BTO Research Report No. 538

Understanding the Causes of Decline in Breeding Bird Numbers in England

Collated by
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Report submitted by the British Trust for Ornithology, Royal Society for the Protection of Birds and Centre of Agri Environmental Research

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CONTENTS

Page No.

Page No.

Page No.

Page No.

LIST OF TABLES

Page No.

Page No.

Page No.

LIST OF FIGURES

Page No.

Executive Summary

1. To meet biodiversity policy commitments, there is an urgent need to develop a robust and comprehensive evidence base of the population status, species resource needs, and potential drivers of decline in declining bird species. This report reviews evidence concerning known and likely causes of decline in nine species in the England wetland bird indicator and 18 species in the England woodland bird indicator, provides the results of preliminary analyses of factors influencing wetland bird trends, additional analyses of the Repeat Woodland Bird Survey dataset, and a regression tree analysis using data on farmland birds and their resource requirements. We then assess potential conservation actions and make recommendations on priorities for future research to fill the gaps in existing knowledge.

2. The first objective was to review the evidence for known and likely causes of decline for each of the declining birds in the woodland and wetland indicators for England. Agricultural intensification and the resulting decrease in the quality and quantity of breeding habitat is thought to be the main driver of the declines in species breeding on wet grasslands and moorland. Large areas of grassland have been drained and converted into arable land. The management of much of the remaining grassland and moorland has become far more intensive and has included extensive drainage, increased use of pesticides and fertilizers, re-seeding, earlier and more frequent mowing and increased grazing pressure. The resulting habitat changes are likely to affect foraging efficiency (through impacts on abundance and availability of invertebrates), availability of nest sites and susceptibility to predation. Earlier spring grass growth, earlier cutting dates and higher stocking levels have increased egg and chick mortality and reduced relaying opportunities. A reduction in the area of mixed farming systems has also reduced the availability of high-quality foraging habitat (e.g. pasture) to birds breeding in arable areas. In the uplands, agricultural improvement has also intensified. Changes in the timing of the sowing of crops have reduced habitat suitability of arable land, with spring-sown cereals, the nesting crops of some wetland species, being widely replaced by autumn-sown cereals. This has also resulted in a loss of winter stubbles, a preferred feeding habitat for over-wintering granivorous species such as Reed Bunting. An increase in numbers of predators, concurrent with changes in habitat are thought to have increased rates of predation and made nests and chicks more vulnerable. Acidification of upland streams is cited as the main factor contributing to past declines in Dipper populations. Decreased rainfall in wintering grounds has reduced the quality of habitat in Africa for some of the migrant species. Sea level rise has resulted in loss of coastal breeding habitats for other species, notably Redshank. Predicted climate change is likely to exacerbate population declines of some species as it is likely to result in further loss of coastal habitats to sea level rise and increased frequency of spring floods and droughts are likely to have an impact on water availability and hence habitat quality.

3. For woodland species, the cessation of active management and woodland maturation, together with over-grazing by deer in many areas, has resulted in large scale changes in structure and many woodland species' population declines are linked to these factors. Changing woodland structure as a result of one or both of these factors may be linked to the decline of thirteen of the woodland species as coppice and early succession habitats and low vegetation cover in woods has reduced nest site availability and foraging areas. Many of the species in the woodland indicator are long-distance migrants and changes in conditions on wintering grounds or on migrations require further study as well as factors operating on breeding grounds. Several woodland species have also shown relationships with climatic variables and so changes in the future climate are likely to effect populations, although several species may actually benefit from climate change. Fragmentation of woodlands and reduced connectivity may be an important contributory driver of decline for at least nine species in the woodland indicator. Agricultural intensification in habitat surrounding woodlands may be a contributory driver in the decline of the song thrush. Loss of hedgerows, scrub and permanent grassland and the widespread installation of drainage may all have had an impact on some species. The

role of competition should be considered a potential contributory factor for Willow Tit, Marsh Tit and Lesser Spotted Woodpecker. Changes in the timing of invertebrate emergence and laying dates of some migratory woodland species may have resulted in mis-timing in the availability of resources. A reduction in food resources may also be linked to the decline in Lesser Spotted Woodpecker, Bullfinch, Lesser Redpoll and Song Thrush. Nest predation may be a contributory pressure for several woodland species.

4. The second objective aimed to identify known and likely causes of changes by analysis of spatial and temperate patterns in bird numbers against appropriate environmental datasets. Wetland birds associated with wet meadow habitats were more likely to be declining, as were, to a lesser extent, reed bed species. Species associated with either fast flowing or slow/standing water bodies increased overall. As a group, those species that commonly use farmland declined (primarily since this group comprised largely the same species as for wet meadows) whereas those that did not commonly use farmland in the breeding season increased. African migrants were also more likely to be in decline than resident species**.** Five out of seven species with significant regional variations in declines were declining faster or recovering more slowly in the Midlands than elsewhere in their range. Declines were faster on arable land for Curlew and Snipe. Large scale analysis of land cover also suggests that Sedge Warbler had faster declines in areas with a higher proportion of arable land. Almost all species were significantly less common in areas surrounded by an increasing proportion of farmland, especially pastoral grassland. This analysis also revealed a possible negative impact of local urban development and woodland area on breeding wetland birds with 4/9 and 5/9 species being significantly scarcer in areas of increasing urban and woodland area respectively.

5. Analysis of woodland birds tested four potential drivers; soil moisture, predation by avian predators, climate change and landscape scale effects. Few relationships were found between declining woodland bird species and soil moisture, suggesting that this may not be an important driver of decline, although this study was limited to a single geographical area and there is no information of how soil moisture has changed through time. In terms of the impact of avian predators, no negative associations were found between declining species and Jay abundance, suggesting predation by this species may not be a cause for concern. There was however, negative relationships between Great Spotted Woodpeckers and Tree Pipit and Willow Warbler. Relationships were detected between declining species and changes winter climate, suggesting that changes in this variable could be having a negative impact on a number of species. Species affected include both migrant and resident species, and woodland specialists and generalists. It seems that there is support for the hypothesis that landscape scale effects are having some impact on some declining woodland bird species. Many relationships were found between the presence, abundance and population change of declining species and landscape scale variables.

6. The key gap in our understanding of the processes driving continued declines in farmland birds is the relationship between field scale resource availability and national population dynamics. We develop a farm-scale model which can provide a rapid assessment of the impacts of land-use change on national bird populations and can be used to explore spatial variation in the threshold levels of resource availability associated with stable/increasing populations. The analyses show that there are a number of land-use combinations associated with declining or stable/increasing population trends, suggesting that there are a number of potential drivers of decline. Furthermore, for 12 of the 19 farmland bird index species there is evidence of regional variation in the drivers of population trajectory and therefore targeted delivery of specific management options may be beneficial. We believe the approach should be applicable to both woodland and wetland birds in the future and therefore has the potential to provide valuable insights into the links between local-scale land use and national population trends for these two species groups.

7. For Objective 3 we reviewed existing conservation actions and identified further priority actions to reverse population declines. For wetland birds, conservation actions are focused on changing specific agricultural practices to provide sufficient resources for breeding populations, but it is also important to protect key wintering sites. Agri-environmental measures are the current mechanism to achieve this. There may be a need for targeting of scheme effort, as the site fidelity of several of these species suggests that creation of new habitat in areas far from existing populations may not be successful. On grassland, ensuring strong or moderate grazing pressure the previous autumn to maintain short areas of sward and delaying grazing turnout in spring should help produce the required heterogeneous sward conditions whilst minimizing the effects of trampling. Maintaining the right grazing pressure on saltmarshes is also important for Redshank. Raising water levels, introducing surface flooding, and managing water levels to ensure that wet areas are maintained throughout the season is also key in order to provide foraging areas. These measures should also benefit other species such as Yellow Wagtail, Reed Bunting and Sedge Warbler. In terms of minimising the impact of predation on ground-nesting birds, manipulating surrounding habitat structure to remove cover for predators is important. Habitat restoration and creation, and better management of existing habitat, are key to reversing the declines in wetland species. In terms of current policy measures, the Higher Level Scheme (HLS) of Environmental Stewardship (ES) offers what is probably the best opportunity to do this. The Entry Level Scheme (ELS) has limited scope. Conservation measures that target wet meadow habitats are likely to have the widest and most profound benefits for wetland species as a whole. Given the notably sharp declines on arable land, as well as the fact that five of the nine declining species are already less abundant in pastoral dominated landscapes, this suggests that arable habitat should also be treated as a priority for conservation action.

8. For woodland species, Environmental Stewardship and the England Woodland Grant Scheme, which provide funds for woodland management targeted at a species or suite of species, have the potential to deliver some recovery for many woodland birds where habitat is thought to be an issue. Options for boundary features and in-field trees can be beneficial to some species. Establishing the ability to control grazing, restoring neglected coppice stands, enhancing wide rides with scrubby edges, developing a scrubby woodland edge, creating new woodland and allowing thicket stages to develop should all be of benefit to several woodland species. Providing buffers and increasing connectivity are also important. New woodland planting will improve connectivity, although mature trees are preferred. Restructuring of closed canopy woodland to open up areas for successional species, in particular birch, will provide habitat for species such as Lesser Redpoll. Species requiring wet woods and damp features within woods, such as Song Thrush, Willow Tit, Marsh Tit and Hawfinch may benefit from actions to reverse drainage inside and outside of the woodland. Deadwood retention is of importance to hole-nesters. However, although some woodland birds could benefit from options in ELS, it is doubtful that these options alone will deliver woodland bird recovery. ELS is aimed primarily at agricultural options and is of most benefit to farmland birds. Generalist species will benefit from many of the options, but specialists such as Hawfinch and Lesser Spotted Woodpecker are unlikely to. Furthermore, ELS can deliver nothing to enhance within-woodland habitat quality. Targeted actions through HLS and EWGS offer more potential for woodland improvement.

9. Objective 4 aimed to identify a set of priorities for future research to address key gaps in the evidence base. For wetlands the highest priorities are quantifying the impact of agricultural intensification and identifying management techniques to counter these, studies on the role of semi-natural habitats, investigating the impact of predation and the development of improved modelling procedures to help to identify key habitat or management requirements and critical stages in the life cycle (productivity, winter survival) influencing population trends.

10. For woodland species the most important area of new research is to investigate structural change due to lack of management and deer and there is a need for trial management experiments to establish the most appropriate methods of reversing trends. There is also a need to understand the interaction between woodland management and deer browsing in modifying woodland understory structures and the consequences for habitat quality in woodland birds. Research into whether appropriate stand structures can be attained in the presence of deer is particularly valuable *e.g* through fencing or control methods. Trial management to find suitable grazing regimes in upland oak woods would be of benefit for Wood Warbler.

11. The intensification of agriculture comprises a suite of potential impacts on wetland breeding birds that are difficult to separate, including effects on vegetation density and structure, insect abundance and availability, as well as the availability of cover for predators. For the species in the wetland bird index, this mainly refers to the intensification of grassland management on lowland wet grasslands and in the uplands. Work should focus on identifying habitat management techniques that counter the effects of grassland intensification and that could potentially be incorporated into agri-environment measures. Priority areas that need addressing include.

12. There is a need better to quantify the impact of predation on the overall population dynamics (overall productivity and recruitment to breeding population) of declining wetland species, particularly the ground-nesters (Curlew, Snipe, Redshank, Lapwing, Yellow Wagtail). The ultimate cause of population declines is not an increase in predation or an increase in predators but what has caused those increases. We need to understand the mechanisms by which predators respond to the environment and thus affect their prey, so that appropriate habitat management measures can be designed. Research should focus on the ecology, behaviour and population dynamics of predators, explore the role of different predator species in nest and chick predation, and consider interactions with habitat.

13. Investigating the importance of specialised habitats within the broader landscape is another priority area, and needs to be carried out at several spatial scales, for instance, reserves within the broader landscape, or features such as wet areas within farms. This will provide information on patch sizes or networks needed to support viable populations of the breeding waders in the wetland bird indicator.

14. Predictive and demographic models can help to identify key habitat or management requirements and critical stages in the life cycle (productivity, winter survival) influencing population trends. There is scope for adapting these approaches for a broader suite of birds including some key declining wetland (and woodland) birds. The use of Bayesian approaches will make the most out of sparse data. Dedicated field research could fill gaps in knowledge regarding demography and habitat-specific survival/productivity**.**

15. For long distance migrants where there is evidence of effects on wintering grounds, work in Africa which sets out to establish specific wintering areas, habitat needs and threats will increase our knowledge of the species and may provide solutions to population change. There is a need to establish how land-use and other changes in Africa such as habitat loss, human encroachment, habitat degradation through agricultural intensification, and a range of other climatic variables (rainfall, storm frequency) may impact on survival.

16. Studies examining food availability for various woodland species are needed. For example, studies that are able to assess how food resources have changed over time or become mis-matched with species need would be valuable. Specific research by species would also be worthwhile. For example, the availability of earthworms in woodlands for Blackbirds and Song Thrush, food availability for Bullfinch and Lesser Redpoll in different age stand structures. Investigation into the link between beech mast years and Jay population declines,

investigations into the abundance of winter and summer food resources for Lesser Spotted Woodpecker and the role of invertebrate availability and abundance in the declines of Wood Warbler. Food availability for Willow Tit and Lesser Spotted Woodpecker may be linked to soil moisture content of woodland soils and this merits further study.

17. Autecological studies of some of the less well researched species such as Lesser Redpoll, Hawfinch, Common Sandpiper and Reed Bunting would help provide further information to enable us to understand the causes of declines. Work on grassland management, habitat models and meta-population processes, disturbance and water table dynamics is needed for wetland species and work looking at the role of competition, the drying out of woodlands, woodland fragmentation and the role of invasive species in population declines of woodland species would also be useful.

1. INTRODUCTION

There is a great deal of research information available on the causes of the decline and options for conservation of farmland birds and, to a lesser extent, on woodland and wetland birds. The aim of this work is to bring this research together, identify common themes and set out actions that deliver conservation benefits for all three groups. There are four specific objectives:

1. To review the evidence for known and likely causes of decline for each of the birds in the woodland, wetland and farmland indicators for England.

2. To identify known and likely drivers of changes by analysis of spatial and temporal patterns in bird numbers against appropriate environmental datasets.

3. To review existing actions and identify further priority actions to reverse the decline in bird populations based on the development of selected modelling frameworks.

4. To identify a set of priorities for future research to address key gaps in the evidence base underpinning the actions needed to reverse the declines in England's farmland, woodland and wetland breeding birds.

This report was written by BTO, RSPB and CAER, and collated by BTO. The first objective is addressed in the first chapter, by way of literature reviews. For each of the species in the wetland and woodland indicators, the review summarises the current population status and trends (including any differential spatial trends within England) alongside their resource requirements, habitat associations and known or likely limiting factors (including climate and land use change). Presented here are executive summaries of two lengthy research reports which contain more detailed information on species accounts.

Objective 2 examines likely causes of decline against bird abundance data. There are three chapters, one for the wetland species, one for the woodland species and one for the farmland species. The wetland and woodland analyses explore the potential drivers behind the declines in bird species, using analysis of existing bird survey data and environmental data sets. The chapter addressing the decline in farmland birds is based on bird abundance and habitat data collected from the 1km squares covered by both the Breeding Bird Survey (BBS) and Winter Farmland Bird Survey (WFBS) and focuses on assessing niche space availability.

Objective 3 presents the results of an objective assessment of drivers in the breeding declines of species in the wetland and woodland bird indicator and makes links, where possible, between key drivers and appropriate conservation actions to mitigate the effects of these drivers. The information collated in the literature reviews and the analyses carried out in Objective 2 provides a detailed evidence base to inform decisions about potential conservation actions to reverse the declines, such as habitat management options and possible policy changes. Using this information, consultation with experts, and drawing on other relevant work, the key drivers identified by the matrix analysis can then be related to actions to reverse the population declines. This includes those currently available under agri-environment initiatives, as well as actions identified as priorities for future development and implementation.

Finally, objective 4 focuses on a discussion of gaps in the knowledge and aims to identify the key priorities for research in the future.

2. REVIEW OF KNOWN AND LIKELY CAUSES OF DECLINE FOR DECLINING SPECIES IN THE WETLAND BIRD INDICATOR FOR ENGLAND

2.1 Review of the Resource Requirements and Causes of Decline of Wetland Birds

Sarah Eglington (BTO)

The following is a summarized version (an executive summary) of the full literature review, which will be published as a BTO Research Report

2.1.1 Introduction

To meet the biodiversity policy commitments there is an urgent need to develop a robust and comprehensive evidence base of the population status, species resource needs, and potential drivers of decline for wetland birds through a combination of literature reviews and the use of statistical modelling approaches. Some species in the wetland bird indictor for England are increasing (i.e. Coot, Mute Swan and Oystercatcher) but this report reviews evidence concerning known and likely causes of decline in the nine species in the indicator which are declining; Common Sandpiper, Curlew, Dipper, Lapwing, Redshank, Reed Bunting, Sedge Warbler, Snipe and Yellow Wagtail.

Birds of the Western Palaearctic and the search engines Google Scholar and Web of Knowledge were used to carry out a comprehensive literature search for each species.

2.1.2 Individual species declines and distributions

There is consensus among survey results that Common Sandpiper numbers have been declining in England since the mid-1980s. There is no indicator trend for England, but the species underwent an 18% decline in the UK between 1994 and 2007 (Risely *et al.* 2009). Its European breeding population is large at more than 720,000 pairs but the species has suffered widespread declines, and undergone a moderate decrease in numbers (>10%, Birdlife International 2004). In the UK, the Common Sandpiper is a migrant breeder and a passage/winter visitor. It is widespread in upland areas and there are approximately 24,000 pairs in Britain, although only 2138 of these are estimated to occur in England (Dougall *et al.* 2004). There is speculation that failure of Sahel rainfall in some years may have caused poor over-winter survival rates of first year birds (Holland and Yalden 2002) although other factors, notably poor breeding success, have also been suggested as possible factors for population declines.

Despite an increase in Curlews nesting alongside waterways, most data point towards a long-term decline in England. BBS data show that the short-term trend between 1994 and 2007 is a 21% decline for England and a 38% decline for the UK (Risely *et al.* 2009). Combined CBC/BBS data indicate a 29% decline between 1967 and 2005 (Baillie *et al.* 2007). Curlews monitored by CBC were mostly in lowland habitats and may have been affected primarily by drainage of farmland (Gibbons *et al*. 1993). It is a widespread breeder across much of northern Europe where some smaller populations were stable or increased during 1990–2000 but key populations in the United Kingdom, Finland and Russia all declined, and overall, the species underwent a moderate reduction in numbers (>10% Birdlife International 2004). Population declines are likely to be driven by the low production of young (Berg 1992, 1994).

Dipper have shown fluctuations in their population in England but have in general shown a slight decline. Due to small sample size there are no trends for England, but in the UK, Dipper declined by 12% between 1994 and 2007 (Risely *et al.* 2009). It is a widespread but patchily distributed resident in the more mountainous areas of Europe, in the UK being widespread in the north and west. Breeding performance has improved strongly over time; broods are on average larger, and there has been substantial reduction in failure rates of nests at the egg stage but the most recent trends still show that

Dipper populations are declining, suggesting some mechanism other than breeding success may be important (Baillie *et al.* 2007).

Lapwing have declined in numbers in most habitats in the UK over the last few decades although BBS data indicate a shallow increase (6%) in England since 1994 (Risely *et al.* 2009). On lowland wet grassland sites in England and Wales, Lapwing declined by 38% between 1982 and 2002 (Wilson *et al.* 2005). It is a widespread breeder across much of Europe although has a 'vulnerable' status due to population declines (Birdlife International 2004). Declines are likely to be driven by low productivity, in part due to changes in agricultural practice, resulting in breeding performance lower than that required to maintain population stability (Siriwardena *et al.* 2000, Newton 2004).

