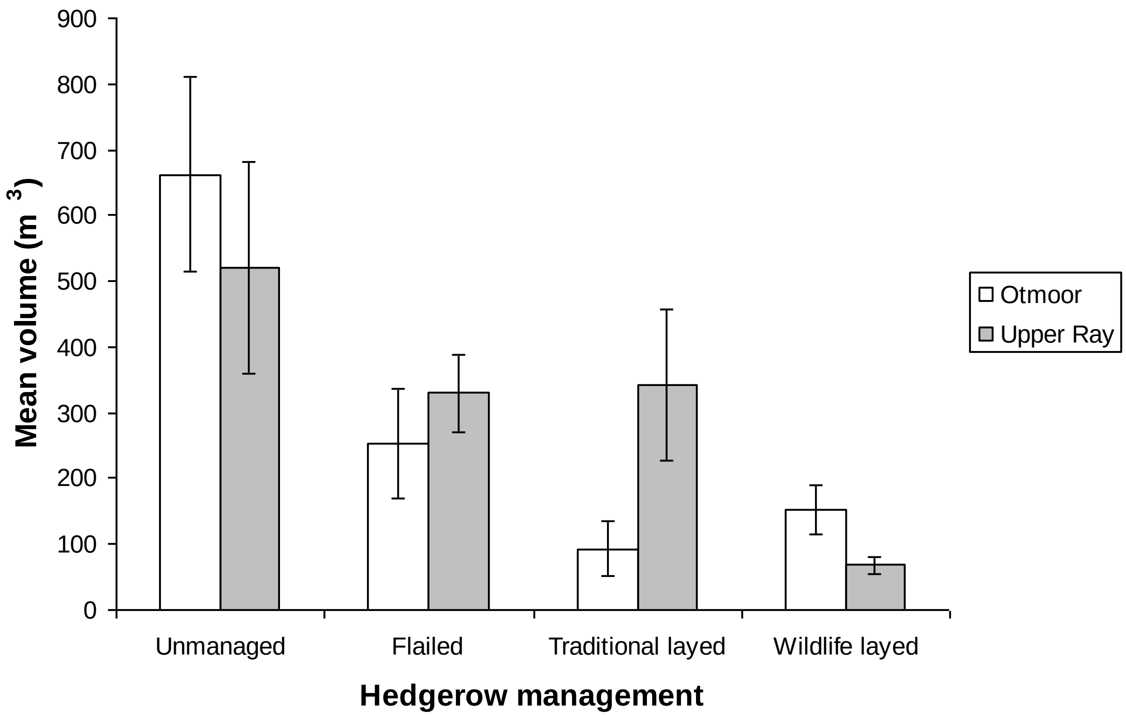


Figure 4.11 Mean volumes of hedgerow treatments at both study sites. Bars show 95% confidence intervals.

The linear regression relationship between volume and bird abundance at Otmoor is as strong as that between width and abundance (R^2=0.60, d.f.=38, P<0.001) (Figure 4.12, next page). It is clear from this sample that hedgerows with a greater volume of woody material in the shrub layer support a higher number of birds during the breeding season. At Upper Ray, however, although there is some evidence of a positive relationship between these variables it is not significant. Hedges of greater volume do support higher numbers of species at both sites (Otmoor R^2=0.54, d.f.=38, P<0.001; Upper Ray R^2=0.14, d.f.=38, P=0.019) (Figure 4.13).

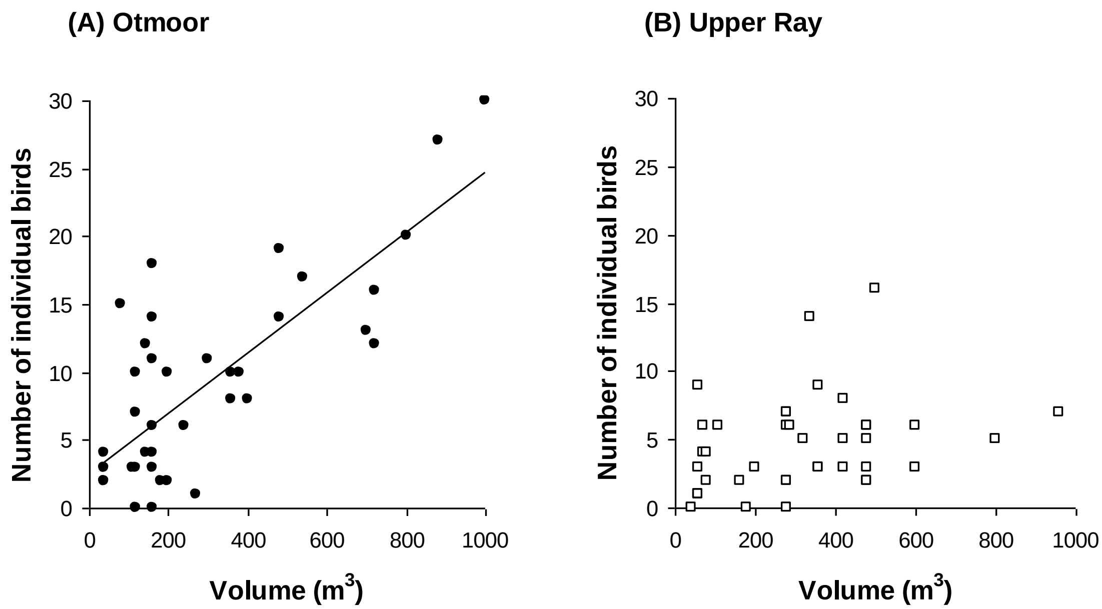


Figure 4.12 Relationship between hedgerow volume and bird abundance at Otmoor and Upper Ray. Trend lines are displayed for significant relationships ($P<0.05$). Otmoor: $y = 0.02x + 2.54$.

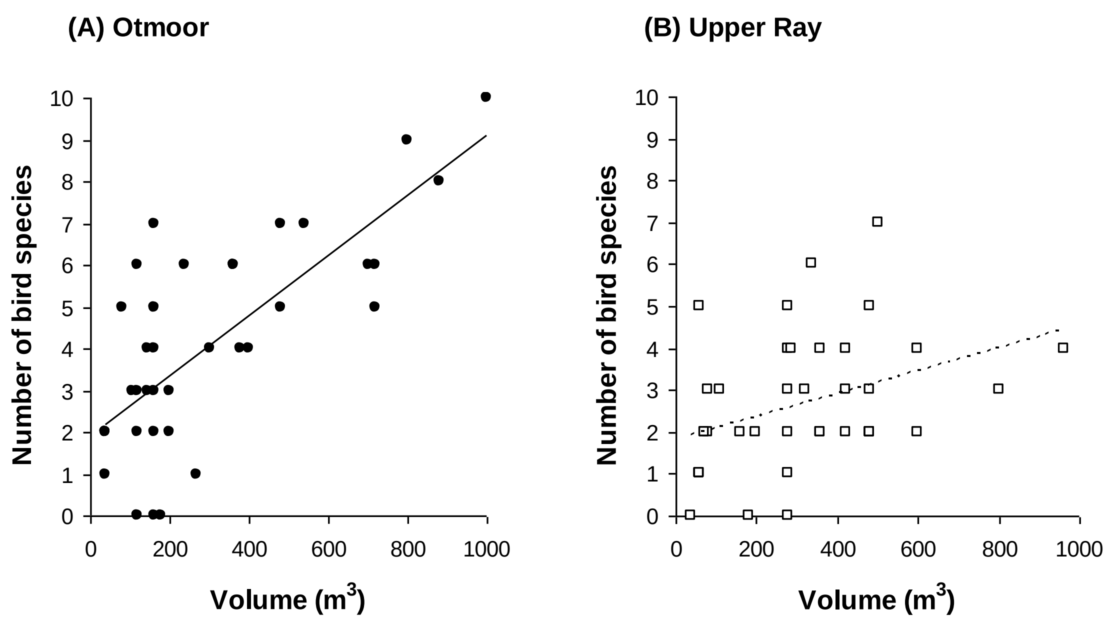


Figure 4.13 Relationship between hedgerow volume and bird species richness at Otmoor and Upper Ray. Trend lines are displayed for significant relationships ($P<0.05$). Otmoor: $y = 0.01x + 1.90$, Upper Ray: $y = 0.002x + 1.79$.