Redshank have undergone a 19% decline in England between 1994 and 2007 (Risely *et al.* 2009). Evidence suggests that Redshank are undergoing a prolonged slow decline, both in lowland grassland and coastal habitats, and within the uplands**.** It is a widespread breeder across Europe but has a 'declining' status (Birdlife International 2004). The highest densities of Redshank in Britain occurred in coastal areas of East Anglia and north-western England. Breeding densities tend to be highest on saltmarsh and coastal grassland but breeding success here can be low, due to a combination of low hatching success resulting from predation and tidal flooding, and poor chick survival (Smart 2005). Adult survival rates can have a large effect on the productivity required to maintain a stable population (Otvall & Harding 2005).

Reed Bunting underwent steep declines during the 1970s, followed by a period of relative stability and in recent years the population has shown signs of increasing in England. Combined CBC/BBS data for England show a 22% decline in Reed Buntings between 1967 and 2006 (Baillie *et al* 2007), although BBS data for England show a 25% increase between 1994 and 2007 (Risely *et al.* 2009). Reed Buntings are widespread in Britain, although are much less common in upland areas. They were formerly restricted to marsh or riverine areas but are now found on rough ground in agricultural areas. First-year (and, to a lesser extent, adult) survival decreased during the late 1970s and the 1980s and these were sufficiently large to have caused the population decline, although low breeding success may have prevented subsequent recovery (Peach *et al*. 1999).

Although Sedge Warbler shows fluctuations in its population, most datasets indicate a long-term decrease in numbers. BBS data shows that the species underwent an 12% decline in England between 1994-2007 (Risely *et al.*2009) although CBC/BBS data for England show a 33% decline between 1967 and 2005 while WBS data points to 20% decline from 1975-2005 (Baillie *et al.* 2007). The Sedge Warbler is a migrant breeder and passage visitor to Britain, wintering in tropical and southern Africa. Much of the year-to-year variation in population size has been driven by changes in adult survival which, in turn, are related to changes in rainfall on their wintering grounds, just south of the Sahara Desert, in the West African Sahel (Peach *et al.* 1991).

In England, numbers of Snipe have fallen rapidly since the 1970s. BBS data suggest that the UK population may be showing signs of recovery although country population trends vary. The combined BBS/CBC/WBBS/WBS trend in England from 1974 to 2007 shows an initial decline followed by a recovery between 1976 and 1982 (Baillie *et al.* 2007) and BBS data show a 14% increase in England (Risely *et al.* 2009). The snipe is a migrant/resident breeder and a passage/winter visitor in the UK. It is widespread, but now relatively scarce on farmland. There are a number of potential drivers in the decline of breeding snipe with habitat quality, breeding season food availability and reduced breeding success being the most likely candidates (Baines 1988, Green 1988, Newton 2004).

In recent decades, Yellow Wagtail have experienced marked declines in abundance and range in Britain, and more widely across Europe. The species declined by 48% in England between 1994 and 2007 (Risely *et al.* 2009), trends derived from combined CBC and BBS data suggest that the Yellow Wagtail decreased by 68% between 1978 and 2003 in England and WBS data recorded a 96% decline between 1975 and 2005 (Baillie *et al.* 2007). It is a summer visitor to Britain, wintering in sub-Saharan Africa. It appears that British Yellow Wagtails are declining in range and abundance in pastoral regions, but increasing in arable regions and showing at least population stability in mixed farming regions (Chamberlain and Fuller 2001).

2.1.3 Resource requirements

The diet of all species except Reed Bunting is composed of predominantly invertebrates year round. Reed Bunting diet consists of mainly invertebrates during the breeding season, although adults and young will consume a variable amount of seeds. During the winter, the diet is composed mainly of seeds when they feed on open ground and cultivated fields.

Common Sandpiper is usually associated with clear lakes, rivers or streams, particularly fast-flowing rocky upper courses with stony, shingly, or rocky edges although time is also spent feeding on wet grassy areas. Dippers are associated with fast-flowing streams and rivers with rocks, boulders, shingle, water-falls and rock outcrops with shallow water.

The waders (Curlew, Lapwing, Redshank and Snipe) have similar broad habitat preferences, favouring wet grasslands in the lowlands and in the uplands, poorly drained moors and rough grass fields. Lapwing, and to a lesser extent, Curlew, also breed in arable fields, while Redshank are also abundant on saltmarsh. Sward height preferences vary, with Curlew preferring medium to tall (10-54cm) tussocky vegetation, Lapwing favouring a short (<15 cm) tussocky sward, Redshank showing preference for tall swards of around 10 - 40 cm and Snipe requiring soft damp ground with a 'tussocky' sward of around 10-30 cm. All four species show positive correlations with site wetness and the provision of surface water and are more likely to persist in fields where the soil conditions are wet and soft, with more standing water and soil moisture.

Yellow Wagtails are often associated with water, but this is not an essential requirement and many birds breed on dry arable farmland in the UK, especially spring-sown crops. They breed in habitats as diverse as lowland wet grassland, arable crops, heathland, upland pastures and hay meadows, requiring heterogeneous swards to provide the appropriate foraging and nesting habitats. Reed Bunting breed on farmland, semi-natural grassland and riparian habitats, often associated with wet margins and their nests are located in thick vegetation near the ground. Oil-seed rape fields have become a favoured arable habitat. Sedge Warblers in farmland breed around the fringes of water in ponds and water courses although they also breed in arable fields. They show a preference for dense vegetation generally along the water's edge, usually avoiding wetter reedbeds in standing water.

2.1.4 Drivers of population change

2.1.4.1 Climate change

Fluctuations in population levels and annual adult survival rates of Sedge Warbler since the late 1960s are strongly correlated with indices of wet season rainfall in the West African winter quarters. Mortality rates of wintering Sedge Warblers increased in years with poor rainfall in West Africa and habitat availability in the winter quarters has probably been the main factor limiting the size of the population in Britain during 1963-1988 (Peach *et al.* 1991). Although Yellow Wagtail also winter in Africa, there is no good evidence to suggest that this factor has had a major contribution to the population decline in this species. However, there is speculation that failure of Sahel rainfall in some years may be at least partly responsibly for poor over-winter survival in first year Common Sandpipers as a result of lower food supplies (Holland and Yalden 2002).

Climate, impacting to increase the frequency and severity of spring and summer flooding since the early 1980s, has been implicated in the decline of Snipe at the Ouse Washes, one of the key lowland wet grassland breeding areas for this species (Green 1988). Spring and summer flooding is thought to reduce breeding success by decreasing the amount of time available for re-nesting following clutch loss as flooding delays the onset of nesting by up to

70 days. However, this is not thought to be the main driver of the population declines on a national level.

For Redshank, loss of coastal breeding grounds as a result of climate change leading to sea level rise may be an issue in the future but there is no clear evidence that saltmarsh losses due to sea-level rise have so far caused reductions in bird populations at a national level (Norris *et al.* 2004, Fuller and Ausden 2008)..

2.1.4.2 Habitat loss and degradation

The main reason for the decline of grassland waders (Curlew, Lapwing, Redshank and Snipe) is thought to be habitat destruction and reduction in the quality of habitats that remain (*e.g.* Newton 2004, Wilson *et al*¸2004, Fuller and Ausden 2008). Breeding habitat has been lost due to changes in agricultural practices, particularly drainage and the intensification of farming. Large areas of grassland have been drained and converted into arable land. The management of much of the remaining grassland has become far more intensive over recent decades and has included extensive drainage, increased use of pesticides and fertilizers, re-seeding, earlier and more frequent mowing and increased grazing pressure. The rapid changes in sward height associated with the intensification of grassland management may affect the foraging efficiency, the availability of nest sites and susceptibility to predation. Earlier spring grass growth, earlier cutting dates and higher stocking levels have increased egg and chick mortality and reduced relaying opportunities. A reduction in the area of mixed farming systems has also reduced the availability of high-quality foraging habitat (e.g. pasture) to birds breeding in arable areas, resulting in reduced breeding success. These changes are also likely to have had an impact on Yellow Wagtail (*e.g.* Newton 2004, Fuller and Ausden 2008) and may also have been responsible for preventing Sedge Warbler populations from recovering from population losses due to poor conditions in the wintering grounds (Foppen *et al.* 1999).

The loss of small wet features such as ponds, field drainage, and the dredging and straightening of rivers and streams is likely to have reduced the suitability of large areas of farmland as a breeding habitat for Reed Bunting (Peach *et al.* 1999, Brickle and Peach 2004). However, this has probably occurred continuously during the 20th century and it is not clear how the loss of such habitat could have caused the relatively sudden population decline between 1976 and 1983 (Peach *et al.* 1999).

Agricultural improvement (drainage, inorganic fertilizing and, in some cases, reseeding) of grasslands in the uplands has also progressed rapidly. Around 20% of upland heather moorland present in England and Wales in the mid 1940s has changed due to agricultural reclamation, high grazing pressures, bracken *Pteridium aquilinum* invasion, afforestation and peat extraction (Thompson *et al.* 1995). The main effects of increased grazing pressure on upland breeding birds are likely to be loss of preferred vegetation types, and the alteration of food supplies and predation pressure.

For those species which nest on arable land (Lapwing and Yellow Wagtail and to a lesser extent Curlew and Reed Bunting) the change in the timing in the sowing of crops has had an important impact on habitat suitability (*e.g.* Newton 2004). Spring-sown cereals were once favoured nesting crops but these have been widely replaced by autumn-sown cereals. The use of autumn crops has resulted in the creation of apparently suitable sites that quickly become untenable as crops grow above acceptable height limits. The large-scale switch from spring-sown to autumn sown crops in the 1970s also resulted in a loss of winter stubbles, a preferred feeding habitat for over-wintering Reed Buntings. However, despite the continued loss of spring-sown cereals since 1983, Reed Bunting numbers have remained relatively stable (Peach *et al.* 1999).

For Redshank, loss of coastal breeding grounds is also an issue. Current loss of saltmarsh is estimated to be more than 100 ha per year in the UK, attributable to coastal squeeze. Inappropriate grazing on many of the remaining saltmarshes has caused further problems. Figures suggest that inappropriate grazing management affects an area of saltmarsh three times larger than the area estimated to be lost to erosion over the next 20 years. The increase in grazing intensity between 1985 and 1996 was found to be sufficient to account for the observed changes in Redshank density on saltmarshes in Britain (Norris *et al.*, 1998).

2.1.4.3 Pollution

There is some concern about the possible indirect effects of ivermectins on birds that feed in, or around, animal dung (McCracken and Bignal 1991), such as Yellow Wagtail but the scientific evidence for these effects are limited.

2.1.4.4 Predation

Predation is thought to be a major driver in the declines of breeding waders and recent empirical evidence suggests that levels of predation on wader nests are unsustainably high (*e.g.* MacDonald and Bolton 2008). In many cases, predation may be limiting the recovery of wader populations, where breeding habitat is otherwise favourable. An increase in numbers of predators and changes in habitat are thought to have made wader nests and chicks more vulnerable to predation.

2.1.4.5 Disturbance

For ground-nesting waders, loss of eggs and chicks due to farming operations is likely to be an important cause of failed breeding attempts (*e.g.* Berg 1992) although the impact of these losses on population size have rarely been quantified. Losses attributable to farming operations are especially pronounced in spring cereals and stubbles where agricultural activity often coincides with the peak nesting period of Curlew and Lapwing (Sheldon 2002). Loss of nests to trampling is also an issue for ground-nesting waders on grassland (*e.g.* Bientema and Muskens 1987, Berg 1992). Although grazing is essential to produce swards of the requisite height and structure, the presence of livestock can depress productivity through nest trampling or disturbance. The frequency and date of grass cutting is important for birds nesting in agricultural grasslands, particularly in silage fields and the increase in cultivation procedures is likely to be responsible for increased destruction of Yellow Wagtail clutches (*e.g.* Newton 2004).

2.1.4.6 Food availability

The increased intensity of farming is thought to have resulted in reduced food supplies for breeding waders as there is evidence to suggest that management intensity influences the size abundance, availability and diversity, of invertebrates. The loss of insects associated with cattle has been cited as a possible cause of the decline in Yellow Wagtails (Gibbons *et al.* 1993, Newton 2004, Nelson *et al.* 2003).

Acidification of upland streams resulting from afforestation and the resulting acid deposition is cited as the main factor contributing to the declines in Dipper populations (Fuller and Ausden 2008). Adults spend more time foraging on more acidic streams because of the decreased abundance of food. At sites of high acidity, reduced brood sizes, low nestling survival and the low incidence of second breeding attempts result in a significant reduction in total productivity at acidic compared with non-acidic sites (Vickery 1992). Although more recently there have been signs of recovery from acidification, the ecological effects are marginal and there is evidence that there is still significant episodic acidification in acid-sensitive areas of Britain (Omerod and Durance 2009), which probably explains the slow biological recovery in many locations.

The most likely cause of the decline in the British Reed Bunting population is the loss of suitable food and habitat on farmland resulting from changes in agricultural practices (Peach *et al.* 1999). Granivorous species such as Reed Bunting are most likely to be limited by the problem of a late-winter 'hungry gap' in food availability (Siriwardena *et al.* 2008) while the abundance of invertebrate prey may limit breeding productivity through its effect on the number and condition of chicks fledged (Brickle and Peach 2004).

Low rainfall in the wintering grounds is thought to have resulted in decreased food supplies in these habitats for Sedge Warblers.

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2.2 A Review of the Resource Requirements and Causes of Decline in Woodland Birds

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The following is a summarised version (the executive summary of the full literature review), which will be published as RSPB research report No. 37.

2.2.1 Introduction

Of 35 species in the woodland indicator for England, 19 are showing population trends below the baseline year estimate. We identified 18 of these to be priorities for knowledge reviews and for each in turn, using a standardised search protocol, summarised the available information on: British population status and trend, distribution and demographic changes, changes in demographic parameters, migration and movements, resource requirements, diet, habitat associations, impacts of environmental change and impacts of biological change.

2.2.2 Species summaries

The indicator trend for Blackbird reports an overall decline of 18% between 1970 and 2007. BBS results show a 25% increase in the UK and 23% increase in England between 1995 and 2007 (Riseley *et al.* 2009) The RWBS (Hewson *et al.* 2007, Amar *et al.* 2006) show a stable or increasing population trend over a 20 year time period and the species may now be said to be recovering from the earlier declines. The species is reliant on large amounts of cover being available for nesting (Hatchwell *et al.* 1996) and may have suffered from changes in woodland structure through cessation of active management. Overgrazing by deer could be a potential issue in some areas. Being a generalist species, common in arable habitats, loss of and degrading of hedgerows could be acting as population sinks, impacting some populations. The species has also been shown to suffer high predation rates that may add further pressure on populations (Hatchwell *et al.* 1996, White *et al.* 2008). However, more extensive work has not found a link between blackbird populations and their potential nest predators (Carpenter and Charman, 2009). A review of predation by Gibbons *et al.* (2007) suggests that there is some evidence that magpie predation rates of blackbird nests is unsustainably high in one small study area (Groom, 1993). However, the same review presents several references with no evidence of the impacts of predations on blackbird populations in the UK.

There is good evidence for long-term population decline of the Bullfinch (the indicator reports a 55% decline between 1970 and 2007). Short term BBS trends suggest a 11% decline between 1995 and 2007 in the UK and a 13% decline in England (Risely *et al.* 2009). Bullfinch is Amber-listed in BoCC (Eaton *et al.* 2009) and is a UK Biodiversity Action Plan species. The demographic mechanisms underlying the Bullfinch's decline are uncertain but one popualtion modelling study suggests that a change in daily nest failure rate during the incubation period could be a factor (Siriwardena *et al.* 2001). Predation rates have been intensively studied for this species in one area of

England and it was a major issue affecting nest success in woodland in this area (Proffit, 2002). Gibbons *et al.* (2007) found no evidence for the an impact of predators on bullfinch populations. The species also relies on a mixed understory and shrub layer for nesting and feeding (Proffit, 2002, Carpenter *et al.* 2008), which has been degraded in many woodlands (Amar *et al.* 2006) as a result of wood maturation and deer browsing. Given their apparent reliance on birch seeds at certain times of the year the Bullfinch may also be suffering from maturation and loss of of birch in woodland and loss of scrub habitats (Carpenter *et al.* 2008). Furthermore, the loss of hedgerows and fragmentation of woodlands may be playing a role in Bullfinch population decline.

According to indicator figures, Dunnock has declined by 32% between 1970 and 2007. Short term BBS results show a 21% increase in the UK and 15% increase in England (1995-2007) (Risely *et al.* 2009). The RWBS report a 5.8% decline and a 13.0% increase (BTO and RSPB data respectively) between the early 1980s and 2003/04 (Hewson *et al.* 2007, Amar *et al.* 2006). Dunnock is Amber-listed in BoCC (Eaton *et al.* 2009) and is a UK Biodiversity Action Plan species. Egg stage daily nest survival rates have declined through the period of decline (Baillie *et al.* 2009). Canopy closure as a result of low levels of forest management and increasing browsing by deer are likely to have reduced the suitability of habitat for this species (Fuller *et al.* 2005). Low shrub cover is needed for nesting and there is concern over loss of this habitat in some woods, possibly because of deer. The degradation of woodland edges (internal and external) may also be a factor in the decline. The species mostly uses arable habitats rather than woodland and could be affected by hedgerow and agricultural practices.

The population trend for Garden Warbler has fluctuated through time after an initial decline and subsequent increase in the 1970s. The indicator trend is currently showing a 6% decline since the base year although other monitoring such as BBS and the RWBS shows larger declines over shorter time periods. The BBS trend between 1995 and 2007 shows a 16% decline in garden warbler in the UK and 17% decrease in England (Risely *et al.* 2009). The RWBS showed a 25.6% and 39.4% decline for BTO and RSPB data respectively (Hewson *et al.* 2007, Amar *et al.* 2006). Nests losses at the chick stage may be substantial and productivity has declined (Baillie *et al.* 2009). As long distance migrants, very little is known about this species on its wintering grounds. Garden Warblers have advanced their laying dates but mis matched breeding and food availability may still be having an impact. The species is associated with young successional scrubby woodland including both young plantations and coppice, both of which have declined in extent and changed in structure as a consequence of deer browsing (Amar *et al.* 2006). Bramble is a key habitat requirement for nesting and foraging and this has decreased in many woods because of deer browsing and changes in woodland.

The woodland indicator shows a 21% decline in Goldcrest numbers, although the species remains widespread. BBS reports a 33% increase between 1995 and 2007 in the UK and a 35% increase in England (Risely *et al.* 2009) and the RWBS showed a 138.3% and 87.5% increase according the BTO and RSPB data (Hewson *et al.* 2007, Amar *et al.* 2006). Goldcrest populations are known to be negatively affected by winter temperatures and fluctuations in numbers occur as a result of harsh winters. The species may also be suffering in some areas because of woodland fragmentation or felling of conifers (Nour *et al.* 1999, Carpenter *et al.* 2008). There is limited evidence from one study that food availability may be an issue (Haftorn, 1982). No information is available on demographic parameters for this species.

Data for Hawfinch are sparse, however, both the woodland indicator and other monitoring sources report large declines. The indicator shows a 19% decline in the population between 1970 and 2007. RWBS trends showed a decline of between 17.4 an 73.5% bases on BTO and RSPB data respectively (Hewson *et al.* 2007, Amar *et al.* 2006). Hawfinch is a UK BAP species and is Red-listed in BoCC (Eaton *et al.* 2009). Hawfinch is one of the species in the woodland indicator for England that has declined the most and for unknown reasons. There has been a striking contraction in the range however no reasonable demographic data is available. The species has a need for mature woodland in a heavily wooded landscape (Smart *et al.* 2008, Dunn and Charman, 2008). It is also a species considered most vulnerable to nest predation by squirrels. Amar et al (2006) found that hawfinch was more likely to have declined at sites with a higher density of grey squirrels.

Jay populations have fluctuated according to several monitoring schemes. BBS shows a 13% increase in the UK and a 4% increase in England between 1995 and 2007 (Risely *et al.* 2009). The RWBS reported declines between the early 1980s and 2003/04 of 19.9% (RSPB data) and 26.8% (BTO data). Given their dependence on acorns and beech seeds, population fluctuations for Jay are likely to be linked to mast years. The species preference for semi-natural, rather than agricultural, surrounding landscapes could also have played a part in population changes as woods in some areas have become increasing fragmented and isolated (Carpenter *et al.* 2008). Jays are also dependent on mature and ancient trees that are decent seed producers.

Lesser Redpoll is the species with the largest decline in the woodland bird indicator, showing a 96% reduction in population since 1970. The BBS trend for the UK between 1995 and 2007 is a 15 increase, but in England it is a 33% decrease (Risely *et al.* 2009). The RWBS reports a decline of 88.9% and 58.7% (RSPB and BTO data) (Hewson *et al.* 2007, Amar *et al.* 2006). Lesser Redpoll is Red-listed (Eaton *et al.* 2009) and a UKBAP species. It is suggested that a decline in survival and productivity may have led to the Lesser Redpoll decline (Siriwardena *et al.* 1998). As with Bullfinch, the importance of birch in the diet is highlighted. The species prefers scrub, pioneer woodland that can quickly become unsuitable. However, much suitable habitat remains unoccupied by lesser redpoll, suggesting another factor is responsible for the decline.

All datasets record a severe and rapid decline in the Lesser Spotted Woodpecker population. The woodland bird indicator shows a 72% decline between 1970 and 2007. The RWBS reports a 43.6% and 58.9% decline according to BTO and RSPB data respectively (Hewson *et al.*, 2007, Amar *et al.* 2006). Lesser spotted woodpecker are Red-listed (Eaton *et al.* 2009) and a UK Biodiversity Action Plan species. The demographic causes of decline are not yet known, although there is low breeding success in some populations. The species has a requirement for mature, open woodland and large areas of woodland at a landscape scale (Charman *et al.* in press). Competition with and nest predation by Great Spotted Woodpecker is a suggested mechanism for the decline although evidence is lacking. Reductions in small diameter deadwood for foraging may be playing a role in the decline, but again, this requires investigation.

Overall, the data for Marsh Tit provides evidence of a long-term population decline. BBS shows a 22% decline between 1995 and 2007 in the UK and a 23% decline in England (Risely *et al.* 2009) and the RWBS showed a 27% decline according to BTO data and a 26% increase according to RSPB data (Hewson *et al.* 2007, Amar *et al.* 2006). The species is Red-listed (Eaton *et al.* 2009) and a UKBAP species. It is suggested that Marsh Tit declines are related to reduced annual survival and that neither increased predation or competition is responsible (Siriwardena 2006). Loss of understory and shrub layer in some areas and habitat fragmentation is highly likely to be playing a role (Amar *et al.* 2006, Hinsley *et al.* 2007).

Nightingale has declined according to data in the woodland bird indicator. BBS reports a 41% decline between 1995 and 2007 in the UK and a 37% decline in England (Risely *et al.* 2009). The species as not covered adequately in the RWBS. Nightingale is Amber-listed in BoCC (Eaton *et al.* 2009). CES reports a sharp decline in productivity, possibly related to weather conditions. Nightingales depend on scrub habitats within woodland and on areas of woodland with very dense low vegetation. Especially within woodland, their preferred habitats can be seriously modified by deer browsing (Gill and Fuller 2007). Changes in land-use, such as the reduction in active coppice management, maturation of lowland conifer plantations, and scrub invasion in unmanaged grassland and fens that has now become over-mature and unsuitable, may all have contributory effects on the decline of Nightingale. As a long distance migrant, changes on wintering grounds also need considering (Fuller *et al.* 2005).

The woodland bird indicator trend shows a 51% decline in the Song Thrush population between 1970 and 2007. BBS shows a 25% increase between 1995 and 2007 in the UK and a 24% increase in England (Risely *et al.* 2009). The RWBS reported 15.7% (BTO) and 52.2% (RSPB) increases (Hewson *et al.* 2007, Amar *et al.* 2006). Song thrush is Red-listed and a UK Biodiversity Action Plan species. Changes in survival in the first winter and possibly post-fledging survival are sufficient to cause the Song Thrush decline (Thomson *et al.* 1997, Siriwardena *et al.* 1998, Robinson *et al.* 2004). The environmental cause of this is unknown but could involve changes in farming practices, land drainage, pesticides and predators (Fuller *et al.* 1995, Robinson *et al.* 2004). In woodland, drainage of wet areas, reduction in shrub layers through canopy closure and deer browsing are also likely to be causes of the decline (Fuller *et al.* 2005).

Data for Spotted Flycatcher provide strong evidence of a severe, long-term population decline. The species has declined by 38% in the UK and by 41% in England according to BBS data between 1995 and 2007. The RWBS reported declines of 70.4 and 36.3% (BTO and RSPB datasets) (Hewson *et al.* 2007, Amar *et al.* 2006). The declines had a distinct pattern, with all areas other than the South-West of England declining. Spotted flycatcher is Red-listed (Eaton *et al.* 2009) and a UKBAP species. Demographic modelling has suggested that a decrease in the annual survival rates of birds in their first year may have driven the decline (Freeman and Crick, 2003). A decrease in survival rates may have been caused by deteriorating woodland quality, conditions in wintering areas or on migration. Habitat issues may include a decrease in in-stand structural diversity, lack of grazing and lack of natural nest sites There is also a strong nest predation pressure on breeding grounds (Stevens *et al.* 2008).

The Tree Pipit population trend has declined by 86% according to the woodland bird indicator. BBS shows a decline of 4%in the UK and 38% in England between 1995 and 2007(Risely *et al.* 2009). The RWBS reports large declines over 25 years – BTO data showing 67.9% and RSPB data showing 85.4% (Hewson *et al.* 2007; Amar *et al.* 2006). Tree pipits are UKBAP species and are Red-listed (Eaton *et al.* 2009). Causes of population decline are unclear, however, changing forest structure may be a potential cause. The species' habitat needs are open areas within woodlands with suitable perches, including young plantations and some types of coppice, and upland grazed woods lacking understorey where glades and clear fells are used. This continuity of suitably structured habitat is important and lack of this may have contributed to the decline. Tree Pipits have high failure rates at the chick stage with predation being a primary cause. Being a long-distance migrant, problems on wintering grounds should not be ruled out.

The woodland bird indicator shows a 28% decline in the Treecreeper population between 1970 and 2007. BBS data shows a 4% increase nationally since 1995 and a 8% decline in England (Risely *et al.* 2009). The RWBS reported a 51.5% increase and a 95.1% increase according to BTO and RSPB data respectively (Hewson *et al.*, 2007, Amar *et al.* 2006). It is unlikely that the habitat required by the species have declined during the population decline. However, Treecreepers may be susceptible to the fragmentation of woodland in an arable landscape (Huhta *et al.* 2004). It is possible that predation risk has become higher in fragmented woods and the species avoid these areas as a result (Jantti et al (2007). Treecreeper over-winter survival is negatively correlated with winter rainfall, therefore, cold and wet winters may have limiting effects on Treecreeper populations (Peach *et al.* 1995).

Willow Tits have undergone a large population change according to several monitoring schemes. The woodland bird indicator trend shows a 90% decline between 1970 and 2007. BBS reports a 67% decline between 1995 and 2007 in the UK and a 68% decline in England (Risely *et al.* 2009). The RWBS (Hewson *et al.* 2007, Amar *et al.* 2006) report a 77.5% decline (BTO data) and a 72.5% decline (RSPB data). Willow tits are Red-listed (Eaton el al. 2009) and a UKBAP species. It is suggested that it is most likely that the major cause of the Willow Tit's decline in Britain is habitat degradation Lewis *et al.* 2007, Lewis *et al.* 2009, Lewis *et al.* in press). Young damp woods have been found to be a key habitat requirement and this habitat may have declined substantially across the Willow Tit's range. However, relationships are not yet fully understood and competition with other tits and predation by Great Spotted Woodpecker must continue to be considered as possible contributory factors.

The woodland bird index shows a 58% decline in the Willow Warbler population between 1970 and 2007, however, this appears to vary by region. BBS reports a 12% decline between 1995 and 2007 in the UK but a 32% decline in England a 8% increase in Scotland (Risely *et al.* 2006). The RWBS showed large declines, again different by region. Overall the BTO dataset showed a 74% decline and the RSPB dataset showed a 66% decline (Hewson *et al.* 2007, Amar *et al.* 2006). The regional disparity in population trends suggests that there could be potential habitat driven causes for the decline of Willow Warblers, particularly in farmland and urban/suburban woodlands in the south and east of England. The reduction in bramble and low cover (possibly by increased deer grazing pressure) may be a factor in reducing potential nest sites (Amar *et al.* 2006). Maturation of woods and increased canopy shading will also have reduced the shrub layer in woodland habitats (Amar *et al.* 2006). Being a long-distance migrant there may also be factors operating on wintering grounds or during migration (Fuller *et al.* 2005).

Wood Warblers have declined by 59% in the woodland bird indicator. BBS trends for the UK show a 60% decline since 1995 (Risely *et al.* 2009). The RWBS indicated a decline of 55% (RSPB) and 64% (BTO) (Hewson *et al.* 2007, Amar *et al.* 2006). Wood Warblers are Red-listed and a UKBAP species. It is unclear whether habitat on the breeding grounds is a major cause of the population decline but work is underway to test this. There is insufficient information on the demographic parameters which could be driving the decline. Importantly, Wood Warbler is one of the long distance migrants that have *not* advanced their arrival and laying dates.

2.2.3 Drivers of population decline

The problem of woodland bird decline is multi-factorial and teasing apart drivers of population decline for individual species and establishing their relative importance is extremely difficult. Different species are likely to respond to different factors and important factors for a particular species are likely to interact in a complex manner with other factors. Key information is lacking for many declining woodland species and so it is impossible to state the full set of drivers. Likewise stating that a factor is not a driver is virtually impossible without full research into each driver for each species.

2.2.3.1 Habitat degradation due to lack of active management

Maturation of woodland and the cessation of active management in many woods has changed structure to such an extent that many woodland species population declines are linked to this factor (Amar *et al.* 2006). Thirteen of the eighteen species reviewed showed evidence of this being a contributory or important driver of decline. Blackbird, Bullfinch, Dunnock, Garden Warbler, Marsh Tit, Nightingale, Song Thrush, Lesser Redpoll, Tree Pipit, Spotted Flycatcher, Willow Tit, Wood Warbler and Willow Warbler are all linked to early succession habitat, open areas within woodlands or to areas with low dense vegetation such as those created through management of woodlands e.g. coppicing and felling (Amar *et al.* 2006). This factor is so important that there is a need for trial management experiments to establish the most appropriate methods of reversing trends.

2.2.3.2 Habitat degradation due to deer grazing

The impact of deer changing woodland structure may be linked to the decline of at least eight species in the indicator. Deer have increased dramatically in many areas of England and their impact on the structure of woodland is well known. In particular, their impact on early succession habitats and low vegetation cover in woods has reduced nest site availability and foraging areas for several species requiring this habitat – Blackbird, Bullfinch, Dunnock, Garden Warbler, Marsh Tit, Nightingale, Song Thrush and Willow Warbler (Amar *et al.* 2006). Conversely, lack of grazing in upland oakwoods formerly heavily sheep grazed has changed woodland structure to such an extent that they have become unsuitable for breeding by Wood Warbler (Amar *et al.* 2006).

2.2.3.3 Climate change

Nine species showed some evidence of relationships with or vulnerabilities to changes in weather patterns, possibly linked to climate change. These may be contributory drivers of population decline. Further work is necessary, however, for most species. Wood warbler, willow tit and lesser spotted woodpecker have been shown to be among the top ten worst performers in the climate change indicator and are expected to decrease their populations in Europe in response to climate change (Gregory *et al.* 2009). Modelling of future climate space for marsh tit suggests climate change could have a severe negative impact in Britain (Carpenter, 2008), however this is contradicted by Huntley et al (2007). Goldcrest populations have declined less in woodlands where temperature and rainfall have remained stable (Amar *et al.* 2006). Long term changes in climate are predicted to lead to a contraction in range for Nightingale; however, shorter term forecasts may be positive (Harrison et al 2003). Climate envelope modelling for this species suggests a northerly increase in range,, with southern areas becoming unsuitable (Huntley *et al.* 2007) Spotted Flycatcher laying dates are positively correlated with May temperatures and nesting success is higher in Junes with a greater amount of sun (O'Connor and Morgan, 1982). This suggests the species is vulnerable to changes in temperature. Cold, wet winters are likely to have limiting effects on Treecreeper populations because over winter survival is negatively correlated with winter rainfall (Peach *et al.* 1995).

2.2.3.4 Woodland fragmentation

Fragmentation of woodlands and reduced connectivity may be an important contributory driver of decline for at least nine species, with Hawfinch and Lesser Spotted Woodpecker populations potentially most at threat through this mechanism. Both of these species have a requirement for large territories throughout the year, but particularly during the winter, and may have suffered declining over-winter survival as a result of this mechanism (Dunn and Charman 2008, Charman *et al.* in press). Blackbirds and Bullfinches use hedgerow habitats in arable landscapes and populations have declined to a greater extent in this habitat, suggesting that these may be acting as sinks for the species (Hatchwell *et al.* 1996, Proffit, 2002). Two studies suggest that Goldcrest is vulnerable to habitat fragmentation and may avoid smaller stands for breeding (Nour et al 1999, Carpenter *et al.* 2008). The same is true for Marsh Tit, which is also sensitive to woodland size for breeding (Hinsley *et al.* 1996). Song Thrush are more abundant in woods set within a more wooded landscape, compared to arable (Carpenter *et al.* 2008). Nest predation levels for Treecreeper are higher in fragmented forest and the species may avoid stands with a greater amount of fragmentation as a result (Huhta *et al.* 2004).

Although landscape in England has been fragmented for many centuries and species may have adapted to live in that context, it is possible that there is a contributory pressure of some populations (such as increased predation) which means it is increasingly difficult for birds to occupy small patches where edge ratios are high.

2.2.3.5 Reduction in food availability

In eight cases there was evidence of a reduction or fluctuation in food availability impacting species. It has been suggested that overgrazing by deer, leading to changes in ground flora could have lead to a reduction in food sources for nestling Bullfinch (Proffit, 2002), but possibly other species too. Birch seeds feature as important dietary components for both Bullfinch and Lesser Redpoll (Proffit, 2002 Evans, 1966). Loss by maturation of birch scrub could therefore be creating sub-optimal foraging habitat for these two species. If availability of food is constraining Goldcrest's ability to produce two broods in a season, this may contribute to a population decline (Haftorn, 1982). Jay are reliant on acorns and beechmast over winter (Pons and Pausas, 2008). Failure of these crops periodically could have lead to reduced over winter survival and the fluctuations in population. It is likely that the population increase in Lesser Spotted Woodpeckers in the 1970s was a result of Dutch Elm Disease providing an abundant food source (Osbourne, 1982). Poor reproductive success has been found to be linked to declining food availability as the season progresses (Rossmanith, 2007). Work in the UK suggests that provisioning may be a problem, especially where the male is left to provide for the chicks alone (Charman *et al.* in prep. Food supply is a candidate cause of decline in the Song Thrush. It is suggested that Song Thrush can not remain in woodlands through winter as a result of lack of food (Simms, 1989). In arable landscape, lack of woodland and permanent grassland and the faster drying of arable soils may combine to limit the availability of key prey (Peach *et al.* 2004). In one study of Willow Tit, starvation was recorded as the main cause of nesting failure, suggesting that in some areas there may be an issue with food supply (Orell and Ojanan, 1983). Finally, Wood Warblers time broods to coincide with peak caterpillar abundance. However, the species is one of the long-distance migrants which has not advanced arrival and laying dates, suggesting that a mis-timing of resources may have occurred leading to a decline in reproductive success.

2.2.3.6 Factors operating on wintering grounds

Factors operating on wintering grounds must be considered a potential contributory driver for all the long-distance migrants in the indicator. Very little is known about where many of these species winter, as well as their resource needs during this stage of their life cycle. This creates a problem in reversing declines of these species, as the solution is likely to be multi-factorial and will involve considerable work outside of the UK. However, there are projects currently underway by both RSPB and BTO to tackle these issues.

2.2.3.7 Drying out of woodlands

Three species appear to favour wetter woodlands which may be a driver of decline. Lesser Spotted Woodpecker and Willow Tit are more likely to occur in wetter woods (Lewis *et al.* 2007, Charman *et al.* in press). The reason for this is unclear but may relate to food availability or the decay of dead wood for nesting. Song Thrush is suggested to suffer as a result of drying of surface soils in arable habitats resulting in reduced accessibility to key prey (Peach *et al.* 2004).

2.2.3.8 Agricultural intensification

Agricultural practices in habitat surrounding woodlands may be a contributing driver of decline in the Song Thrush. It is suggested that loss of hedgerows, scrub and permanent grassland and the widespread installation of drainage have all contributed to the decline (Peach *et al.* 2004).

2.2.3.9 Disturbance

Three species appear sensitive to disturbance. However, the extent to which this may be a driver of decline needs further consideration. A study of Hawfinch found they had declined more in woods with a greater number of tracks, however, nothing was known about the use of the tracks and this factor may be correlated with another unmeasured causal factor (Amar *et al.* 2006). Similarly, Tree Pipit populations have been shown to decline more in woods with more tracks and seem to prefer woods away from roads and edges (Kuitunen et al, 1998, Burton, 2007). Willow Warblers have been found to avoid habitat near roads in Europe, suggesting that this is a limiting factor for populations of this species (Reijnen, 1994, Kuitenen *et al.* 1998).

2.2.3.10 Predation

Gibbons et al (2007) reviewed the evidence for the impact of predation on songbirds. This extensive scientific review provided little evidence that songbird numbers in the UK are limited by predation and concluded by recommending recovering songbird population through managing their habitats more appropriately. Predation is a common cause of nest failure, with the majority of species being vulnerable to varying degrees. There are several studies showing strong predation pressure in limited geographical areas at a small scale. With this in mind, several species in the woodland indicator which have had predation studied have been shown to suffer high predation rates or be vulnerable to predation pressure. In almost all cases there is no evidence that nest predation is having population level impacts on the species concerned. For one, Spotted Flycatcher, there is slightly stronger evidence that this may be an important driver of recent declines in some areas.

Blackbird reproductive success has been found to be low, with predation the main reason for failure (Hatchwell *et al.* 1996). Furthermore, in an experimental study, predator control resulted in an increase in Blackbird populations, although other factors could not be excluded (White *et al.* 2008). For Bullfinch, one study reported that two thirds of nests failed as a result of predation (Proffit, 2002). Data for Hawfinch is lacking but associations between population change and grey squirrel and Great Spotted Woodpecker have been found (Amar *et al.* 2006, Carpenter and Charman, 2009). Great Spotted Woodpeckers are suspected to be contributing to Lesser Spotted Woodpecker declines, however, evidence is sparse. Treecreepers suffer high predation pressure according to several studies (Huhta *et al.* 2003, Jantti *et al.* 2007). There is contrasting evidence for the role of predation in the Willow Tit declines, however, Great Spotted Woodpecker may be significant predators at the nest stage and Sparrowhawks have been implicated as predators of adults (Orell and Ojanan, 1983, Rytokonen and Soppela, 1995). Willow Warblers suffer high nest predation rates, although the role of this in population decline remains unclear (Tiainen, 1986). Wood Warblers have been found to suffer high predation rates in several studies (Wesolowski, 1985, Stowe, 1987).

Jay has been found to be the primary cause of failure of Spotted Flycatcher nests and there is reasonable evidence that recent population decline is consistent with being caused primarily by factors affecting productivity, through the proximate mechanism of predation by avian predators (Stevens 2008, Stevens *et al.* 2008). Furthermore, a study of predator removal reported an increase in breeding success in this Spotted Flycatchers (Stoate and Szczur, 2006).

The extent to which predation is a major driver of population decline is not clear. In several cases, predation pressure leads to nest failure but little work has tried to establish how this translates into a population level effect. Furthermore, little is known as to how and why predation has changed over the period of many of the declines. As such, predation should be considered an contributory driver but not at the exclusion of other factors.

2.2.3.11 Hunting

Hunting of adult birds by humans in the Mediterranean may be contributing to the declines of migrant species, although in no cases is this considered a major driver.