Number of mature trees

Mature hedgerow trees were unevenly distributed between treatments, particularly so at Otmoor where 22 of the 30 trees recorded were in unmanaged hedgerows (Figure 4.14). The pattern for this site broadly follows that of the structural attributes, although no trees were present in wildlife-layed hedgerows. A G-test on the Otmoor tree data revealed a significant difference between treatments (G=42.35, d.f.=3, P<0.001). Differences in the numbers of trees at Upper Ray and between the layed hedges were not significant. Note that the Upper Ray dataset was limited by a small sample size (N=12).

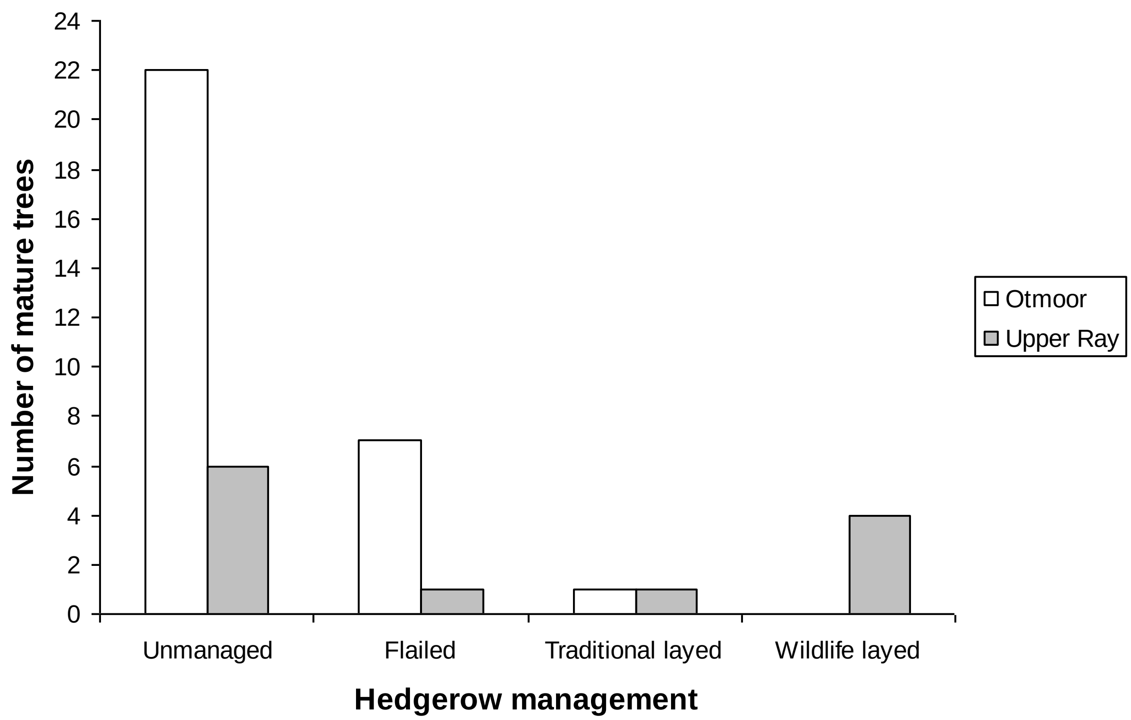


Figure 4.14 Total number of mature trees recorded in each hedgerow treatment at both study sites.

Despite a highly significant difference in the distribution of hedgerow trees at Otmoor, bird abundance was not related to tree number at this site (Figure 4.15, next page). Conversely, a good relationship between these variables was observed at Upper Ray, with the highest numbers of birds found in transects with two trees (R^2=0.53, d.f.=38, P<0.001). Species richness showed a weak but significant increase with tree number at Otmoor (R^2=0.11, d.f.=38, P=0.034) and a stronger relationship with this attribute at Upper Ray (R^2=0.35, d.f.=38, P<0.001) (Figure 4.16). Again, the relatively small sample sizes of the latter site should be noted.

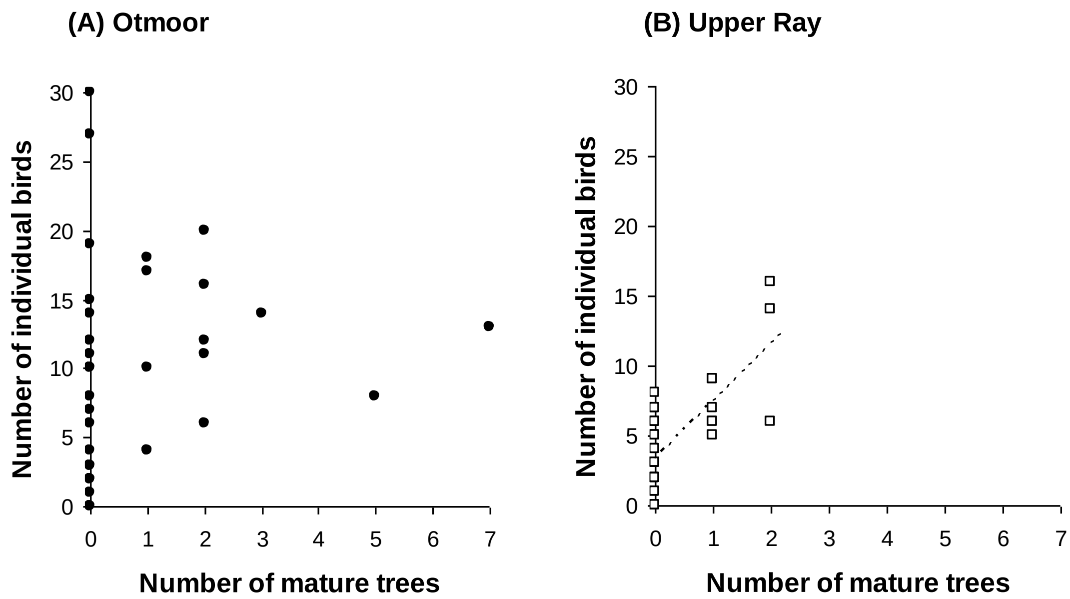


Figure 4.15 Relationship between number of mature hedgerow trees and bird abundance at Otmoor and Upper Ray. Trend lines are displayed for significant relationships (P<0.05). Upper Ray: y = 4.10x + 3.34.

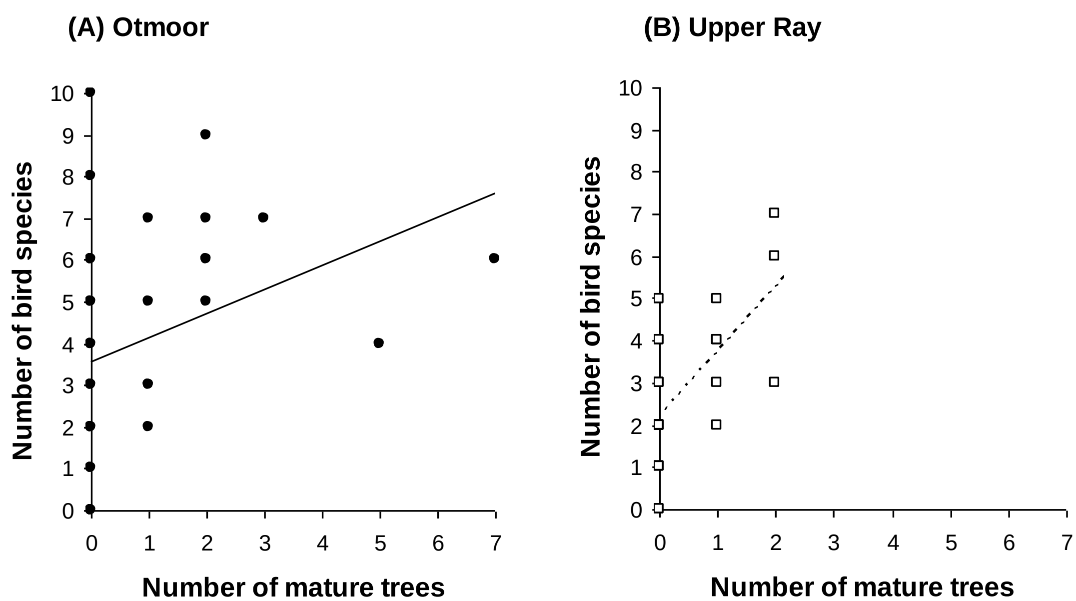


Figure 4.16 Relationship between number of mature hedgerow trees and bird species richness at Otmoor and Upper Ray. Trend lines are displayed for significant relationships (P<0.05). Otmoor: y = 0.57x + 3.57, Upper Ray: y = 1.54x + 2.19.

Number of woody species

The richness of woody plant species counted in the hedgerow transects did not show clear patterns of distribution like the other attributes (Figure 4.17). Flailed hedgerows unexpectedly harboured the highest numbers of woody plants at both sites, and wildlife-layed hedgerows the fewest. The differences between treatments, however, were not large enough to be significant at either site.

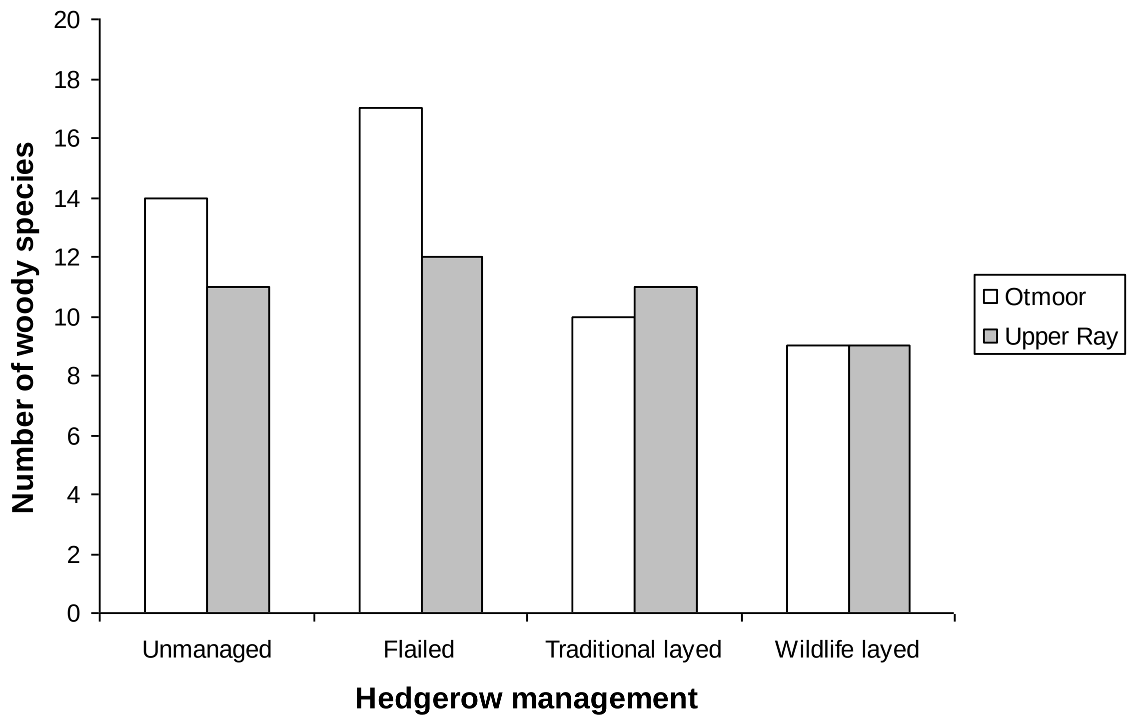


Figure 4.17 Woody plant species richness of each hedgerow treatment at both study sites.

Regression analysis revealed no significant trends of bird abundance (Figure 4.18, next page) or species richness (Figure 4.19) with woody species richness. The figures suggest that the highest abundance and richness of bird species is found in transects with an intermediate number of woody plant taxa (six at Otmoor, seven at Upper Ray).

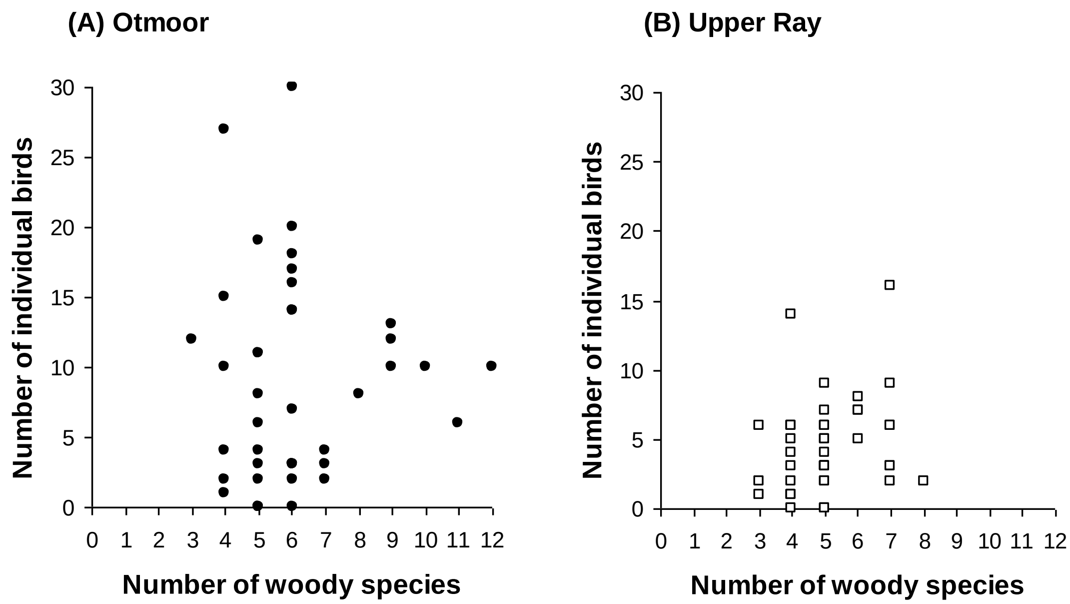


Figure 4.18 Relationship between woody species richness and bird abundance at Otmoor and Upper Ray. These relationships are not significant (P>0.05).