2.2.3.12 Competition

Three resident species and one migrant may be suffering as a result of competition from dominant species. Lesser Spotted Woodpecker, Marsh Tit and Willow Tit may be suffering as a result of inflated populations of larger, more dominant counterparts - Great Spotted Woodpecker and other tits. However, there is very little evidence of this in the scientific literature. Willow Warbler may be suffering as a result of the increasing Chiffchaff, which may have advantage by being increasingly adaptable to different habitats. However, habitat requirements are different in Lowland England so this needs further investigation. In all cases, the decline has coincided with an extremely large population increase in the closely related species. This may result in competition for resources or aggression reducing breeding probability or success. However, evidence for competition resulting in population decline for these species is very limited.

2.2.3.13 Invasive Species

Finally, invasive species, particularly rhododendron, is creating sub-optimal habitat for one species, the Wood Warbler. This has created dense stands in many areas of Welsh upland woods creating a woodland structure less suited to the species (Stowe, 1985). However, the impact is due to a change in the woodland structure rather than the effect of the invasive itself.

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3. ANALYSIS OF WETLAND BIRDS

Simon Pickett and David Noble (BTO)

3.1 Introduction

3.1.2 Aim

This chapter explores patterns of declines in a suite of breeding wetland bird species in the wetland bird indicator. The aim of this chapter is to identify common factors that may explain the drivers behind these declines, using analysis of long-term bird survey data and existing environmental data sets.

3.1.3 Analytical approach

The analysis is primarily focussed on the identification of common drivers across wetland breeding species with similar habitat types and ecological traits. Following the hypothesis that species sharing similar population drivers are more likely to share similar population change through time, we compared trends among the full suite of breeding wetland species included in the government's bird indicator PSA28. The criteria for species inclusion in the indicator, and the data used to derive the population trends are described fully in a series of reports (Noble *et al*. 2008a, 2008b; Everard & Noble, 2008) and paper (Everard & Noble, in press). We then tested whether those sharing habitats and broad ecological traits were more likely to exhibit similar trends implying similar drivers of population change. Using land class and land cover data from CEH (Centre for Ecology and Hydrology) we also investigated regional and habitat-specific variations in trends of the declining species in order to determine the areas and habitats for priority action.

3.2 Methods

3.2.1 National trends

Population trends for England were calculated for 21 species in the waterway bird indicator (see Noble *et al*. 2008a) including Common Sandpiper, Coot, Curlew, Dipper, Goosander, Grey Wagtail, Kingfisher, Lapwing, Little Grebe, Mallard, Moorhen, Mute Swan, Oystercatcher, Redshank, Reed Bunting, Reed Warbler, Sand Martin, Sedge Warbler, Snipe, Tufted Duck and Yellow Wagtail. Following the approach described in Noble *et al*. (2008a) and Everard & Noble (2008), trends were based on joint modelling of data from four different surveys (WBS, WBBS, CBC & BBS) for most wetland species that occur in a broad range of wetland habitat types. However, trends for waterway specialist species that are less effectively monitored on BBS/CBC surveys, such as Common Sandpiper, Dipper, Goosander, Grey Wagtail and Sand Martin, were based on WBS/WBBS joint survey data. Similarly, only CBC/BBS data was used for species such as Lapwing, Reed Bunting and Yellow Wagtail, where a substantial proportion of the population occurs on farmland, and which for that reason are also included in the farmland bird indicator. Mean estimates were back-transformed from the log scale, standardised and centred using Equation 1, then plotted against year. No data was available for 2001 due to survey restrictions as a result of the foot and mouth epidemic.

Eq. 1. Index=(exp(estimate)/CI(upper)-CI(lower))-mean(exp(estimate))

All statistics were conducted using R (R Development Core Team, 2005). Post-hoc smoothed trend values were created from the index estimates using General Additive Models (GAMs, Hastie and Tibshirani, 1990), using the "gam" package in R, (Hastie, 2008) with a smoothing spline of 8 degrees of freedom. In order to assess general population trends and how they have changed over time, "broken-line" linear regression coefficients were also computed using the "segmented" function in R (Muggeo, 2008), which calculates the optimal broken least-squared regression line through the index points. When the segmented analysis failed to reveal significant statistical evidence for a broken trend, a single least squared regression line was fitted to the data. The benefit of fitting broken trend lines where appropriate helped to identify species that have not declined overall but that are currently declining.

3.2.2 Regional variation in population declines

For the suite of species that are currently declining, additional analyses were conducted to determine regional variation in these declines. Using the same modelling approach as that used for national trends, GLM models with a log link and Poisson error structure were used to assess the effect of the interaction of year with region on counts using F tests. The effect of site and year were controlled for as covariates in the model and a weighting variable was also incorporated controlling for the methodological differences between the survey schemes (Freeman *et al.* 2002).

Regions were split according to "Regional Development Agency" (RDA) area (http://www.englandsrdas.com/visit_rdas/) for England only and the analysis was conducted at this scale wherever possible. Data for London RDA and South East RDAs were merged together as a result of a low sample size and are jointly referred to as "South East". Wales was included as an additional region. Combining data for all four surveys at the regional level was not possible for most species, because trends became very sensitive to differences in survey specific weightings due to a low sample size. Therefore either CBC-BBS or WBS-WBBS data were used depending on the ecology of the species, as described above. An RDA level split was generally suitable for species best represented by CBC-BBS surveys (Curlew, Redshank, Reed Bunting, Snipe and Yellow Wagtail). However, for some WBS-WBBS survey species (Little Grebe and Redshank) insufficient samples did not allow for RDA level analysis. Instead RDAs were grouped into latitude categories ("North": North West, North East and Yorkshire; "Midlands": Wales, West Midlands, East Midlands and East England and "South": South West and South East) and longitude categories (West: North West, Wales, South West) and the analysis was conducted at these regional levels. Regions with insufficient sites or a very high proportion of zero counts (usually as a result of the fact that some species are range restricted to an extent) often did not produce viable model estimates and so were excluded from the analyses. Table 3.2.2.1 displays the surveys and the region levels used for each species. To visualise significant regional effects, separate GLM models were run for each region, (using the same parameters as those used to create national trends as described above) and the smoothed index estimates from these models were plotted together.

Table 3.2.2.1 Survey data and regions included in the analysis for 9 declining species.

Species	Survey used	Regions included
Common Sandpiper	WBS/WBBS	North West, North East, West Midlands, Wales
Curlew	CBC/BBS	North West, North East, Yorkshire
Lapwing	CBC/BBS	North West, North East, Yorkshire, West Midlands, East Midlands, East England, South East
Little Grebe	WBS/WBBS	North, Midlands, South
Redshank	WBS/WBBS	North, Midlands, South
Reed Bunting	CBC/BBS	North West, North East, Yorkshire, West Midlands, East Midlands, East England, South West, South East
Sedge Warbler	WBS/WBBS	North East, East Midlands, South East
Snipe	CBC/BBS	North West, North East, Yorkshire, West Midlands, East Midlands, East England, South East
Yellow Wagtail	CBC/BBS	North West, Yorkshire, West Midlands, East Midlands, East England, South East

3.2.3 Analysis of population trajectories

Similarities in population trends between species were calculated as follows. Population indices were first smoothed using the GAM approach as described above, but with a higher degree of smoothing (spline d.f. = 5); this level being chosen as an optimum trade off between "ironing out" minute inter-annual fluctuations in population trends, but also retaining detail in deviations from the overall linear trajectory. In order to assess general population change but also to capture information regarding the timing of changes in trend we calculated the gradient of change between one year and the year directly preceding it for n -1 years. This resulted in a set of annual rates of change for each species. Two species sharing parallel population trends will be similar in terms of direction and magnitude of these gradients through time. Tests of similarity between all possible combinations of the 21 species were conducted on this data set using hierarchical cluster analysis and a multi-dimensional scale analysis (MDA).

3.2.4 Species ecology versus population trend

An analysis was conducted to assess the degree to which shared aspects of ecology or life history may determine similarities in population trends. Three potentially important categorical predictors were selected (See Table 3.2.4.1) including broad-scale habitat niche (1 = fast flowing water, 2 = slow moving or standing water, 3 = wet meadow, 4 = reed bed), migrant status (1 = resident or 2 = African migrant) and whether or not the species had a significant proportion of its breeding population on farmland (1 = yes, 2 = no based on data from the Breeding Bird Survey). The broad-scale habitat affiliations are based on the assessments of habitat association described in Everard & Noble (2008). The primary coefficients from the MDA were treated as proxies describing the main features of the population trends and were used as dependent variables in multiple regression analyses to assess how species ecology predicts population trend.

Table 3.2.4.1 Habitat type (FF = fast flowing water, S = standing water or slow moving, WM = wet meadow, R = reed bed) migrant status (M = migrant, R = resident) and farmland status (Y = significant proportion of breeding population nest on farmland, N = negligible proportion of population nest within farmland) of all species included in the analyses.

	Habitat type	Migrant status	Farmland status
Common Sandpiper	FF	M	N
Coot	S	R	N
Curlew	WM	R	Y
Dipper	FF	R	N
Goosander	S	R	N
Grey Wagtail	FF	R	N
Kingfisher	FF	R	N
Lapwing	WM	R	Y
Little Grebe	S	R	N
Mallard	S	R	N
Moorhen	S	R	N
Mute Swan	S	R	N
Oystercatcher	WM	R	Y
Redshank	WM	R	Y
Reed Bunting	R	R	Y
Reed Warbler	R	M	N
Sand Martin	FF	M	N
Sedge Warbler	R	M	N
Snipe	WM	R	Y
Tufted Duck	S	R	N
Yellow Wagtail	WM	M	Y

3.2.5 The influence of habitat variables on trends and abundance

An analysis was conducted using BBS data for England and Scotland (England only for Lapwing) to examine differences in trends of six declining species across broad habitat categories, as defined at the 1 km square level. Common Sandpiper, Little Grebe and Sedge Warbler were not included in this analysis because the data used to produce trends were insufficient for further breakdown by habitat. Habitat categories were defined from those in the CEH Land Class Map (1990) and grouped into broad pastoral, arable, upland and marginal classes based on the dominant habitat type. As with the regional analysis, interactions between habitat class and year were assessed in GLM models with Poisson errors, controlling for site as a fixed effect and significant effects were represented by running separate models for each habitat type to visualise non-linear relationships.

We also examined the relationship between population change and habitat at a broader scale – the 10 km square rather than 1 km square. Habitat data was taken from the Land Class Map and for each 10 km^2 grid square in the U.K. the proportion of woodland, pastoral, arable and urban/rural land was calculated. WBBS start points and BBS squares were associated with the 10 km^2 square that they fell within. Missing data and a large number of zero counts did not allow population gradients to be calculated for each survey point so population change was calculated as the difference in mean counts between 1995-2000 and 2002-2007 periods. The proportion of each of these habitats were treated as explanatory variables in a GLM for each species, to assess how population change was affected by surrounding habitat (BBS or WBBS surveys were chosen based on species ecology, see Table 3.2.2.1).

The potential effects of surrounding habitat on abundance were also considered using a higher resolution Land Cover Map 2000, (LCM, CEH). These remote sensed satellite images provide a thematic classification of spectral data with habitats grouped into 25 broad classes according to their reflective qualities. These categories were “Broad leaved woodland”, “Coniferous woodland”, “Arable (cereals)”, “Crops” (including arable bare ground, carrots, field beans, horticulture, linseed, potatoes, peas, oilseed rape, sugar beet, mustard, unknown, non-cereal), “Arable set aside” (including orchards), “Improved grassland”, “Grass set aside”, “Rough grass”, “Calcareous grass”, “Acid grass”, “Bracken”, “Dwarf shrub heath (dense or gorse)”, “Dwarf shrub heath (open)”, “Fen, marsh and swamp”, “Bog”, “Inland water”, “Montane”, “Inland rock”, “Suburban/rural”, “Urban”, “Supra-littoral rock”, Supra-littoral sediment”, “Littoral rock”, “Salt marsh”, “Sea”. Coniferous and broadleaved were combined into one “Woodland” class and urban and suburban/rural categories were combined to make one “Urban” class for the analysis.

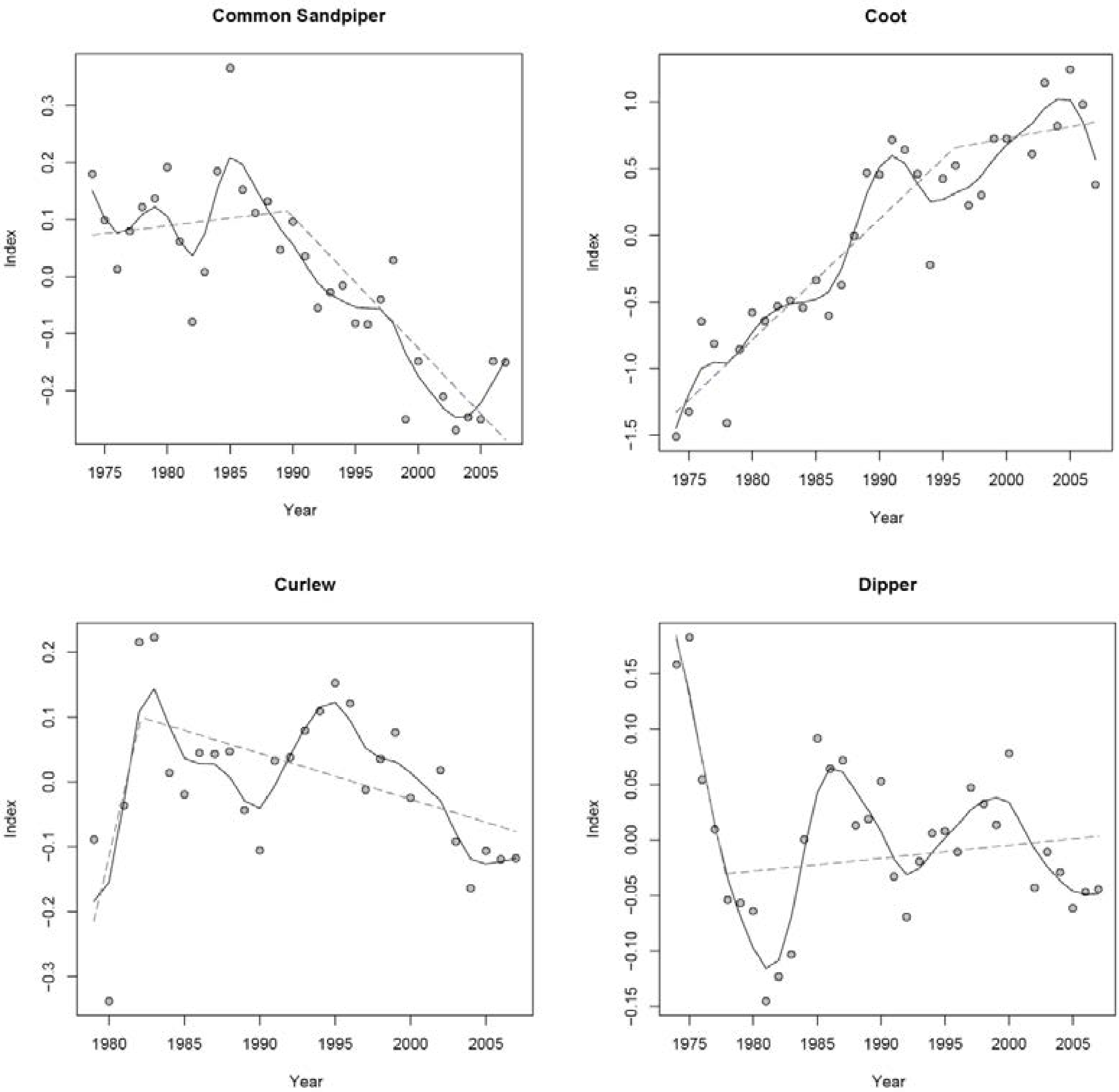
Bird data was extracted for the year 2000 for all declining species, from both the BBS and WBBS surveys for all species. Habitat data was extracted from the LCM in a buffered area of radius 3km around the centre of the BBS/WBBS survey square. Distance to the coastline and the areas of arable (cereals) (referred to as “arable”), Other crops (referred to as “crops”) , improved grassland, urban and woodland environments were all used as explanatory variables in a GLM assessing the relationship between broad scale surrounding habitat and bird abundance.

3.3 Results

3.3.1 Species trends

Of the 21 species included in the analyses, nine were identified as declining (Common Sandpiper, Curlew, Lapwing, Little Grebe, Redshank, Reed Bunting, Sedge Warbler, Snipe and Yellow Wagtail; Figure 3.3.1.1). Goosander was not included despite evidence of very slight decline from the mid-nineties because of the strong preceding increase from 1980. Table 3.3.1.1 summarises the estimated gradients of the trends from the segmented analyses.

Figure 3.3.1.1 Standardised population trends for 21 species in the wetland bird indicator in England. Points show mean bootstrapped estimate for each year; continuous lines represent estimates from GAM regressions and broken lines represent segmented least-squares regression lines (see methods). Data for all species were taken from WBS/WBBS/CBC/BBS surveys where available or appropriate except for Common Sandpiper, Dipper, Goosander, Grey Wagtail and Sand Martin which were taken from WBS/WBBS surveys, and those for Lapwing, Reed Bunting and Yellow Wagtail which were taken from CBC/BBS survey data. [over page]