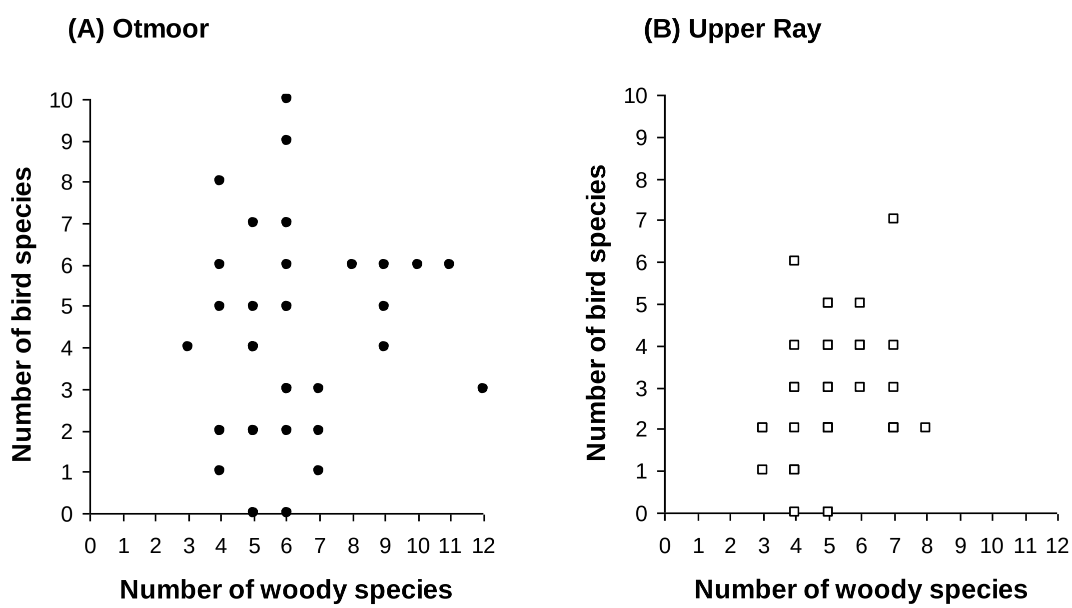


Figure 4.19 Relationship between woody species richness and bird species richness at Otmoor and Upper Ray. These relationships are not significant (P>0.05).

Chapter 5: Discussion and Conclusion

The results of the study are discussed below and links to existing research on hedgerow birds are explored. The observed variance in breeding bird distribution with hedgerow management is explained with regard to the structural and botanical characteristics of the different hedgerows. Limitations and possible improvements in the study methodology are discussed and the chapter concludes with some suggestions for further work and management recommendations.

5.1 Bird distribution and hedgerow management

Breeding bird abundance

The main aim of this study was to determine whether, during the breeding season, birds were distributed unevenly between hedgerows under different management regimes. In terms of all species abundance this was found to be the case. At both sites there was a clear preference for overgrown, unmanaged hedges. Of the hedges that were managed, those subject to regular maintenance by mechanical flail trimming supported more birds in total than those recently restored by hedgelaying. This pattern fits with the findings of previous research on hedgerow management and bird populations, such as Moore *et al.*'s 1967 study on hawthorn and elm hedgerows in the East Midlands reported by Pollard *et al.* (1974). Furthermore, although the RSPB's hedgerow management strategy at Otmoor Reserve was the main focus of this study, the results from Upper Ray showed the same broad pattern of bird distribution. This suggests that these findings are not simply the result of a particular set of ecological factors operating at one site.

Perhaps a more important population indicator than the total number of birds is the abundance of potential breeders, in this case singing male birds. Here the picture is less clear. At Otmoor the trend was similar to the one observed for all birds and it was significant. At this site breeding use of the hedgerows can be explicitly linked to management: male birds preferentially used unmanaged hedgerows for song posts, suggesting a greater territory density along those hedgerows. By contrast recently layed hedgerows supported the fewest songbirds and it can be reasonably inferred that territories in these hedges were sparse. The fact that several (presumed same) individuals were recorded singing from the same parts of particular transects over weekly visits adds weight to the evidence for territories being held in those transects. Given more time and resources, territory mapping using CBC techniques would be able to confirm this (Marchant, 1983). However it should be noted that holding a territory is not in itself a measure of breeding success; males are not guaranteed to attract a mate and nests in good quality territories can still fail.

At Upper Ray the distribution of possible breeders did not vary significantly between hedgerows even though the distribution of all birds did. This result is difficult to explain because the probability of encountering singing birds should be higher in a hedge supporting a larger number of birds overall. In fact songbirds at this site formed a lower proportion of the total recorded (roughly one third) than at Otmoor and it may be that the numbers observed were too low to reveal any significant trends. Or perhaps the resources used by breeding birds, such as insect food and nest cover, were fewer at Upper Ray and more evenly distributed between the hedgerows.

These trends held when the data were reanalysed without birds recorded in mature trees included. The aim was to demonstrate that the patterns of abundance across hedgerow treatments were not simply due to of the presence of trees in particular transects, especially as unmanaged hedgerows had more trees (see Figure 4.14, page 49). Several studies have shown that hedgerow trees positively influence bird numbers and species richness (e.g. Arnold, 1983; Green *et al.*, 1994; Macdonald & Johnson, 1995; Sparks *et al*., 1996). This influence was potentially great enough to mask the effect of shrub layer management, which was of primary interest to this study. Excluding tree records would not completely control for this effect because bird numbers in the shrub layer may also be positively affected by the presence of a nearby tree (Lack, 1992). However, because the distribution patterns were largely unchanged by this exercise it is reasonable to conclude that the trends in abundance are mainly due to hedgerow management and not mature trees. The effect of hedgerow trees is revisited in the next section of this chapter.

The differences in bird abundance between the two hedgelaying treatments are of particular interest. As outlined in Chapter 2, there is anecdotal evidence that wildlife-layed hedges provide a better habitat for birds and other wildlife (Dodds, 2005) but this has not been tested empirically. This technique has only been trialled in Buckinghamshire and Oxfordshire since 2000 and there is a clear need for scientific evidence on its wildlife value if the practice is to be more widely adopted. At both sites a significantly different number of birds were recorded in wildlife-layed and traditionally-layed hedgerows, although interestingly at Upper Ray only this was only true of possible breeders and not all birds. This result is most likely due to differences in the size of the layed hedgerows, and hence the amount of available nesting habitat – this is explained further in the next section.

The results provide evidence of the influence of management age on bird numbers. This factor was controlled at Otmoor by selecting hedgerows that had been recently layed. At this site wildlife-layed hedges supported three times as many birds in total, and nearly six times as many possible breeders, as those layed by the traditional method. At Upper Ray, where the wildlife-laying had mostly been carried out over the previous winter and the traditional laying 4–5 years previously, the latter treatment contained more possible breeders. This is because hedges that were layed earlier have had longer to regrow and can provide more song posts, nesting habitat and cover. Similar total numbers of birds may have been recorded in the two treatments because the wildlife-layed hedgerow counts were boosted by the presence of trees in some transects; when tree records were excluded wildlife-layed hedges held significantly fewer birds (Figure 4.2, page 37).

Although the quantity of data gathered was insufficient to test the hedgerow preferences of individual species some general patterns of abundance did emerge at Otmoor, where most of the bird surveys were conducted. Unsurprisingly, five of the commonest woodland birds (blue tit, chaffinch, robin, woodpigeon and wren) were most abundant in tall, unmanaged hedges resembling a woodland edge, with decreasing numbers recorded in flailed and layed hedges. The presence of these common species probably had the greatest influence on the patterns of abundance discussed above. Chaffinch, wren and great tit showed a small preference for wildlife-layed over traditionally-layed hedges while blue tit and robin avoided layed hedges altogether.

The chaffinch was the most abundant species recorded, which reflects its breeding success on lowland farmland while many other common and widespread species have declined. Hedgerows play an important role in this; up to 75% of visits made by adults foraging for young are to shrubs and trees within field boundaries (Whittingham *et al.*, 2001). However from a habitat management perspective the rarer and specialist hedgerow birds are probably of most interest. Several species of conservation concern were observed during this study as detailed in Chapter 4. The most frequently recorded of these was the Red-listed reed bunting. This wetland bird is usually associated with reed beds but it also makes use of the herbaceous ground flora of hedgerows for nesting and foraging (Pollard *et al.*, 1974). It was most abundant in wildlife-layed and flailed hedges at Otmoor and least abundant in unmanaged and traditionally-layed hedges, which probably reflects its preference for short, thick structures that provide good cover at the base. The sedge warbler, another wetland bird with similar habitat preferences, showed the same distribution pattern. It should be noted though that the hedges where these species were most often found were near to open water and reed beds, and this may have boosted their numbers in those transects.

Using analyses of farmland and woodland CBC data from the 1990s, Fuller *et al.* (2001) identified seven species that were closely associated with hedgerows and could be regarded as hedgerow specialists: dunnock, whitethroat, lesser whitethroat, linnet, goldfinch (*Carduelis carduelis*), greenfinch (*Carduelis chloris*) and yellowhammer. These were all recorded in this study, although only whitethroat occurred frequently. This bird showed a preference for wildlife-layed and flailed hedgerows, although the usual caution about small sample size applies. Like the wetland birds, the whitethroat prefers dense cover for nesting at a hedge base. It could be argued that hedgerow breeding resources are most valuable to specialists like the whitethroat and that hedgerow management should therefore aim to meet the needs of these species. This approach leads to an inherent conflict, however, in that the habitat requirements of different species vary and do not always match the hedgerow characteristics that support the greatest number of individuals or species in general (Hinsley & Bellamy, 2000). Even the hedgerow specialists show considerable variation in their preferences for particular attributes such as height, length of woody vegetation and number of trees (Fuller *et al*., 2001). Thus successful management lies in achieving a heterogeneous mix of hedgerow types and structures to provide essential resources for many different species.

Species richness and diversity

In contrast to abundance, measures of bird species richness and diversity showed little or no variation across the hedgerow treatments. Although the distribution patterns broadly followed those of abundance, with the highest numbers of species recorded in unmanaged hedgerows and the lowest numbers in layed ones, these differences were mostly not significant. This was particularly the case at Upper Ray, where the Jacknife estimated number of species in each treatment was fairly uniform. This may be due to the relatively low number of species recorded at this site over the six weekly visits (22 in total and 10 breeding) such that distribution trends were harder to detect than at Otmoor, which was sampled over a longer time period and generally had a more diverse birdlife. Another explanation is that the number of breeding species that could be supported by the Upper Ray hedgerows, and to a lesser extent those at Otmoor, was determined by resource limitation (e.g. several rarer farmland species including linnet and yellowhammer require the seeds of weedy plant species in their diet, which would have limited their ability to nest in the transects lacking a herbaceous margin). Thus while larger hedgerows with a greater amount of habitat could support more birds in total, the number of species may have been limited at Upper Ray by food availability and other essential breeding requirements.

This explanation is supported by the Shannon diversity index results (Table 4.1, page 40) which indicated a relatively low species diversity that did not vary significantly between treatments. This suggests that across all hedgerows a few commoner species, such as chaffinch and wren, tended to dominate by contributing a higher proportion of individuals to each transect count than the scarcer species; in other words the species were unevenly distributed (Krebs, 1999). Indeed common woodland species are the ones most frequently observed breeding in hedgerows (Hinsley & Bellamy, 2000). The hedgerows in this study may have provided resources to support only the commoner and more generalist species in most transects.

Even so, breeding species richness at Otmoor did vary significantly with hedgerow management, with unmanaged hedges supporting approximately 20 species, wildlife-layed hedges 9 species, flailed hedges 8 species and traditionally-layed hedges 4 species. This suggests that hedgerows layed using the wildlife method may be of equal value in supporting breeding species to those flailed on three year rotation, which is an established wildlife-friendly management practice (Winspear & Davies, 2005).

5.2 Hedgerow size and composition

The second part of this study set out to identify the particular hedgerow characteristics that explained the variance in bird distributions between management types. Based on inspection of the raw data and the findings of similar studies, three measures of hedgerow size (height, width and volume) and two measures of hedgerow composition (number of mature trees and number of woody shrub species) were identified as the most likely factors to determine bird numbers (Arnold, 1983; Osborne, 1984; Green *et al.*, 1994; Parish *et al.*, 1994, 1995; Macdonald & Johnson, 1995; Sparks *et al*., 1996; Chamberlain & Wilson, 2000). Importantly, these attributes are all affected to some degree by the type and age of management. An overgrown hedge that has not been trimmed for several years will typically provide a much denser structure in which to nest than a thin, recently layed one. It may also contain more large trees.

The approach of this study was to test each of the five attributes separately and look for individual associations with the bird distribution data using linear regression, rather than to attempt a multivariate analysis which pooled all the variables together. The advantage of multivariate methods like Principle Component Analysis (PCA) and Stepwise Multiple Regression (SMR) is their ability to separate out the independent variables that best explain observed variance. This circumnavigates the problem of high intercorrelations between variables like height and width which make it hard to interpret their relative importance (Macdonald & Johnson, 1995). However such detailed analysis was deemed unnecessary for the purposes of this study, which was principally interested in testing for differences between hedgerow management treatments. Relationships between factors such as bird abundance and hedgerow height have been examined by a number of studies and are comprehensively reviewed by Hinsley & Bellamy (2000). Nonetheless it was desirable to plot each hedgerow attribute against the bird data to reveal any trends that might be related to the management used at the two study sites.