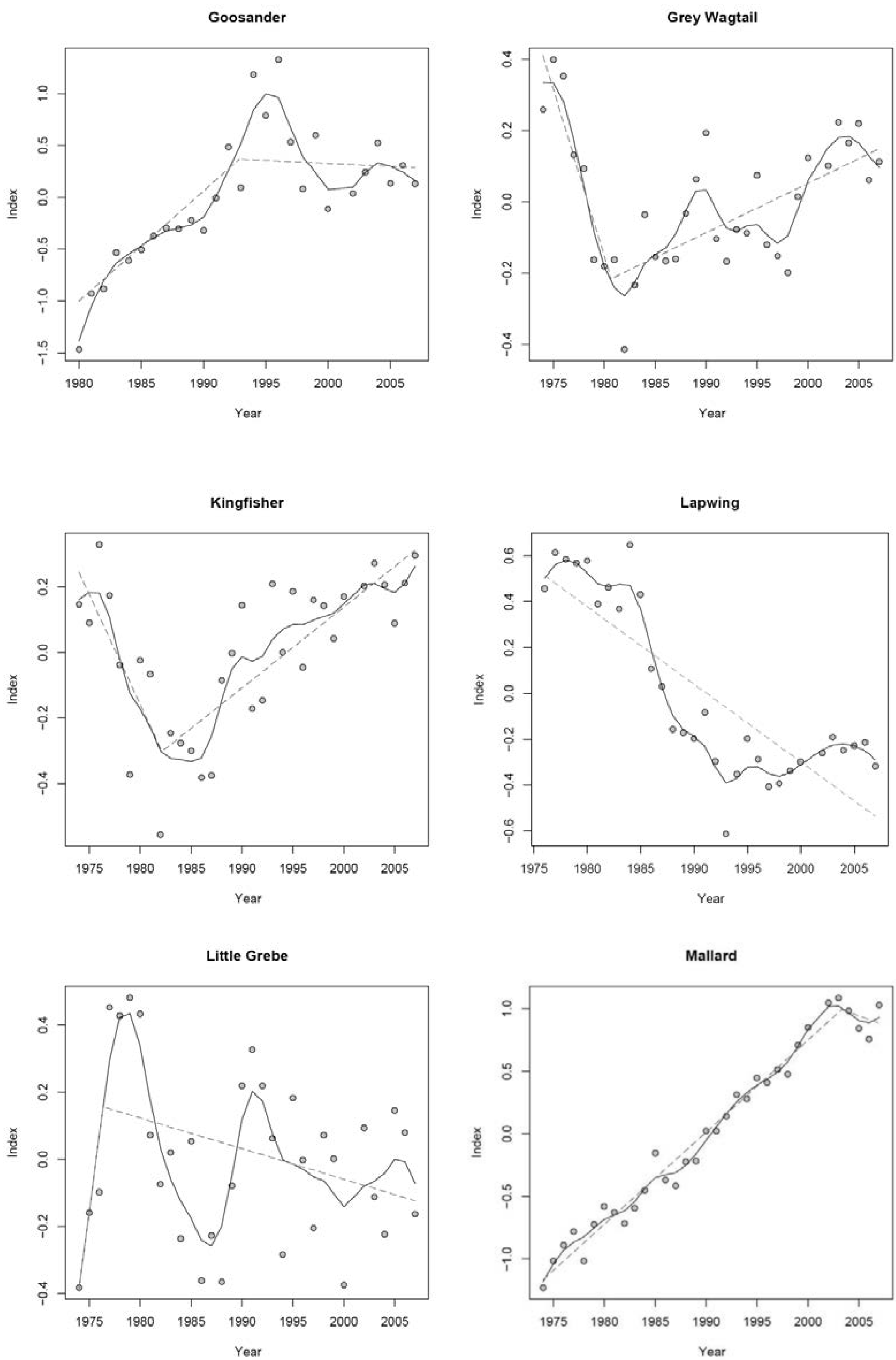
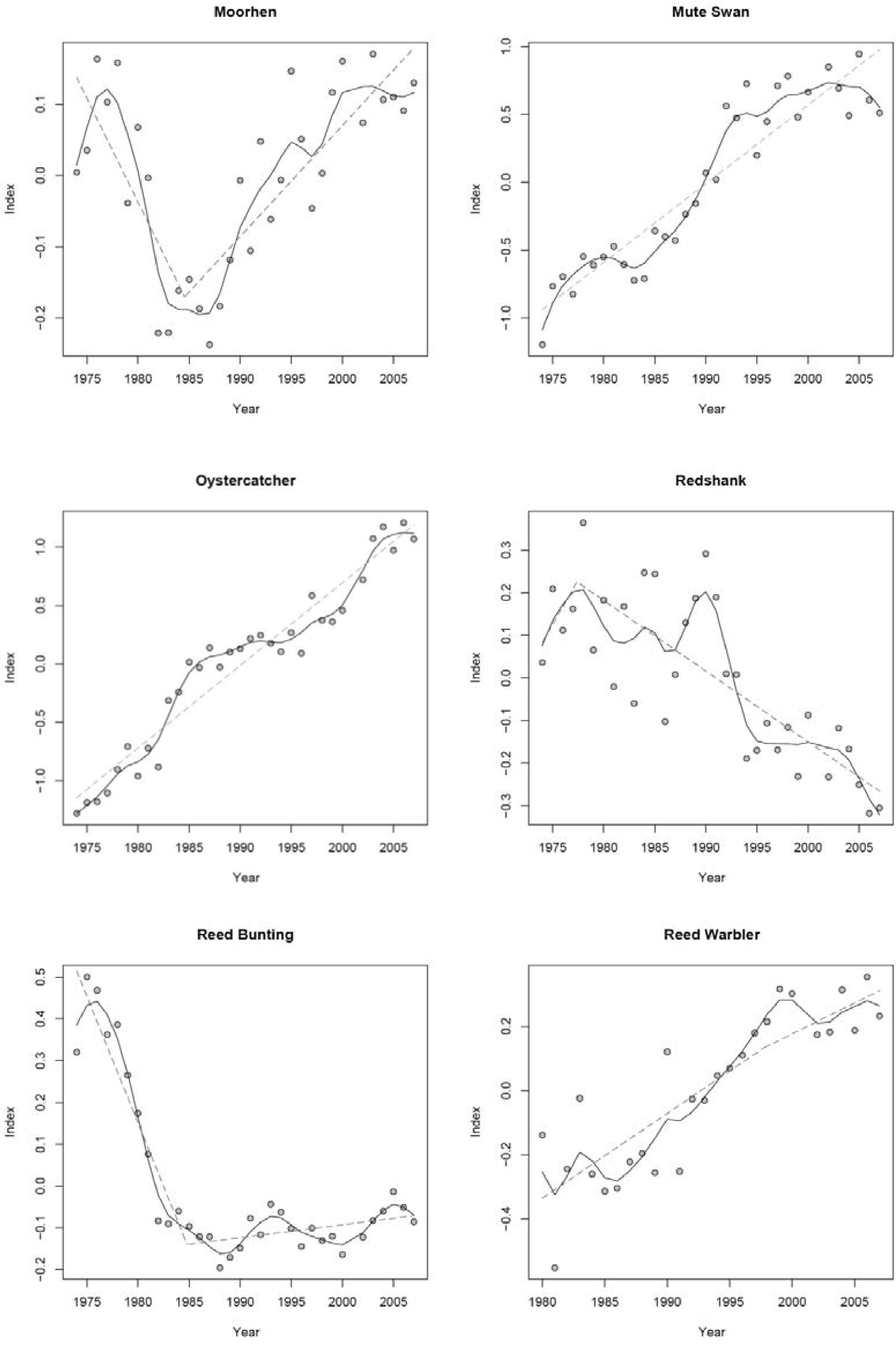


Figure 3.3.1.1 Continued**.**



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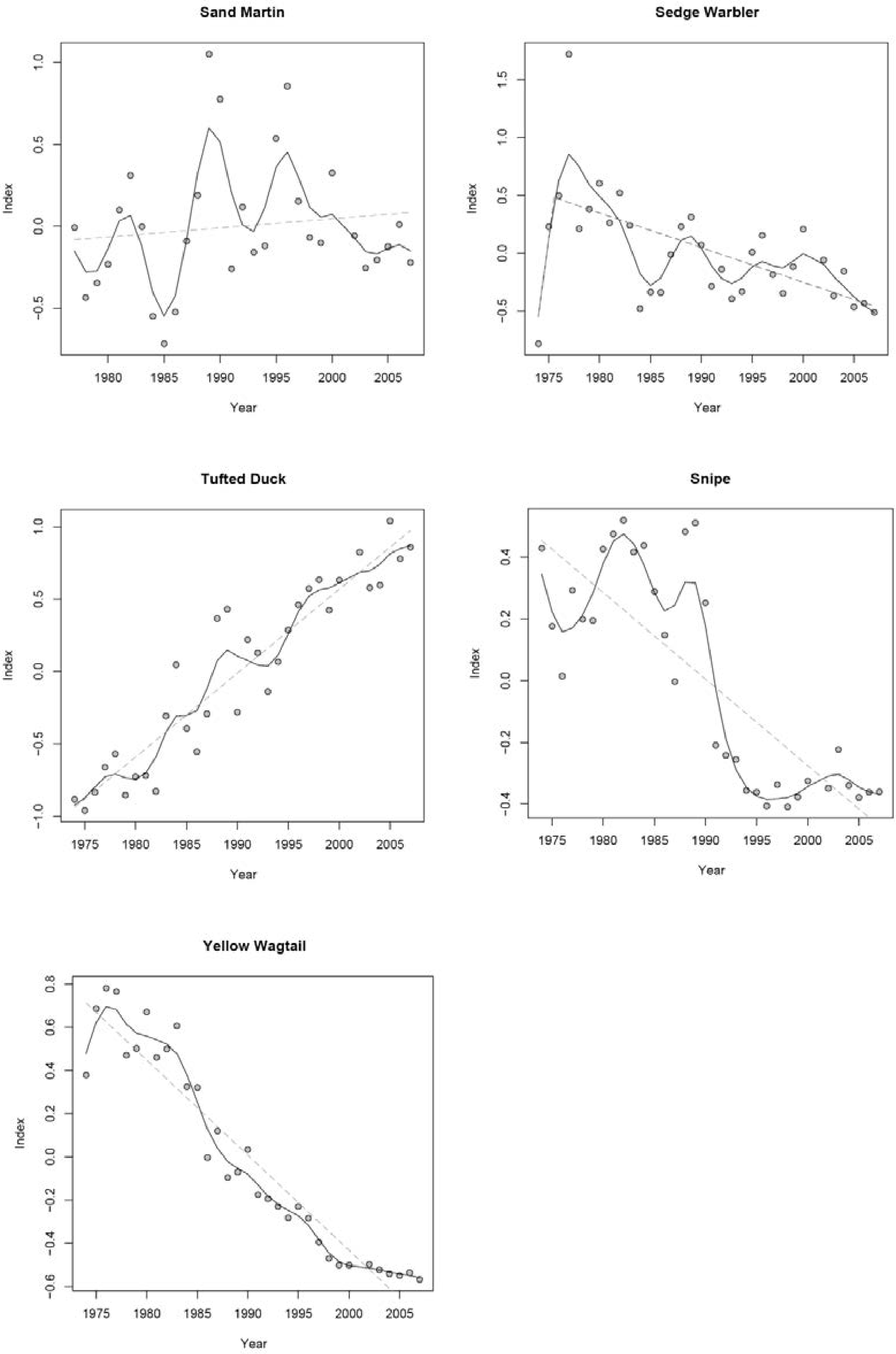


Figure 3.3.1.1 Continued.

Table 3.3.1.1 The estimated gradients for the segmented trends. x1=first gradient; x2=second gradient. For species with insufficient evidence to produce segmented trends, x1 is the gradient for the single linear trend.

Species	x1	x2
Common Sandpiper	0.003	-0.015
Coot	0.078	0.032
Curlew	0.100	-0.007
Dipper	-0.045	0.001
Goosander	0.106	-0.049
Grey Wagtail	-0.143	0.014
Kingfisher	-0.128	0.024
Lapwing	-0.034	
Little Grebe	-0.009	-0.009
Mallard	0.074	-0.010
Moorhen	-0.051	0.016
Mute Swan	0.057	
Oystercatcher	0.069	
Redshank	0.011	-0.017
Reed Bunting	-0.082	0.003
Reed Warbler	0.026	
Sand Martin	0.006	
Sedge Warbler	-0.031	
Snipe	-0.030	
Tufted Duck	0.058	
Yellow Wagtail	-0.046	

3.3.2 Regional effects

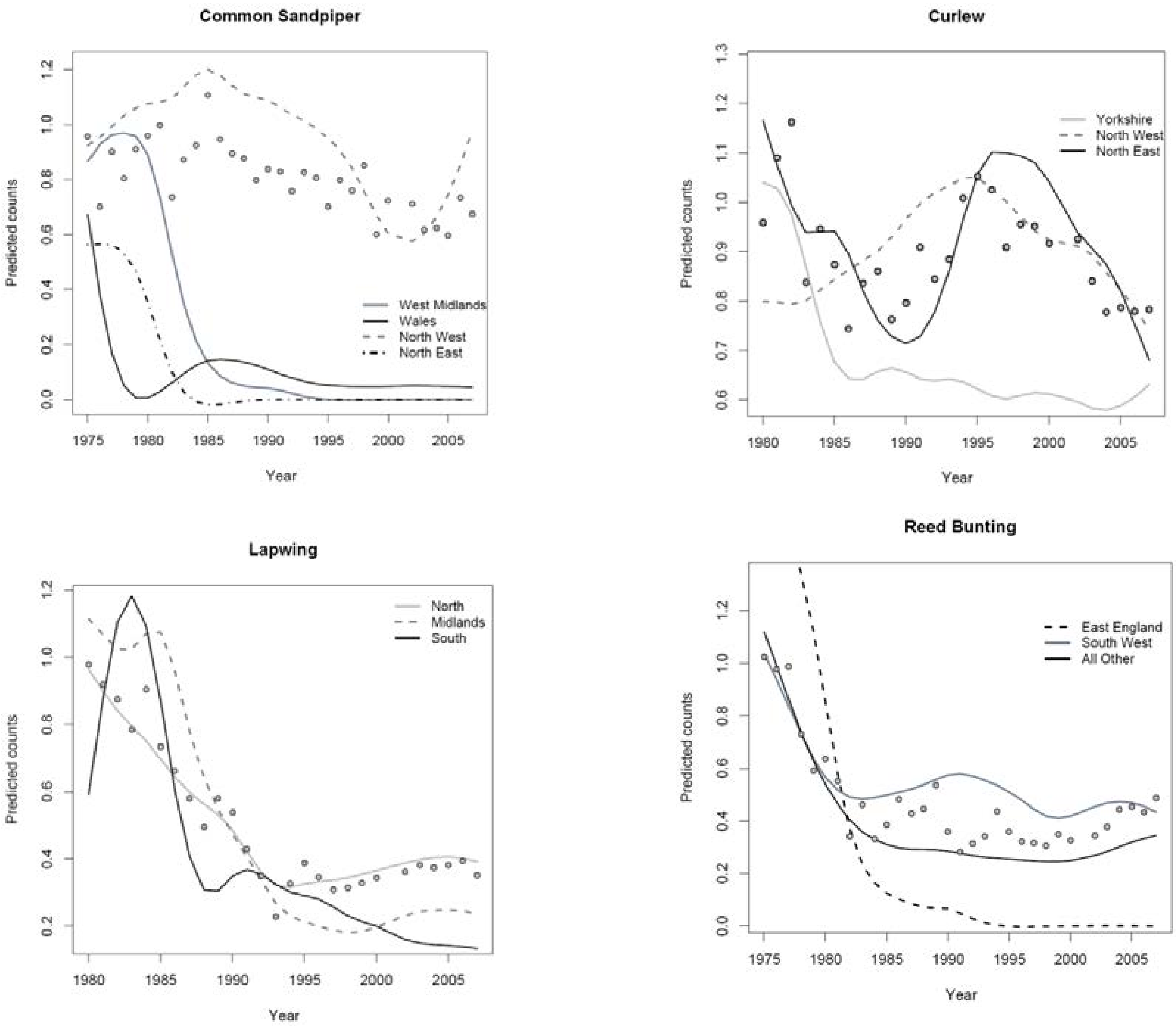
The regional analysis identified significant regional differences in trends for six out of the nine declining species (Curlew, Lapwing, Reed Bunting, Snipe, Sedge Warbler and Yellow Wagtail; Table 3.3.2.1, Figure 3.3.2.1). Common Sandpiper populations have declined faster in the West Midlands than elsewhere (North East:- $t = 2.53$, $P = 0.0115$*; North West:- $t = 2.69$, $P = 0.0073$**; Wales:- $t = 2.53$, $P = 0.0117$**). Curlew populations in Yorkshire exhibited significantly faster declines than in the North West ($t = 3.81$; $P = 0.0001$**) or elsewhere in the North East ($t = 3.74$; $P = 0.0002$**). Significant regional effects for Lapwing could be simplified to a North-Midlands-South split, with populations in the Midlands exhibiting the sharpest declines (North; $t = 6.68$, $P < 0.0001$***; South; $t = 7.20$, $P < 0.0001$***). This was similarly true for Snipe, (although available data only allowed for comparisons in trends since 1995) with populations recovering from sharp preceding declines much faster in the South East ($t = 3.50$, $P = 0.0005$**) and North ($t = 4.40$, $P < 0.0001$***) than in the Midlands. Reed Bunting and Sedge Warbler trends* both revealed sharper declines in the East Midlands than elsewhere (Reed bunting:- East Midlands:- $t = 2.24$, $P = 0.0254$*; North East:- $t = 0.54$, $P = 0.5868$; North West:- $t = 3.17$, $P = 0.0016$**; South East:- $t = 2.04$, $P = 0.0412$*; South West:- $t = 0.57$, $P = 0.5668$; West Midlands:- $t = 2.87$, $P = 0.0041$**; Yorkshire:- 3.58, $P = 0.0003$***; for Sedge Warbler East Midland declines were highest but post hoc comparisons revealed no significant differences between this area and either North East:- $t = 1.73$, $P = 0.0839$; or South East:- $t = 0.59$, $P = 0.5544$). For Yellow Wagtail, the slope for the West Midlands was steeper than elsewhere in the country (East England:- $t = 2.85$, $P = 0.0044$**; East Midlands:- $t = 1.68$, $P = 0.0937$; North West:- $t = 1.77$, $P = 0.0765$; South East:- $t = 2.82$, $P = 0.0048$**; Yorkshire:- 0.19, $P = 0.850$), although this effect appears, at least in part due to a higher increase in this region than others from the mid-1970s to the mid-1980s.

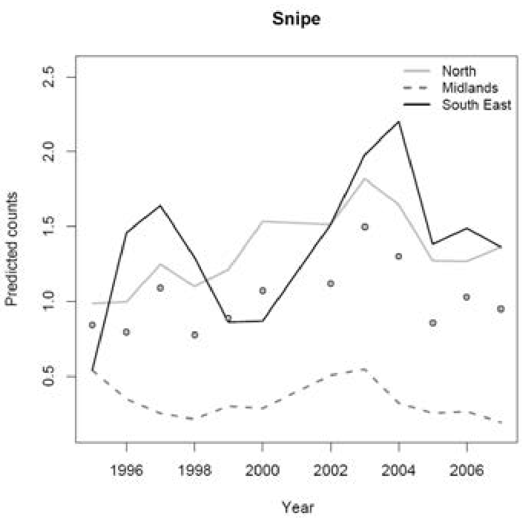
*there was insufficient data to allow East England to be included in the analysis for Sedge Warblers.

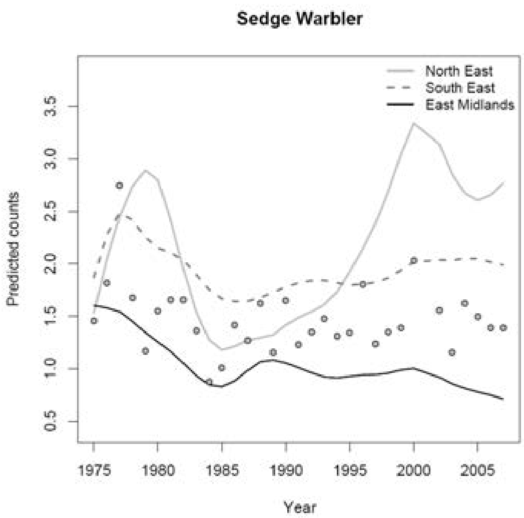
Table 3.3.2.1 Results of GLM models of abundance against year, site and region highlighting regional interactions (see methods for details).

	Effect	**d.f.**	**deviance**	***F***	***P***	**Region level**
Common Sandpiper	Year	1	30	11.98	0.0005***	district
	Site	172	14697	38.37	<0.0001***	
	Year*District	4	81	2.94	0.0321*	
Curlew	Year	1	4694	32.27	<0.0001***	district
	Site	4831	1641780	22.52	<0.0001***	
	Year*District	3	3087	10.65	<0.0001***	
Lapwing	Year	1	10924	16.64	<0.0001***	district
	Site	1526	5409914	9.57	<0.0001***	
	Year*District	6	10923	12.78	<0.0001***	
Little Grebe	Year	1	12	4.48	0.0346*	north/midlands/south
	Site	312	3599	9.516	<0.0001***	
	Year*District	2	8	1.38	0.2518	
Redshank	Year	1	1	0.75	0.3868	north/midlands/south
	Site	134	6438	22.72	<0.0001***	
	Year*District	2	10	2.28	0.1026	
Reed Bunting	Year	1	3289	25.49	<0.0001***	district
	Site	1592	1580714	12.33	<0.0001***	
	Year*District	8	5384	5.98	<0.0001***	
Sedge Warbler	Year	1	566	3.45	0.0639	district
	Site	152	128409	5.27	<0.0001***	
	Year*District	2	1588	4.95	0.0072**	
Snipe	Year	1	15053	111.87	<0.0001***	district
	Site	634	672643	4.34	<0.0001***	
	Year*District	7	4045	4.09	0.0002***	
Yellow Wagtail	Year	1	2993	28.39	<0.0001***	district
	Site	1120	1273312	9.98	<0.0001***	
	Year*District	5	1631	3.09	0.0086**	

Figure 3.3.2.1 Trends for declining species with significant regional effects. Points indicate mean model estimates. Trend lines are a result of smoothed estimates from separate GLMs for each region (see methods for details).