Hedgerow size

The hedgerows at both sites were quite similar in structure, averaging 3 m high, 2 m wide at the top and 3 m wide at the base. This puts them in a 'medium' size category (2–4 m high and wide) which is generally favoured by many breeding bird species (e.g. Sparks *et al*., 1996; Hinsley *et al*., 1999 cited in Hinsley & Bellamy, 2000) and probably reflects the fact that these hedges are being managed for wildlife. Height and width varied significantly between treatments at both sites and followed the same patterns as observed in the bird data. Thus the tallest and widest hedgerows at Otmoor were the unmanaged ones and the shortest and thinnest were those traditionally-layed. The unmanaged hedgerows tended to have outgrowths of blackthorn and more perennial weeds at the base, providing better cover for birds like whitethroat that prefer to nest and forage in this part of the hedge (Pollard *et al*., 1974). Tall, overgrown hedgerows also tend to support more common woodland birds like the robin, which use the upper branches as prominent song posts. Recently-layed hedges, by contrast, appeared better suited to scrubland birds like the linnet, which is known to prefer short hedges for nesting in (Macdonald & Johnson, 1995; Chamberlain & Wilson, 2000).

Most of the traditionally-layed hedgerows at Otmoor were very short and thin (1–2 m) which was in part due to the fact that several had been annually trimmed after laying, a practice not used on the wildlife-layed hedges. It is significant that wildlife-layed hedgerows at this site were both wider at the base and taller than those layed using traditional methods, given the strong positive trends of bird abundance and species richness observed with increasing hedgerow size (Figures 4.6–4.7, page 44 and 4.9–4.10, page 46). It is clear that the retention of side branches and the ability to lay over more woody material using this method provides more nesting habitat than standard methods. It is interesting that the tallest hedges at Otmoor did not support the most individual birds or bird species, which corroborates the theory of an 'optimum' height of around 2–3 m, above which the threat of predation from above makes it increasingly risky to nest (Macdonald & Johnson, 1995).

The size trends at Upper Ray were mostly significant (bird abundance and hedgerow width being the exception) but they were less obvious. This is probably because there was less variation in the height and width of hedges at this site. Nonetheless, traditionally-layed hedgerows, which had been layed some years previously, were significantly bigger than wildlife-layed ones and this is probably why they were able to support higher numbers of breeding birds. This provides further evidence that the long-term effects of restoration should be considered in hedgerow management decisions, and that the size advantage of wildlife-layed hedges is likely to be greatest in the 3–4 years immediately following the work but may subsequently diminish.

It is no surprise that hedgerow volume showed similar trends to height and width because volume is a function of these variables, i.e. the cross-sectional area of the hedge along a given length. The other determiner of volume, the length of gaps in the shrub layer, was less than 10% in all but one of the transects surveyed. Gaps comprising 10% or less of a hedgerow's length are considered unlikely to be important to bird abundance or richness (Lack, 1992) and it is reasonable to infer from this that the hedgerows at Otmoor and Upper Ray are suitably intact to provide a good habitat for birdlife. Simple positive relationships with hedgerow volume have been demonstrated using measures of bird incidence (Green *et al.*, 1994) and species richness (Parish *et al.*, 1994) and it follows that a larger volume of woody material can provide better cover, more foraging opportunities and more space in which to establish territories. The clear linear trends of volume with bird abundance and richness at Otmoor (Figures 4.12–4.13, page 48) confirm this.

The high correlations between the three size attributes mean that it is impossible to conclude which is the most important to bird distribution in this study. It is probable that hedgerow height, which showed the weakest regression relationship of the three attributes, is less important than the other two, and so management decisions to increase overall bird diversity in the hedgerows should not necessarily be made on height alone. Based on these results, the practice of laying tall hedgerows to reduce predation pressure on the young of ground-nesting waders is likely to significantly reduce the overall abundance and richness of breeding birds in those hedgerows in the first three or four years after management. However this negative impact can be reduced by keeping layed hedges at least 2 m tall and 2 m wide and planting up or filling gaps with deadwood.

Number of trees and woody species

At both study sites overgrown and unmanaged hedgerows had the most mature trees, presumably because a lack of regular trimming had allowed more saplings to become established. The trees were mainly oak, with some ash and willow in the wetter parts of the sites. It was evident early on that the presence of trees could positively influence hedgerow bird numbers because common species such as blue tit and chaffinch were frequently observed singing and foraging in the upper branches. Trees are clearly an important component of the hedgerow complex and their removal from farm hedges due to crop shading effects has undoubtedly reduced their value to woodland birds, although lapwings and other open field species that avoid trees may have benefited (Tucker *et al.*, 1994 cited in Hinsley & Bellamy, 2000).

It was expected that the large number of trees in unmanaged hedgerows at Otmoor would help to explain their high bird abundance; however the regression analysis of tree number and bird abundance did not support this conclusion (Figure 4.15, page 50). It may be that these trees provided value as song posts to a few individuals while the majority of birds breeding in unmanaged hedges preferred the cover of the woody shrubs. Tree number did positively influence bird richness, suggesting the provision of a greater diversity of food and other resources to suit a wider range of species, particularly if there is more than one species of tree. Interpretation of the Upper Ray data is limited by a small sample size, but it does appear that the presence of two trees in a transect coincides with the highest numbers of individuals and species. Green *et al.* (1994) reported that the incidence of several bird species was strongly related to tree number and this tended to increase with up to one or two trees in a 30 m hedgerow length. A higher tree density may not be beneficial to overall abundance because linnet and other scrubland birds may be deterred from nesting in hedgerows with many trees.

The correlation analysis revealed that trees were associated with larger hedgerows at Otmoor but not at Upper Ray. At the former site hedgerow size showed the highest positive correlations with the bird variables while at the latter it was tree number. Thus mature trees may have played a bigger role in determining bird distribution at Upper Ray. This is significant because large mature trees generally fall outside the scope of trimming and hedgelaying management. Although, as described earlier, bird distribution trends across management treatments were largely unaffected by excluding tree records from the analysis, it is difficult to rule out trees as a significant influence on breeding bird distribution at this site. This is particularly true of the wildlife-layed hedgerows in which several trees were located. At Otmoor hedgerow trees are subject to greater management (for instance older willows are rejuvenated by pollarding) and bird distribution appears to be more explicitly linked to hedgerow size, which is to a large degree a function of management type. Therefore conclusions about the merits of different management techniques for breeding birds can be made with a higher degree of confidence at Otmoor than at Upper Ray.

The number of woody species in a hedgerow had little or no effect on breeding bird distribution in this sample. This is surprising because other studies have shown that plant species-rich hedgerows support more individuals and species due to their ability to provide a greater structural complexity and diversity of food resources (e.g. Green *et al*., 1994; Parish *et al*., 1994, 1995; Macdonald & Johnson, 1995). Hedgelaying using traditional methods often necessitates the removal of bramble (*Rubus fruticosus* agg.) and other species growing out from the hedgerow base, in order to provide access to the main structural shrubs. However this was not a significant influence in this study because the different hedges harboured roughly the same numbers of woody plant species. This would explain why patterns of bird abundance and richness were unrelated to this attribute. It is probable that woody species richness is determined by hedgerow age more than any other factor (Lack, 1992) and as the hedges studied dated back to Enclosure they would likely have developed a similarly-diverse woody flora. Woody species richness may have had a small effect on the quality of the breeding habitat but this was probably masked by the effects of hedgerow size and tree number on habitat availability. It would be interesting to test the effect of this attribute over a wider range of hedges to see whether links to management and bird distribution emerge.

5.3 Review of survey methods

The transect methods used in this study allowed a relatively large amount of data to be gathered simply and efficiently, without the need for complicated equipment or a high level of previous field experience. The surveys were successful in generating meaningful data for comparison, largely because they were based on established bird survey (Green *et al*., 1994; Macdonald & Johnson, 1995) and hedgerow survey (DEFRA, 2007) techniques which were easy to adapt. Even so, a number of limitations to the survey methods were encountered along the way and the main ones are discussed below with suggestions for possible improvements.

Accurately identifying and counting birds which were often hidden deep in the hedgerow proved challenging and necessitated the help of an experienced birdwatcher on the bird surveys, particularly for the less conspicuous species and non-singing individuals. Distance sampling methods, in which the observer records bird observations in set distance bands to correct for undercounting bias, are used in transect surveys (Bibby *et al.*, 1992) but were considered difficult to apply to a highly linear feature like a hedgerow where only one side is observed. It is highly likely that the less conspicuous species such as dunnock and stationary individuals (e.g. females sitting on eggs) were undercounted, an effect that would be exacerbated in wider and denser hedgerows. Furthermore the relatively low bird counts obtained for individual transects over the survey period gave greater weight to the more common and conspicuous species in the final dataset, as the Shannon index results confirmed. Several authors caution against drawing general conclusions about best management practice for birds when rarer and threatened species are underrepresented in species richness or abundance data (Green *et al.*, 1994; Parish *et al*., 1994).

Using Jacknife estimates of species richness helped to partly correct the undercounting of larger hedgerows including the overgrown, unmanaged ones. Further improvements could be gained by surveying both sides of the hedgerow at the same time (one observer walking along each side) providing access was not an issue. A much larger sample of hedges would also increase the chances of encountering the rarer species. The study was constrained by limitations on time and resources and were it conducted again, e.g. as a PhD, a comprehensive census using territory mapping methods would be able to yield much more detailed data on individual species–habitat associations linked to hedgerow management, and provide a better indication of breeding activity (i.e. number of territories held) than relying on the song behaviour of individual male birds. This would also avoid the problem of inadvertently repeat-counting the same individuals over multiple visits leading to overestimates of abundance for some species.

It was difficult to control some of the factors that were not explicitly linked to hedgerow management but could have influenced bird distributions. For example the presence of adjacent features such as wet ditches are known to benefit hedgerow birds due to their associated invertebrate fauna (Hinsley & Bellamy, 2000) while the shading of north-facing hedgerows may reduce insect activity and hence their value to breeding birds (Lack, 1992). No attempt was made to estimate hedgerow age using Hooper's Rule due to limitations on the reliability of this method (Clements & Tofts, 1992). These factors would undoubtedly have had some effect on the results of this study, although a review of the literature indicated that they were likely to be minor in comparison to the effects of hedgerow size and trees. Even classifying hedgerows into discrete management types was harder than expected because some 'unmanaged' hedges revealed signs of flailing and pollarding that only became evident during the detailed hedgerow surveys. The inherently variability in the landscape, and within individual hedgerows, means that it is extremely difficult to exclude all outside influences. The result was a non-random sample design driven by the necessity to find suitable lengths of hedgerow that met the criteria for inclusion. A wider sample of hedges (particularly wildlife-layed hedges) and a better controlled environment, such as the experimental hedgerow plots at Monks Wood Research Station in Cambridgeshire (CEH, 2008) would help to improve data accuracy.

This study would also benefit from being conducted over a longer time period, say three to five years. This would have two advantages. Firstly, seasonal effects could be investigated, for example yearly changes in food availability that may impact in different ways on the breeding success of different hedgerow birds. The effect of management regime on a hedgerow's ability to provide berry crops and roost sites to overwintering species such as the thrushes is an area in need of further research (Barr *et al*., 2005). Secondly, such a study would allow a detailed investigation of the long-term effects of hedgerow management on breeding and wintering birds. This could involve comparing bird abundance and richness before and after different types of management work, or comparing the woody regrowth rates of the two hedgelaying methods over several years, as Croxton *et al*. (2004) have done on coppiced and pollarded hedges. Little is known about the effect of the frequency of hedgelaying on bird populations and it would be interesting to investigate how often wildlife-layed hedges would need to be re-layed to maintain a dense, rejuvenated structure for birds and other wildlife, in comparison to other restoration methods.

5.4 Conclusion

In summary, this study set out to investigate whether hedgerows managed using different methods were able to support a different abundance and richness of passerine birds during the April to June breeding season and this objective has been met. Results from both the sites sampled revealed that overgrown, unmanaged hedgerows held the highest numbers of birds in total and the highest numbers of possible breeders. Hedgerows maintained by flail-cutting on three year rotation also held large numbers of breeding birds and hedgerows that had been recently restored using hedgelaying techniques were relatively thin on birdlife. Patterns of species richness were not as strong as those of abundance and while the number of breeding species did vary significantly between hedgerow types at Otmoor, further data are needed to reliably confirm that this trend is real. Further investigations are also required to reveal the preferences of individual species for particular hedgerow types, although it is reasonable to infer from previous studies that common woodland birds in the study area would prefer tall, overgrown hedges and those of scrub and open country (which include several lowland farmland species of conservation concern) would prefer or at least tolerate short hedges with good cover at the base.

The height, width and volume of the sample hedges was very clearly linked to the type of management used on them, and this in turn explained much of the variance in the bird distributions. As a general rule, larger hedges can provide a greater abundance and diversity of breeding resources such as nest sites, food and shelter, and so they are more valuable to the majority of breeding birds. However, as noted above, this rule does not apply to all species and the key to maximising hedgerow bird diversity is to provide a heterogeneous mix of hedgerow structures at the same site (e.g. see Hinsley & Bellamy, 2000). At Otmoor and Upper Ray this has been achieved by using a mixture of hedgerow management regimes. The presence and number of mature hedgerow trees was also an influential positive factor and it is recommended that these features are maintained as part of ongoing hedgerow management to provide nest sites and foraging resources that are otherwise lacking in the sparsely-wooded open landscape of the River Ray catchment.

The study has provided good preliminary evidence that wildlife-layed hedgerows are beneficial for breeding birds in the short term because they retain a greater volume of woody material and a wider hedge base than those layed in the normal fashion. When hedges of similar management age were compared higher numbers of birds were recorded in the wildlife-layed hedges; further work is needed to establish whether they can support a greater diversity of breeding species as well. However hedges layed using traditional methods that had 4–5 years longer to regrow and establish a dense structure were able to support many more birds than recently-layed wildlife hedges. A useful next step will be to compare the regrowth rates of different restoration methods (hedgelaying and coppicing) to determine which type can provide the best habitat in the long term for birds and other wildlife, taking into account variations in woody plant species composition and environmental conditions on the regrowth of hedgerow shrubs (Croxton *et al*., 2004).

A final point is that the management of hedgerows for birds should not be considered in isolation from management of the wider countryside. Many bird species use hedgerows as part of a wide network of resource patches and woodland birds may only use hedgerows for breeding because suitable woodland habitat is unavailable when populations are at high densities (Lack, 1992; Hinsley & Bellamy, 2000). Hedgerows also play an important role in landscape connectivity for other creatures such as the dormouse (Bright & MacPherson, 2002). Thus any work to benefit hedgerow wildlife should fit into a management strategy that coordinates nature conservation efforts across the site and wider area.