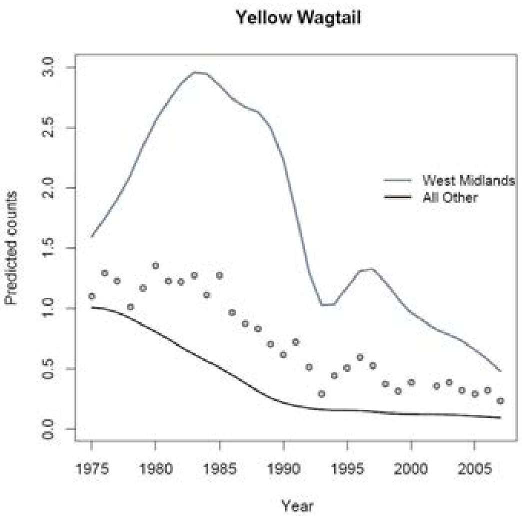
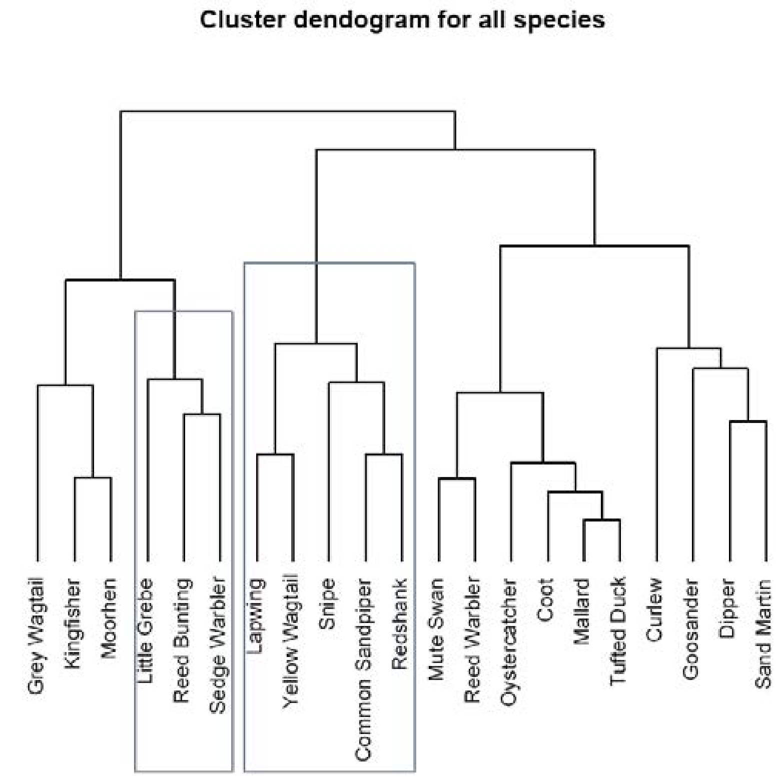


Figure 3.3.2.1 Continued**.**

3.3.3 Analysis of population trajectories

Figure 3.3.3.1 shows the results of the cluster analysis on the set of annual gradients. Clusters tended to separate firstly along an axis according to whether the species was generally declining or increasing. All the species exhibiting strong increases were grouped into a distinct cluster including Mute Swan, Reed Warbler, Oystercatcher, Coot, Mallard and Tufted Duck. Similarly, those with close to linear declines also formed a fairly distinct cluster including Lapwing, Yellow Wagtail, Snipe, Common Sandpiper and Redshank. Species experiencing similar changes in trends through time also tended to be grouped together in clusters:- Grey Wagtail, Kingfisher and Moorhen, all of which declined sharply then showed subsequent recoveries formed a cluster next to another including Little Grebe, Reed Bunting and Sedge Warbler, which exhibited exactly opposite patterns of sharp rise followed by a later decline in numbers. A fairly indistinct cluster was identified around Curlew, Goosander, Dipper and Sand Martin; these species generally had stable or oscillating trends.

Figure 3.3.3.1 Dendogram displaying the results of a cluster analysis on the set of annual index gradients (see methods for details). The length of the vertical lines indicates the degree of dissimilarity between clusters. Grey boxes were drawn around clusters uniting those species that are declining.



The multi-dimensional scale analysis resulted in generally similar groupings to that of the cluster analysis. Figure 3.3.3.2 displays the orientation of all species on the primary and secondary principle coordinate axes. The second axes largely explained overall linear trend (r^2 = 85%), with declining species tending to have lower and increasing species tending to have higher coordinate scores. Axis 1 appears to generally explain the degree to which population trends changed over time, with low scores for species tending towards linear trends and high scores for those with more marked changes in trajectory over time.

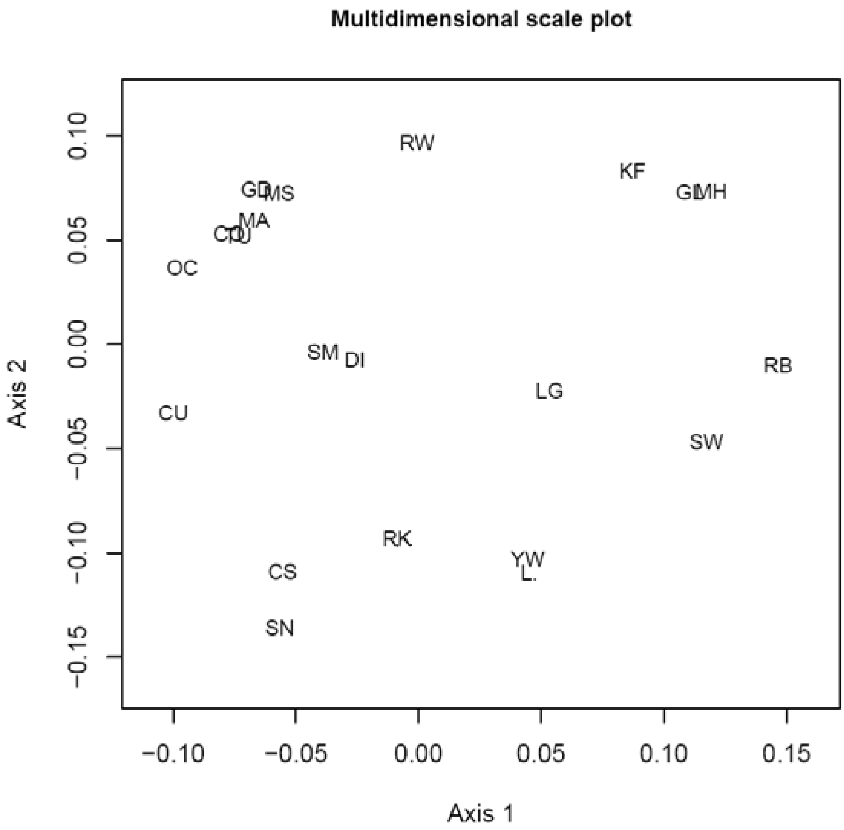


Figure 3.3.3.2 Primary (Axis 1) versus secondary (Axis 2) principle coordinate scores from an MDA (see methods for details). (CS = Common Sandpiper, CO = Coot, CU = Curlew, DI = Dipper, GD = Goosander, GL = Grey Wagtail, KF = Kingfisher, L. = Lapwing, LG = Little Grebe, MA = Mallard, MH = Moorhen, MS = Mute Swan, OC = Oystercatcher, RK = Redshank, RB = Reed Bunting, RW = Reed Warbler, SM = Sand Martin, Sedge Warbler = SW, SN = Snipe, TD = Tufted Duck, YW = Yellow Wagtail).

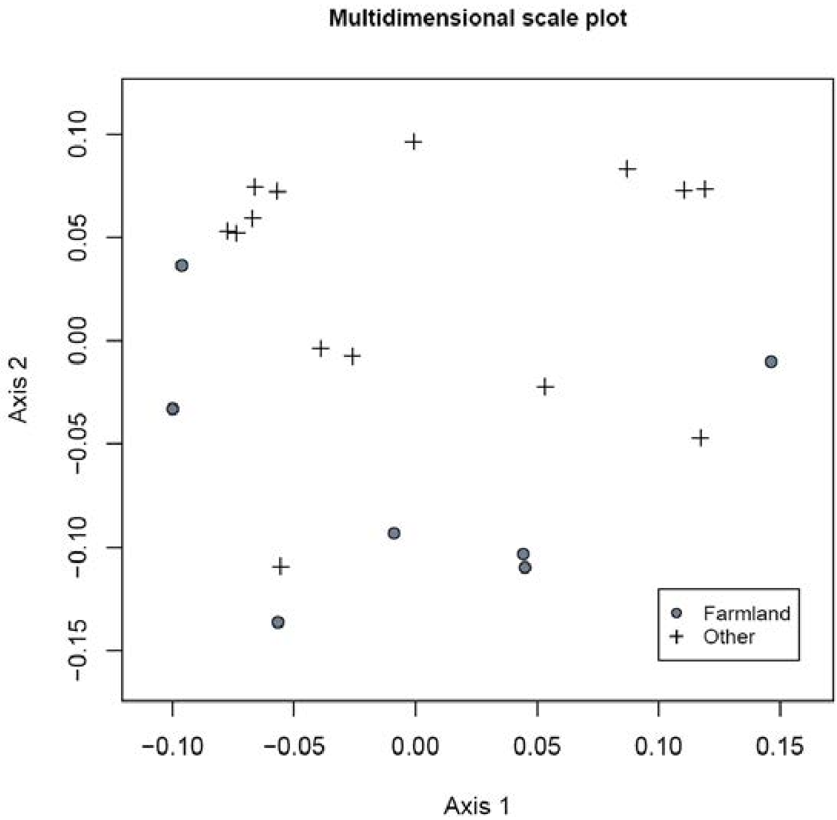
3.3.4 Species ecology and trends

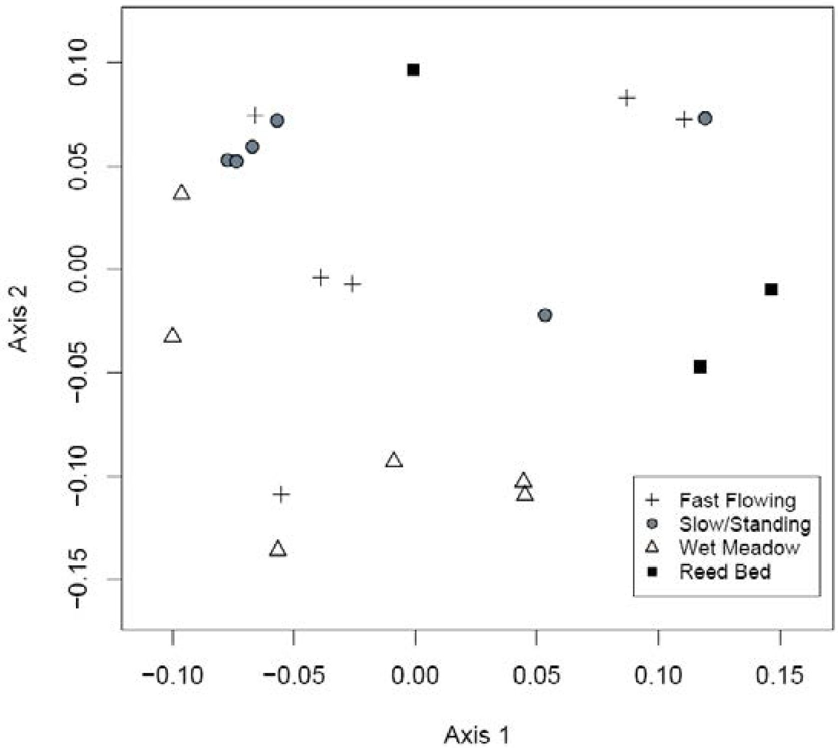
Broad habitat niche, migrant status and farmland status did not predict significant variation in the primary coordinate scores from the MDA (Table 3.3.4.1). However, species which often breed on farmland had significantly lower secondary coordinate scores than those which very rarely breed on farmland (Table 3.3.4.1, Figure 3.3.4.2) and species most commonly inhabiting wet meadow habitats had significantly lower secondary coordinate scores than those using other habitats (Table 3.3.4.1, Figure 3.3.4.2).

Table 3.3.4.1 Results of 2 multiple regression tests analysing the effect of habitat type, migrant status and farmland status on primary (component 1) and secondary (component 2) principle coordinate scores from a multi-dimensional scale analysis on annual gradients of index change (see methods for details). Statistics show type II ANOVA F tests.

	source of variation	**d.f.**	***F***	***P***
component 1	Broad Habitat Niche	3,17	1.73	0.199
	Migrant Status	1,19	0.18	0.680
	Farmland Status	1,19	0.02	0.886
component 2	Broad Habitat Niche	3,17	4.19	0.022*
	Migrant Status	1,19	1.29	0.269
	Farmland Status	1,19	11.54	0.003**

Figure 3.3.4.2 MDA plot for species grouped by i) farmland status and ii) broad habitat niche.





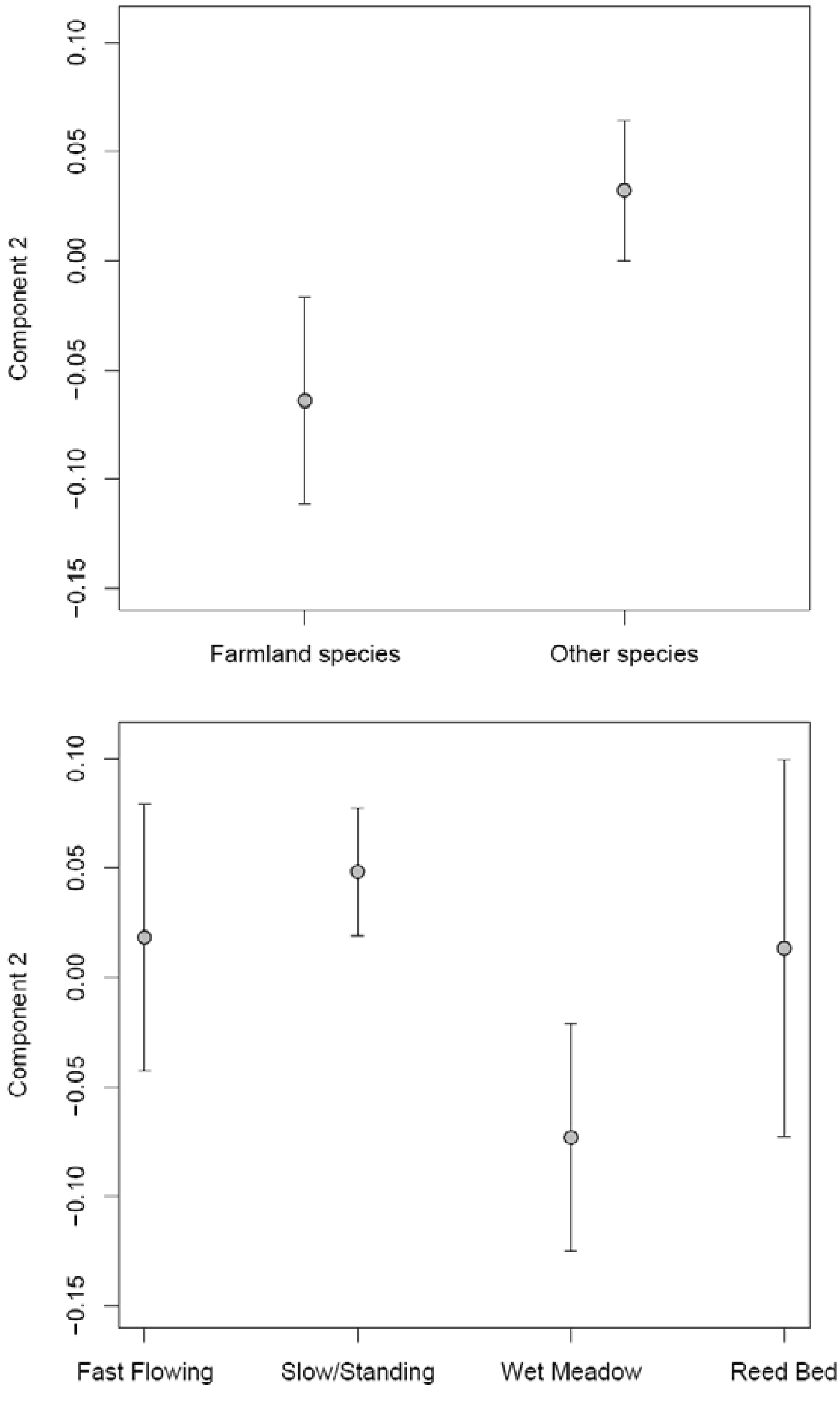


Figure 3.3.4.3 Error bar plot of secondary principle coordinate scores (component 2) from a multi-dimensional scale analysis on annual gradients of index change (see methods for details) versus farmland (a) and broad habitat niche (see Table 3.2.2.1 for habitat niche and farmland classes and Table 3.2.4.1 for summary statistics). Points = mean; whiskers = 2 x standard error.

Since the habitat analysis revealed how species sharing similar broad habitat niche classes and farmland classes were best separated along principle coordinate 2 and since this coordinate essentially explained overall linear trend, a further set of formal analyses were conducted to assess whether population gradients differed between groups based on farmland, broad habitat and migrant classes. Similarly, these analyses revealed significant differences in slope between groups based on farmland status and broad habitat niche, but also for migrant status (Table 3.3.2.4; Figure 3.3.4.4).

Table 3.3.4.2 Results of 3 multiple regression tests analysing the interaction between habitat type, migrant status and farmland status and year on standardised annual indices. Statistics show type II anova tests.

	d.f.	*F*	*P*
Farmland status*Year	1	54.57	<0.0001***
Migrant status*Year	1	14.43	0.0002***
Broad habitat niche*Year	3	22.46	<0.0001***

Of the species considered here, those often associated with farmland habitats during the breeding season have generally declined while those not commonly associated with farmland have generally increased (Figure 3.3.4.4). Wet meadow species have shown significantly different population trends from others, generally declining overall, whereas those most commonly found in fast-flowing, slow-moving or standing water bodies have generally increased. The three reed bed species included in the indicator have shown mixed population trends (Figure 3.3.3.2; Figure 3.3.4.4) but on average have declined overall (Figure 3.3.4.4). As a group, African migrants have also generally declined, whereas resident/European migrant species have generally increased (Figure 3.3.4.4).

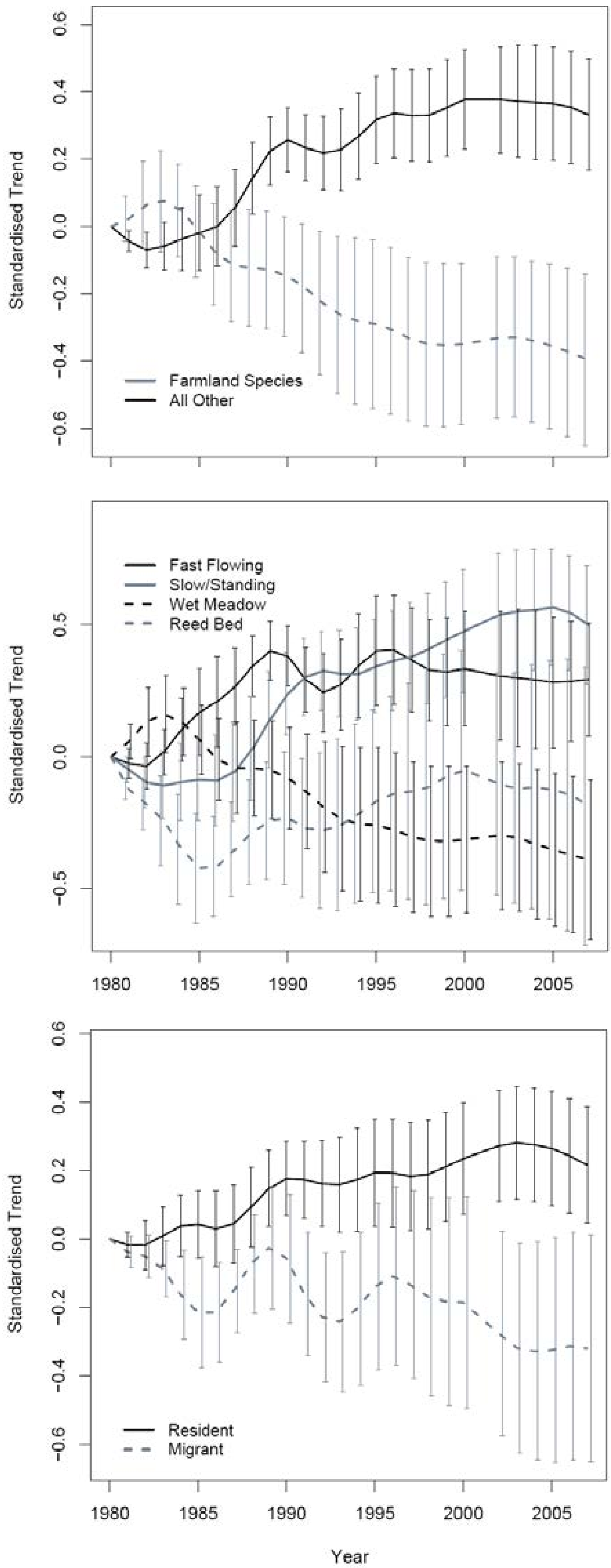


Figure 3.3.4.4 Error bar plots of standardised population indexes versus time for species grouped by a) Farmland status, b) Broad habitat niche and c) Migrant status. See methods of how indexes are calculated. Whiskers = standard error.