Appendix 1: Bird Survey Form

Date:	Weather:
Observers:	Wind:
Start time:	Start point:
End time:	End point:

Survey unit	Species	No.	Sex	Location where first registered			Activity			
				Hedge	Tree	Margin	Song	Forage	Nest	Other

Appendix 2: Hedgerow Survey Form

Date:	Surveyors:	Start time:	End time:
Weather:			

REFERENCE			
Survey unit	Landowner	Orientation of side surveyed	Grid reference
		N E S W	SP

MAIN ADJACENT LAND USE (Phase 1)	Side A	Side B
B2.1 Unimproved neutral grassland		
B2.2 Semi-improved neutral grassland		
B4 Improved grassland		
J1.1 Arable		

ADJACENT FEATURES					
Within 10m	Side A	Side B	Within 30m	Side A	Side B
Dry ditch			Woodland		
Wet ditch			Open water		
Path/track			Reed bed		
Fence					
Separate hedgerow					

DIMENSIONS			
Average height (m)	Average top width (m)	Average base width (m)	% gaps in canopy

MATURE TREES (>10m high)					
Species	No.	Height (m)	Species	No.	Height (m)
Oak (*Quercus* sp.)					
Ash (*Fraxinus excelsior*)					
Willow (*Salix* sp.)			TOTAL NO:		

WOODY SPECIES (excluding mature trees)				
Species	Present	Species		Present
Blackthorn (*Prunus spinosa*)				
Bramble (*Rubus fruticosus agg.*)				
Hawthorn (*Crataegus* sp.)				
Hazel (*Corylus avellana*)				
Willow (*Salix* sp.)		TOTAL NO:	DOMINANT SP:	

MANAGEMENT			
Management age	< 3 years	4-6 years	> 6 years
Management type	Main: U F T W	Secondary: U F T W	

NOTES

Appendix 3: Bird Survey Results

Numbers of all birds and breeding birds of each species recorded at Otmoor (400 transect visits) and Upper Ray (240 transect visits).

		Otmoor		Upper Ray	
		All	Breeding	All	Breeding
Blackbird	*Turdus merula*	11	3	9	0
Blackcap	*Sylvia atricapilla*	0	0	1	0
Blue tit	*Parus caeruleus*	50	7	14	2
Bullfinch	*Pyrrhula pyrrhula*	5	0	7	1
Carrion crow	*Corvus corone*	1	0	4	0
Chaffinch	*Fringilla coelebs*	48	17	43	17
Chiffchaff	*Phylloscopus collybita*	4	3	0	0
Cuckoo	*Cuculus canorus*	1	1	0	0
Dunnock	*Prunella modularis*	5	3	6	4
Fieldfare	*Turdus pilaris*	3	0	0	0
Goldfinch	*Carduelis carduelis*	2	1	2	0
Great tit	*Parus major*	14	4	9	2
Greenfinch	*Carduelis chloris*	6	1	0	0
Lesser whitethroat	*Sylvia curruca*	6	2	1	0
Linnet	*Carduelis cannabina*	5	0	2	0
Long-tailed tit	*Aegithalos caudatus*	11	0	2	0
Magpie	*Pica pica*	6	0	4	0
Meadow pipit	*Anthus pratensis*	0	0	2	0
Pheasant	*Phasianus colchicus*	1	0	0	0
Red-legged partridge	*Alectoris rufa*	1	0	0	0
Reed bunting	*Emberiza schoeniclus*	38	12	16	5
Robin	*Erithacus rubecula*	25	21	11	9
Sedge warbler	*Acrocephalus schoenobaenus*	26	17	0	0
Song thrush	*Turdus philomelos*	2	1	1	1
Starling	*Sturnus vulgaris*	0	0	1	0
Whitethroat	*Sylvia communis*	20	6	12	9
Willow warbler	*Phylloscopus trochilus*	4	4	0	0
Woodpigeon	*Columba palumbus*	9	0	16	0
Wren	*Troglodytes troglodytes*	35	31	11	10
Yellowhammer	*Emberiza citrinella*	2	1	3	0
Unidentified	–	19	0	6	0
Total	–	360	135	183	60

Appendix 4: Hedgerow Survey Results

Summary of hedgerow structural and botanical characteristics and associated landscape features recorded at Otmoor (40 transects) and Upper Ray (40 transects). # = number of transects.

		Otmoor	Upper Ray
Dimensions			
Mean height (m)	–	2.80	2.78
Mean top width (m)	–	1.95	2.20
Mean base width (m)	–	2.68	3.18
Mean width (m)	–	2.31	2.69
Mean volume (m^3)	–	290.10	314.95
Mean gaps in canopy (%)	–	1.25	2.25
Mature trees			
Number of ash	*Fraxinus excelsior*	9	0
Number of oak	*Quercus* spp.	19	7
Number of willow	*Salix* spp.	2	5
Mean tree number	–	0.8	0.3
Mean tree height (m)	–	12.8	12.6
Woody species			
# Ash	*Fraxinus excelsior*	9	4
# Beech	*Fagus sylvatica*	0	1
# Bittersweet	*Solanum dulcamara*	13	15
# Blackthorn	*Prunus spinosa*	37	38
# Bramble	*Rubus fruticosus* agg.	37	28
# Buckthorn	*Rhamnus cathartica*	7	4
# Crab apple	*Malus sylvestris*	1	3
# Dog rose	*Rosa canina*	36	31
# Dogwood	*Cornus sanguinea*	2	1
# Elder	*Sambucus nigra*	2	2
# Elm	*Ulmus* spp.	7	10
# Field maple	*Acer campestre*	8	6
# Field rose	*Rosa arvensis*	6	4
# Hawthorn	*Crataegus* spp.	39	40
# Ivy	*Hedera helix*	3	0
# Oak	*Quercus* spp.	13	7
# Spindle	*Wuonymus europaeus*	5	0
# Spurge-laurel	*Daphne laureola*	1	0
# Travellers-joy	*Clematis vitalba*	2	0
# Wild privet	*Ligustrum vulgare*	3	3
# Willow	*Salix* spp.	13	8
Mean number of species	–	6.1	5.1
# Ash dominant	–	1	0
# Blackthorn dominant	–	24	4
# Elm dominant	–	1	1
# Hawthorn dominant	–	14	35

Appendix 4 continued.

		Otmoor	Upper Ray
Orientation (side surveyed)			
# North	–	4	0
# East	–	16	23
# South	–	3	17
# West	–	17	0
Adjacent features			
# Ditch within 10 m	–	23	35
# Bank within 10 m	–	15	0
# Path/track within 10 m	–	28	5
# Fence within 10 m	–	16	32
# Hedgerow within 10 m	–	18	4
# Woodland within 30 m	–	1	0
# Open water within 30 m	–	14	2
# Reed bed within 30 m	–	4	0
Adjacent land use (on each side of hedgerow)			
Unimproved grassland	–	3	18
Semi-improved grassland	–	59	55
Improved grassland	–	7	7
Scattered scrub	–	7	0
Swamp	–	4	0

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