3.3.5 Habitat analysis at the one square km scale

An analysis of BBS data from the start of the scheme in 1994 until present reveals how Curlew have continued to decline overall, and are declining fastest on arable dominated landscapes (Figure 3.3.5.1, Table 3.3.5.1), relative to pastoral, marginal and upland habitats (Pastoral-: t = 3.80, P = 0.0001***; Marginal:- t = 2.67, P = 0.0075**; Upland:- t = 4.03, P < 0.0001***). Yellow Wagtails are declining fastest in pastoral zones (relative to Arable-: t = 4.61, P < 0.0001***; Marginal:- t = 1.98, P = 0.0473* and Upland:- t = 1.93, P = 0.0533) followed by arable landscapes (Figure 3.3.5.1, Table 3.3.5.1). Similarly, Snipe, whilst generally increasing elsewhere (after a sharp preceding crash in numbers) continue to decline on fastest on arable land compared to other habitat categories (Figure 3.3.5.1, Table 3.3.5.1; Pastoral-: t = 2.98, P = 0.0029**; Marginal:- t = 2.67, P = 0.0076*; Upland:- t = 5.03, P < 0.0001***). Reed Buntings show a general recovery in all habitats after a sharp fall in numbers, although this increase appears to be marginally slower in farmland habitats (Figure 3.3.5.1, Table 3.3.5.1). Lapwing are also continuing to decline on arable, marginal and pastoral habitats, but showing evidence of recovery in upland landscapes (Arable-: t = 6.15, P < 0.0001***; Pastoral:- t = 6.48, P < 0.0001***; Marginal:- t = 7.00, P < 0.0001***). Redshank have remained fairly stable over this period on marginal land, but continue to decline in the other habitats (Pastoral-: t = 1.48, P = 0.1384; Arable:- t = 1.92, P = 0.0556; Upland:- t = 3.60, P < 0.0003***).

Table 3.3.5.1 Results of multiple regression tests analysing the main (linear) interaction between habitat class and year. Statistics show the results of type II Anova tests.

Species	**d.f.**	X^2	P
Curlew	3	19.63	0.0002***
Redshank	3	13.71	0.0033**
Snipe	3	31.05	<0.0001***
Yellow Wag	3	40.25	<0.0001***
Reed Bunting	3	7.65	0.0537
Lapwing	3	15.80	0.0012**

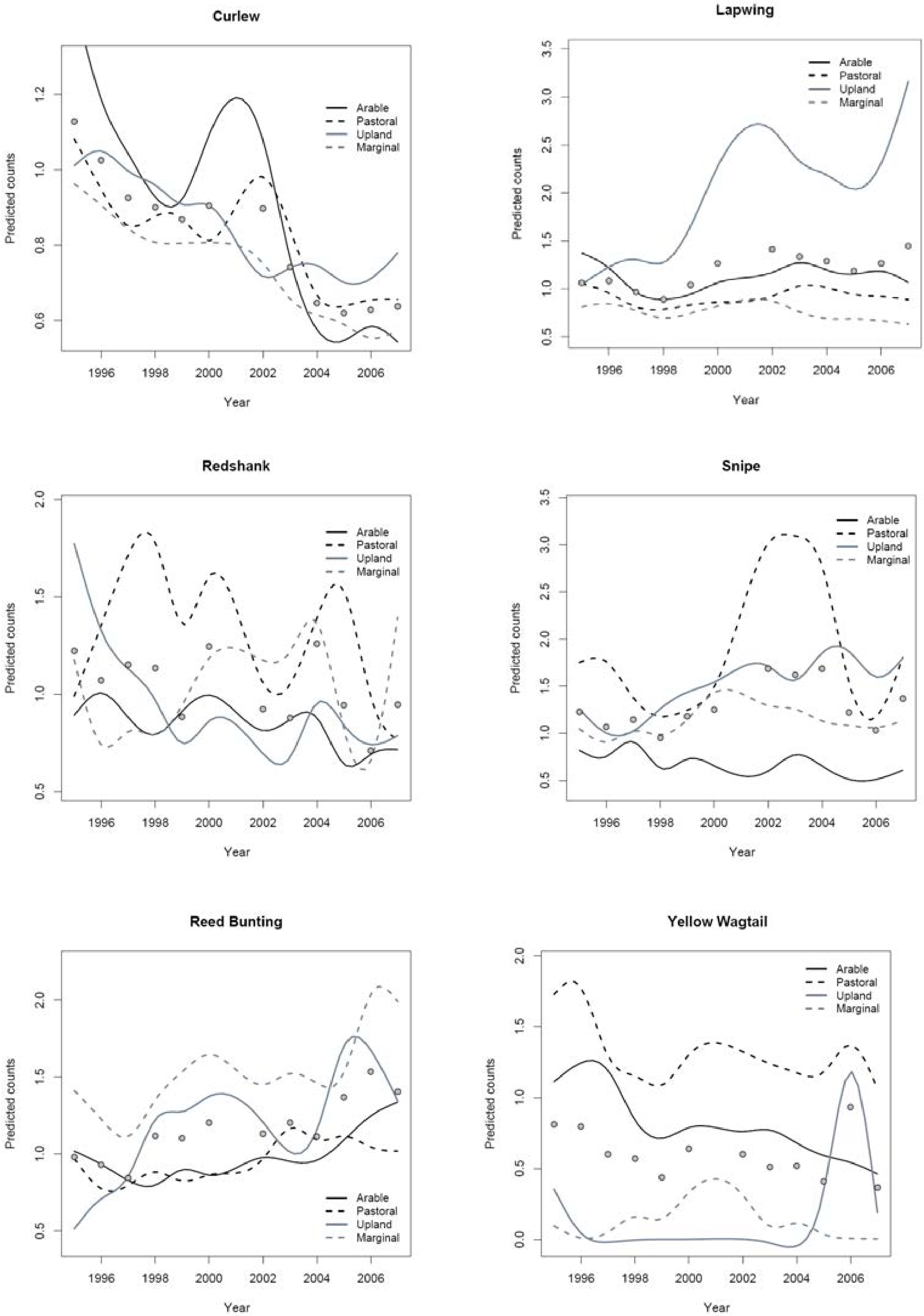


Figure 3.3.5.1 Broad habitat specific BBS trends for Curlew, Lapwing, Redshank, Snipe, Reed Bunting and Yellow Wagtail. Trends shown are the result of smoothed estimates from separate GLM models (see methods).

3.3.6 Habitat analysis at the ten square km scale

Table 3.3.6.1 highlights the significant effects of the proportions of surrounding woodland, arable pastoral and urban/rural land in the associated 10 km^2 land encompassing the survey square on the standardised change in counts between the periods 1995-2000 and 2001-2007. Lapwing showed a significant tendency to decline more steeply in areas with a high proportion of urban or rural land and Sedge Warbler declines were significantly higher in landscapes with more arable land. There was a slightly (barely significant) effect of surrounding woodland on Reed Bunting trends, such that areas with more woodland tended to show a greater decline or less of an increase.

Table 3.3.6.1 Results of separate regression tests assessing the effect of the amount of woodland, arable, pastoral and urban area in the surrounding 10km^2 on absolute count change between 1995-2000 and 2002-2007. Statistics show type II anova tests.

Species	**habitat**	***F***	***P***
Curlew	wood	0.03	0.859
Curlew	arable	2.25	0.134
Curlew	pastoral	0.16	0.693
Curlew	urban	0.05	0.821
Redshank	wood	0.36	0.547
Redshank	arable	0.01	0.916
Redshank	pastoral	0.09	0.763
Redshank	urban	0.05	0.821
Snipe	wood	0.31	0.580
Snipe	arable	1.42	0.234
Snipe	pastoral	3.59	0.059
Snipe	urban	0.64	0.425
Yellow Wagtail	wood	2.81	0.094
Yellow Wagtail	arable	1.75	0.186
Yellow Wagtail	pastoral	0.37	0.545
Yellow Wagtail	urban	0.46	0.500
Reed Bunting	wood	4.52	**0.034**
Reed Bunting	arable	0.59	0.444
Reed Bunting	pastoral	0.42	0.515
Reed Bunting	urban	0.53	0.466
Lapwing	wood	1.11	0.291
Lapwing	arable	2.24	0.135
Lapwing	pastoral	1.97	0.161
Lapwing	urban	7.92	**0.005**
Little Grebe	wood	0.00	0.979
Little Grebe	arable	0.29	0.595
Little Grebe	pastoral	3.06	0.092
Little Grebe	urban	0.54	0.470
Common Sandpiper	wood	2.02	0.158
Common Sandpiper	arable	0.21	0.650
Common Sandpiper	pastoral	0.47	0.495
Common Sandpiper	urban	0.72	0.399
Sedge Warbler	wood	0.31	0.577
Sedge Warbler	arable	7.84	**0.006**
Sedge Warbler	pastoral	0.04	0.848
Sedge Warbler	urban	0.21	0.646

3.3.7 Fine scale habitat analysis

Table 3.3.7.1 shows the relationship between bird abundance and the proportion of surrounding habitat (cereals, other crops, improved grassland, woodland, and urban/rural land) within a 3 km radius of the survey square for all declining species. Almost all species exhibited negative relationships between abundance and area of farmland, particularly with improved grassland. Both Common Sandpiper and Curlew were less abundant with increasing proportions of all farmland types; similarly Lapwing and Redshank were significantly scarcer in areas with a high proportion of crops and improved grassland and both Reed Bunting and Yellow Wagtail were less abundant with increasing area of grassland. Only Yellow Wagtail showed a positive relationship with increasing areas of farmland, being more common areas of cereals and crops. Common Sandpiper, Curlew, Redshank and Snipe were all significantly scarcer in areas with an increasing proportion of urban land, although the opposite was true for Little Grebe. Curlew, Lapwing, Reed Bunting, Sedge Warbler and Yellow Wagtail were all less common in highly wooded areas.

Table 3.3.7.1 Results of separate regression tests assessing the relationship between abundance and the area of "Cereal", "Other crop", "Improved grass", "Urban" and "Woodland" in the surrounding 3km radius around the survey area in the year 2000. Results are from type III ANOVA tests and indicate the direction of the relationship (NS = Non significant; +/- = p<0.05; ++/-- = p<0.01; +++/--- = p<0.001).

	Cereal		**Crop**		**Grass**		**Urban**		**Wood**	
Species	**BBS**	**WBBS**	**BBS**	**WBBS**	**BBS**	**WBBS**	**BBS**	**WBBS**	**BBS**	**WBBS**
Common Sandpiper	---	NS	-	NS	NS	NS	NS	--	NS	NS
Curlew	--	NS	---	NS	NS	NS	---	NS	---	-
Lapwing	NS	NS	-	NS	-	NS	NS	NS	---	NS
Little Grebe	NS	NS	NS	NS	NS	NS	+++	NS	NS	NS
Redshank	NS	NS	-	-	---	NS	-	NS	NS	NS
Reed Bunting	NS	NS	NS	NS	--	NS	NS	NS	---	NS
Sedge Warbler	NS	NS	NS	++	NS	NS	NS	NS	-	NS
Snipe	NS	NS	-	NS	NS	NS	-	NS	NS	NS
Yellow Wagtail	++	NS	+++	NS	-	NS	NS	NS	---	NS

3.4 Discussion

Almost half (9/21) of the species included in these analysis were identified as declining, namely Common Sandpiper, Curlew, Lapwing, Little Grebe, Redshank, Reed Bunting, Sedge Warbler, Snipe and Yellow Wagtail, and two are currently red-listed and six amber-listed for that reason. Both the cluster analysis and the multi-dimensional scale analysis grouped species according to the degree of similarity in the national population trends. As these groupings were not random with respect to species ecology, they suggest that those sharing similar ecological requirements also share common drivers of population change. These results, along with the further analyses showing differences in trends related to other ecological parameters, show that species that commonly breed on farmland have generally declined, whereas those that do not typically use farmland have, on average increased. Similarly, wet meadow species have declined more sharply than those inhabiting other habitats, although the effects of wet meadow and farmland groupings are largely analogous since they include mostly the same species. As a result it would be impossible to separate these effects within the limits of this study.

Comparing BBS trends across broad habitats within a species shows that for two of the five declining wet meadow species (Curlew and Snipe), declines have been most marked (or in the case of Snipe, recoveries have been slowest) on arable land relative to trends in pastoral, upland and marginal upland habitats. Lapwing are continuing to decline in arable land and pastoral landscapes and the recovery in the trend is primarily driven by those populations in the uplands. Yellow wagtail also continue to decline in both arable and pastoral dominated areas. These results imply that land-use management on farmland and especially in arable dominated areas is a significant driver behind the declines of these species, at least during the past ca 15 years since the start of the BBS. This is supported by the fact that Lapwing, Yellow Wagtail and Snipe have all experienced very similar, almost parallel population trends, as evident from the cluster analysis.

The results from the fine scale analysis of abundance in relation to Land Cover habitat suggest that for many species, such as Common Sandpiper, Curlew, Lapwing, Redshank, Reed Bunting, Snipe and Lapwing, numbers on farmland are particularly low. Yellow Wagtail showed a strong affinity with cereal and pastoral land, presumably as a result of nesting habitat requirements; this could also explain the positive relationship between Sedge Warbler abundance and arable crops. However, these results suggest that intensively managed grassland may have become a sub-optimal habitat for breeding wetland birds, since four of the nine declining species examined are less common (as measured on BBS) in areas with more pastoral land. The processes behind the negative relationships between woodland area and wetland bird abundance certainly warrants further research, as does the apparent negative impact of nearby urban developments on Common Sandpiper, Curlew, Redshank and Snipe. In both cases, these habitat differences may be confounded with differences predation rates, disturbance and other factors.

Our results support the view that the declines in these species may be driven by the destruction of habitat, through drainage of wet meadows for arable conversion and general agricultural intensification in arable dominated landscapes (Vickery *et al.* 2001; Wilson *et al*. 2005). Notably pesticide use has generally increased on arable land over the time period of this study, whereas it has generally decreased on grassland (Pesticide usage survey, http://www.fera.defra.gov.uk/plants/pesticideUsage/index.cfm#pusstats). This is one particular additive factor that may have detrimental effects for birds nesting in this habitat, not only because of the adverse effects on insect prey *per* se, but because this increase in pesticide use is associated with an increase in spraying frequency which may cause increased disturbance and loss of nests/chicks through destruction by machinery. Lapwing has also declined faster in landscapes with a higher proportion of urban/rural land, possibly as a result of additional rural expansion into these areas. Lapwing, Snipe and Yellow Wagtail all declined faster in the Midlands (specifically West Midlands for Common Sandpiper and Yellow Wagtail) than elsewhere. This may simply reflect the high proportion of arable habitat in this area, but may also be indicative of particular aspects of agricultural intensification and habitat destruction in this region.

Three species associated with reed beds were included in this analysis, two of which, Sedge Warbler and Reed Bunting, have declined overall and share similar population trajectories. In contrast, Reed Warbler numbers are increasing. This trend is in contrast to the declining trend evident from another BTO survey, the Constant Effort Site (CES) scheme where the Reed Warbler trend is more similar to that of the Sedge Warbler. The discrepancy between the two surveys trends may represent recent range expansion of Reed Warblers into a broader range of habitats including linear waterways covered by the Waterways Breeding Bird Survey scheme, with populations in larger *Phragmites* reed beds continuing to fall. Overall declines in reed bed species could also be partly attributable to drainage for arable conversion and urban development. Our results provide some support for this since landscapes containing a high proportion of arable farmland had steeper declines of one species – Sedge Warbler - than elsewhere. Another possibility is that poor management in reed beds allows woodland succession, and our results show that Reed Buntings declines have been more severe in landscapes with a higher proportion of woodland. A problem with interpreting trends for these three reed bed species is that two (Sedge Warbler and Reed Bunting) occur widely in other habitats. A research possibility is further analysis of reed-bed-specific trends in a larger range of wetland species following the approach in (Noble *et al*. 2008b). As with the wet meadow species, both Reed Bunting and Sedge Warbler declined more rapidly in the Midlands than elsewhere within England.

These results show that migrants wintering in Africa, as a group, have declined, whereas resident species have generally increased. This suggests common effects due to wintering conditions or effects on migration. Knowledge is currently lacking on the wintering distribution of many African migrants, but there is good evidence that a range of species wintering in the Sahel region south of the Sahara have suffered marked declines in breeding numbers in the UK (Hewson & Noble, 2009) and across Europe (Sanderson *et al.* 2006). Wetland species include Reed Warbler, Sedge Warbler, Yellow Wagtail and Common Sandpiper. Sand Martin was the only migrant that also winters in this region not found to be in decline. However, whilst the trend since the 1970s has oscillated considerably, there are signs of decline since the mid 1990s. More research to assess the degree of overlap of wintering ranges of the species in question, to assess land use and climatic conditions on wintering grounds and stop-over sites, would be helpful.

3.5 Conclusions and Recommendations

Wet meadow species as a group have suffered the steepest declines compared to those occupying other habitats. Conservation effort to reverse trends in these species would therefore have the highest impact in improving the trajectory of the wetland bird indicator. These preliminary analyses suggest that changes in land use (through habitat destruction, as a direct result of the drainage of land and the overall intensification of farmland since the 1950s) is linked to the observed declines. Our results further suggest that declines in arable-dominated areas are generally particularly severe for wet meadow species. Targeted conservation measures, potentially providing incentives for sensitive land management in arable farming areas (where breeding birds still occur) or the creation of new wet meadow habitat could have a profound positive influence.

Much work remains to be done to identify the particular detrimental aspects of agricultural intensification on numbers of wetland birds, and knowledge regarding the mechanistic links between land use management, habitat microstructure and the ultimate effects of these practices on the quality of the habitat for breeding wetland birds is very scant. Research into the relationship between current agricultural practices and key environmental variables such as moisture content or pesticide/fertiliser levels in soil and how these factors in turn affect the habitat quality for breeding birds would be a useful first step in bridging this gap.

The reed bed species included here have also declined (with the exception of Reed Warbler), probably primarily as a result of changes in habitat. Continuing the development and active management of reed bed habitat should aid recovery of these and other more specialised reed bed species. Reed Bunting appears to have started making a slow recovery, but this is likely to be also influenced by concurrent changes in farmland. As with wet meadow species the most marked declines have occurred in the Midlands, suggesting a focus for conservation effort.

Exploration of factors such as the influence of climate change and predation were beyond the scope of this project but are undoubtedly important drivers (see section 2.1) and ongoing research by the BTO and other organisations are beginning to address these areas.

3.6 Other Data Sets and Statistical Approaches Considered

We identified three major data sets, that with some effort, might be used to assess the influence of other key ecological parameters on changes in population trends and abundance of wetland birds. The Centre for Ecology and Hydrology were consulted about the use of pesticide and fertiliser data for this report. The Department for Environment, Food & Rural Affairs (DEFRA) and Scottish Government, Rural and Environment Research (RERAD) hold data from the "Pesticides Usage Survey" regarding annual use of pesticides and insecticides, which is a result of a small number of stratified survey points across U.K. farms. Survey points are not repeated each year but are averaged to obtain broad scale regional figures. This did not allow us to directly relate pesticide use to bird abundances at a suitably fine scale. However, some broad regional comparisons might be possible.

There are also some national data relating to fertiliser use; "The British Survey of Fertiliser Practice", initially carried out by the Ministry of Agriculture, Fisheries and Food and the Scottish Agriculture, Environment and Fisheries Department (and later by the University of Cambridge) for DEFRA is a volunteer survey of fertiliser use by land owners. Data are broken down by year and by broad scale habitat type. The possibility of obtaining and manipulating these data could be investigated for future research.

Stocking rates, which may be a suitable surrogate for grazing pressure are available from the Cattle Tracing Scheme (DEFRA) which keeps a record of all animals entering and leaving U.K. farms. The main caveat of relating these data to bird abundance was that there was no way to ascertain where the cattle are within a farm.

An additional "turning points" analysis was conducted but not reported here. This method involves taking the second derivatives of smoothed trends to isolate periods in time when population change was most dramatic. This approach has proved useful in defining significant turning points in groups of farmland birds (Siriwardena *et al*. 1998). However, we found that the location of turning points were largely influenced by the degree of smoothing of trends and also governed by the temporal autocorrelation of change between consecutive years. Also the definition of turning points depended largely on the arbitrarily defined significance level. As a result we decided that the methods we developed for the comparison of population trends between species provided a more robust framework for comparison of trends.

3.7 Problems and Potential Solutions

For further analyses of the effects of specific agricultural land use variables (beyond that of broad habitat classes) environmental data and agricultural data available or collected at the same time as bird survey data would be ideal for fine scale modelling of habitat effects. Currently agricultural survey data is at too coarse a scale to allow for particularly useful analyses. Digitisation of the routes of historical data sets used in modelling trends (for example CBC and WBS) would also make it possible to analyse the effects of land use over longer time periods.

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4. ANALYSES OF WOODLAND BIRDS

Jane Carpenter and Elisabeth Charman (RSPB)

4.1 Introduction

4.1.1 Aim

The aim was to use statistical analysis of available current datasets to further understand the likely drivers of changes in woodland bird populations. Four potential drivers were identified where significant gaps in knowledge exist, but for which some data were available for analysis. These were: soil moisture, predation by avian predators, climate change and landscape scale effects.

4.1.2 Background: The Repeat Woodland Bird Survey

The main dataset available for use was that of the Repeat Woodland Bird Survey (RWBS). The original RWBS investigated trends in breeding bird populations in British broadleaved and mixed woods (Amar *et al.* 2006). Data were collected on both bird populations and habitat variables, allowing some investigation of relationships between the two. The survey established for the first time the declines of the specialist residents and migrant woodland birds using data collected within just woodland, and was able to confirm the national trends. In total trends were established for 34 species, 9 of which were shown to be in large decline and 11 which were increasing. The data was used to establish relationships between bird populations and habitat in two follow up reports, Habitat Associations of Woodland Birds (Smart *et al.* 2007) and Habitat Associations of Woodland Birds II (Carpenter *et al.* 2009a). In these reports, a number of habitat, and other, variables were correlated with the presence and abundance of several bird species in woodlands across Britain. Thirty-one of the 35 woodland indicator species were included in either the first or second report. Four species (Lesser Whitethroat, Nightingale, Sparrowhawk and Tawny Owl) could not be included due to a lack of data.

These reports, therefore, were a major achievement in understanding some of the possible reasons for decline of woodland birds, and of understanding their habitat associations, which for several species was previously unknown, or poorly known. However, the scope of these reports was limited mostly to wood level habitat associations and some further areas of investigation have been identified which are addressed in these analyses.

The findings of these current analyses, taken alongside the findings of Carpenter *et al.* (2009b), will allow greater understanding of the likely drivers of decline for each species.

4.2 General Methods

Detailed methods can be found in Amar *et al.* (2006), Smart *et al.* (2007) and Carpenter *et al.* (2009a).

4.2.1 Study sites

The RWBS dataset includes data collected by RSPB and BTO for different projects in the past. However, the methods for gathering the bird data differed and it was deemed inappropriate to merge these two datasets with respect to the current study. Therefore, we used the data collected by the RSPB only. The RSPB study sites (253 sites) were originally selected for a project in the 1980's, which aimed to establish the relative importance of different UK woodlands for woodland birds and as a result have a clumped distribution. Figure 4.2.2.1.1 shows the distribution of study sites and the clustering of sites within specific localities (16 localities). However, some localities only have a small number of sites and/or are geographically distant from all other localities. For these reasons, for the current analyses Haweswater was excluded (1 site), Cree (1 sites) was joined with Argyll, and Tudeley (2 sites) and Hertfordshire (4 sites) were joined with Buckinghamshire. Furthermore, other localities were excluded from some analyses because of restricted species distribution. This was determined by overlaying the locality map on the dot-distribution maps of the breeding atlas (Gibbons *et al.* 1993). When the area covered by the locality had < 40% of the total area with the species present then that locality was excluded for that species (See Smart *et al.* 2007 and Carpenter *et al.* 2009a for more details). Sites were included from Scotland and Wales as we believe this greatly improves the dataset.

4.2.2 Bird population data

4.2.2.1 Bird presence and abundance

Birds were surveyed in two episodes; the 1980s, referred to as episode 1, and 2003-2004, referred to as episode 2. Bird presence and abundance, in this report, is taken from episode 2 data. Abundance estimates were obtained through point counts. Most sites had 10 points within each wood, although this varied between sites (mean ± SE no. points = 9.76 ± 0.11, range = 2 - 27). Point count locations were chosen using a random number table. Points were not permitted to be closer than 50 m from the edge of the wood, nor were any two points within 100 m of each other. Points were marked on a map, located in the field and then marked with flagging tape to allow easy relocation. Each point count lasted 5 minutes and was carried out during two visits to each site. First visits were in April or the first week of May, and the second visits were in the last three weeks of May or first half of June. Around 20% of sites (n = 56) were surveyed in both 2003 and 2004, and the remainder were surveyed in only one year, either 2003 or 2004.

For each species, this gave us information on their presence and abundance in each woodland. Species abundance was the sum of the maximum count from visit 1 and 2. Where sites were surveyed in two years, the maximum count across all visits from both years was used.

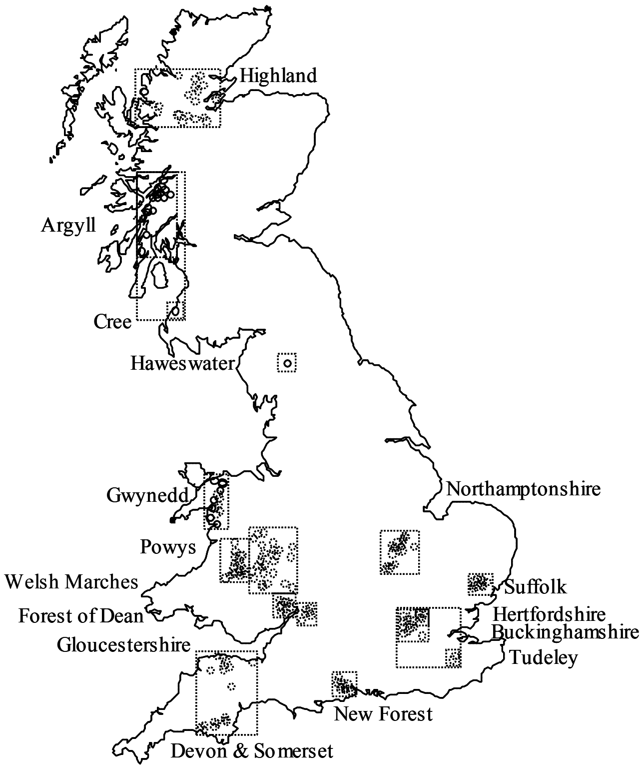

Figure 4.2.2.1.1 The location of all study woodlands across the UK showing the localities within which woodlands are clustered. Solid lines show the localities used in analyses and dotted lines show localities that were joined with other localities (Cree, Tudeley & Hertfordshire) or excluded completely (Haweswater only).

4.2.2.2 Bird population change

To allow us to investigate bird species' population change at each site, we used data from episode 1 (N1) and 2 (N2), and calculated a proportional change value: N2 / (N1+N2). Therefore, change values fall on a scale of zero to one, where 0 = extinction, 1 = colonisation, 0.5 = stable, <0.5 = decline and >0.5 = increase. This scale of values was used to investigate population change and soil moisture, winter climate change and landscape effects. However, the analysis of population change and predation was carried out previously to this report, and was done slightly differently. In this case, values from 0 to 0.49 were rounded down to zero, and values from 0.50 to 1 were rounded up to one. Hence, birds with a population change value of zero had declined at that site between the two episodes; those with a change value of one were stable or had increased. The reason for this difference is that results from Smart *et al.* (2007) and Carpenter *et al.* (2009a) can be directly compared.

4.2.3 Explanatory variable data

In the original surveys (Amar *et al.* 2006, Smart *et al.* 2007, Carpenter *et al.* 2009a) various habitat and other variable data was collected, to be compared with bird species presence, abundance and population change. See these reports for further information. In this report, further information of how data for the four drivers considered was obtained is included in each 'additional methods' section, below.

4.2.4 Statistical analyses

We aimed to answer three questions for each species, at the woodland scale, as follows:

1. Is bird species presence correlated with the driver concerned?
2. In occupied woods, is bird species abundance correlated with the driver concerned?
3. Is bird species population change correlated with the driver concerned?

To answer these questions we undertook separate analyses for each species in turn.

4.2.4.1 Analysis 1. Bird species presence

The probability of species presence was modelled using binary logistic regression using the LOGISTIC procedure in SAS v9.1 (SAS Institute 2001). We examined a range of model performance statistics for the final models including the area under the ROC curve (AUC), a measure of the trade-off between true positives and false positives in a binomial trial, and percent concordant and these statistics are shown. In addition, we also tested for a lack-of-fit using the Hosmer-and-Lemeshow test. Locality was included as a fixed effect.

4.2.4.2 Analysis 2. Wood-abundance (occupied woods only)

We first excluded any woodlands where the bird species in question was not present. We modelled woodland-scale species abundance using a generalised linear model with the GENMOD procedure in SAS. We specified a Poisson error structure, a logarithmic link and the natural logarithm of the number of points surveyed in each wood as an offset to account for the likelihood of higher species counts in woods where more points were surveyed. We examined the proportion of deviance (R^2 statistic) explained by the driver covariate concerned, and this is presented in the results. Locality was included as a fixed effect

4.2.4.3 Analysis 3. Population change

We modelled population change data using a generalised linear model. We examined the proportion of deviance (R^2 statistic) explained by the driver covariate concerned, and this is presented in the results. Locality was included as a fixed effect

4.3 Results

4.3.1 Soil moisture

4.3.1.1 Introduction

A change in soil moisture content within woodlands is a candidate cause of some woodland bird declines. For example, this has been identified as a major potential driver of declines in Willow Tit in England (e.g. Amar *et al.* 2006) and there may be an emerging issue between lesser spotted woodpecker habitat use and soil moisture (Charman *et al.* In prep). Changing soil moisture in woodland may be linked to food availability or nesting sites and thus has the potential to influence populations. Our original aim was to use the Met Office Rainfall and Evaporation Calculation System (MORECS) data for soil moisture on a national scale, and combine this with the RWBS dataset to test for relationships between soil moisture and bird presence, abundance and population change. However, on further inspection of the MORECS dataset, we realised this would not be possible. This was due to the scale of the MORECS data, and that of the RWBS woods, being incompatible. MORECS data is provided on a 40x40km grid, with a datapoint at the centre of each square. Therefore, there was only one MORECS data point covering a large geographical area, and many RWBS woods, which made further meaningful analysis impossible.

Data were available for soil moisture at each of the New Forest RWBS woodland sites. Therefore, we have used these 20 woodlands to test for relationships between bird presence, abundance and population change and soil moisture.

4.3.1.2 Additional methods

At each woodland, maximum and minimum soil moisture content was measured. In each woodland in the New Forest, soil moisture readings were taken during July 2007. Ten random points were generated in each wood, and a soil moisture probe used to measure the soil water content at each point. Readings were taken only once. The sum of readings was then used to establish the mean soil moisture in each woodland. Maximum and minimum readings were also used. Each of these values was tested against the presence, abundance and population change of each declining species.

4.3.1.3 Results

It was not possible to run any models for four species (Tree Pipit, Garden Warbler, Lesser Redpoll and Dunnock), due to a lack of bird data from the New Forest (occurrence at less than 8 sites in the dataset). For a further five species (Blackbird, Goldcrest, Treecreeper, Song Thrush and Marsh Tit) it was not possible to test for relationships with bird presence, as these species were present at all, or nearly all, sites.

In the remaining analyses, only one significant relationship was found, between Goldcrest abundance and maximum soil moisture content ($F_{1,18} = 5.47$, $P = 0.03$, $R^2 = 0.23$). Goldcrests were less likely to be abundant in woodlands with high maximum soil moisture content (Figure 4.3.1.4.1).

4.3.1.4 Conclusion

Few relationships were found between declining woodland bird species and soil moisture, suggesting this may not be an important driver of decline. However, this study was limited to a single geographical area, the New Forest, and so can only reflect the situation here. Information on the impact of soil moisture at a national scale is still lacking, and still of high importance, to be sure that these initial results represent the national situation.

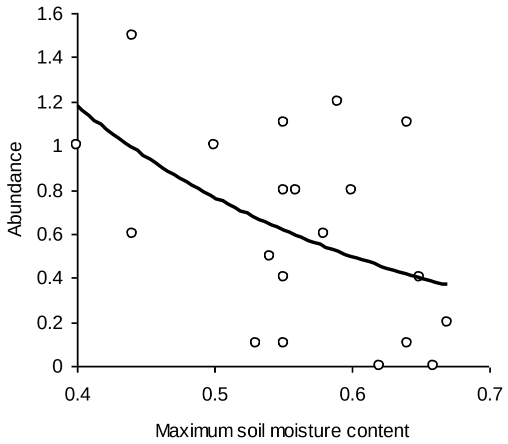

Figure 4.3.1.4.1 Relationship between Goldcrest abundance and maximum soil moisture content ($F_{1,18} = 5.47$, $P = 0.03$, $R^2 = 0.23$).

4.3.2 Predators

4.3.2.1 Introduction

The original RWBS report (Amar *et al.* 2006) looked at the evidence that grey squirrels may be contributing to the decline of woodland birds. However, no other potential nest predators were included in the analyses. Furthermore, a detailed study into possible reasons for decline of the Spotted Flycatcher (Stevens *et al.* 2008) suggested that Jay predation could be a significant factor in this species' decline. Therefore, we considered it pertinent to further research the possible role of avian predators in the decline of woodland birds.

Contemporary data of avian predators (Jay and Great Spotted Woodpecker) have been examined for any correlative relationships with woodland bird presence, abundance and population change.

Firstly, data for correlations between woodland bird presence and abundance and avian predators is presented. This analysis formed part of the 'Habitat Associations of Woodland Birds II' report (Carpenter *et al.* 2009a), although unfortunately avian predators were not included in the first report (Smart *et al.* 2007). For declining species included in the first report the analysis has been carried out separately for inclusion here.

Secondly, data for correlations between population change of the 17 declining woodland birds and avian predator abundance is presented. This data has not been presented elsewhere, but is part of the larger RWBS dataset.

4.3.2.2 Presence and abundance of woodland birds in relation to avian predators

Additional methods
Data for the abundance of each avian predator was collected at the same time as for all other bird species in the field data collection for the RWBS. Therefore, we simply used this data in our analyses and tested for relationships with bird presence and abundance.

Results
Table 4.3.2.2.1 summarises the relationships between 25 woodland bird species' presence and abundance in woods and avian predator abundance. Declining species are included, plus any non-decliners from Carpenter *et al.* (2009a). Significant associations, whether positive or negative, with avian predators are shown.

All but five of the 17 declining species presented showed some association with either Great Spotted Woodpeckers or Jays, and all but one of the 8 non-decliners presented showed relationships. However, the majority of these relationships were positive associations, rather than negative.

The Tree Pipit was the only species to show a negative association between its presence in woodlands and an avian predator, the Great Spotted Woodpecker (Table 4.3.2.2.1, Figure 4.3.2.2.1). However, the R^2 value was low and the model fit was questionable (see Figure 4.3.2.2.1). The abundance of five species (Hawfinch, Lesser Spotted Woodpecker, Tree Pipit, Willow Warbler and Siskin) was negatively correlated with Great Spotted Woodpecker abundance (although results for Hawfinch and Lesser Spotted Woodpecker need further clarification) (Table 4.3.2.2.1, Figures 4.3.2.2.2 a to e). Four of these five species are declining.

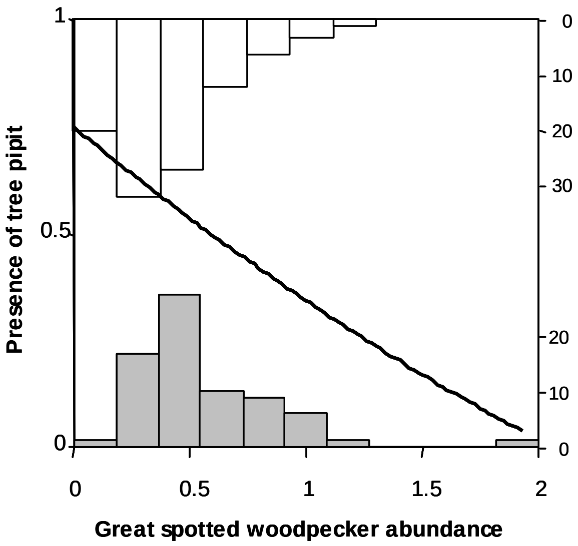

Figure 4.3.2.2.1 Relationship between Great Spotted Woodpecker abundance and the presence of Tree Pipits in woods (Wald X^2_1 = 9.62, P = 0.002; % concordant = 60.4, AUC = 0.65, R^2 = 0.07, Hosmer and Lemeshow goodness-of-fit P = 0.03).

Table 4.3.2.2.1 Summary of results of correlations between the presence and abundance of woodland bird species and potential avian predator abundance. The test statistic (Wald or F Value) and P Value category (+ = P < 0.1, ++ = P < 0.05, +++ = P < 0.01, ++++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected. na = test not appropriate. Species in bold are considered to be woodland specialists (Defra, 2006). Original Report 1 = Smart *et al.* 2007; Report 2 = Carpenter *et al.* 2009a. GRSWO = Great Spotted Woodpecker.

Species	**Original Report**	**GRSWO association**				**Jay association**			
		Presence		**Abundance**		**Presence**		**Abundance**	
		Wald	**P**	**F**	**P**	**Wald**	**P**	**F**	**P**
Blackbird*	2			35.50	++++	2.81*	+++*	9.16	+++
Bullfinch	2								
Dunnock	2	5.04	++			3.33	+		
Garden Warbler									
Goldcrest	2	8.70	+++						
Hawfinch**	1			5.50	- -				
Jay	2	3.68	+	45.31	++++	na	na	na	na
Lesser redpoll	1								
Lesser Spotted Woodpecker**	1			3.16	-				
Marsh Tit	1								
Song Thrush	2	na	na	14.54	++++	na	na	8.74	++
Spotted Flycatcher	1								
Tree pipit	1	9.62	- - -	19.73	- - - -				
Treecreeper	2	5.94	+++	10.33	++				
Willow Tit**	2			na	na	5.61	+++	na	na
Willow Warbler	1			36.88	- - - -				
Wood Warbler	1			2.95	+				
Non-decliners from Carpenter *et al.* 2009a									
Chaffinch	2								
Coal Tit	2	2.97	+	9.03	+++			4.24	++
Green Woodpecker	2			3.09	+	3.91	+		
Long-tailed Tit	2					4.53	++		
Nuthatch	2			37.78	++++			8.43	+++
Robin	2	na	na	20.76	++++	na	na	6.87	+++
Siskin	2			4.05	- -				
Wren	2	na	na	8.73	+++	na	na	5.78	++

* = Blackbird presence analysis carried out for Scottish woods only, as birds were present in all English/Welsh woods.
** = Species' recorded in very few woods Results to be interpreted with caution

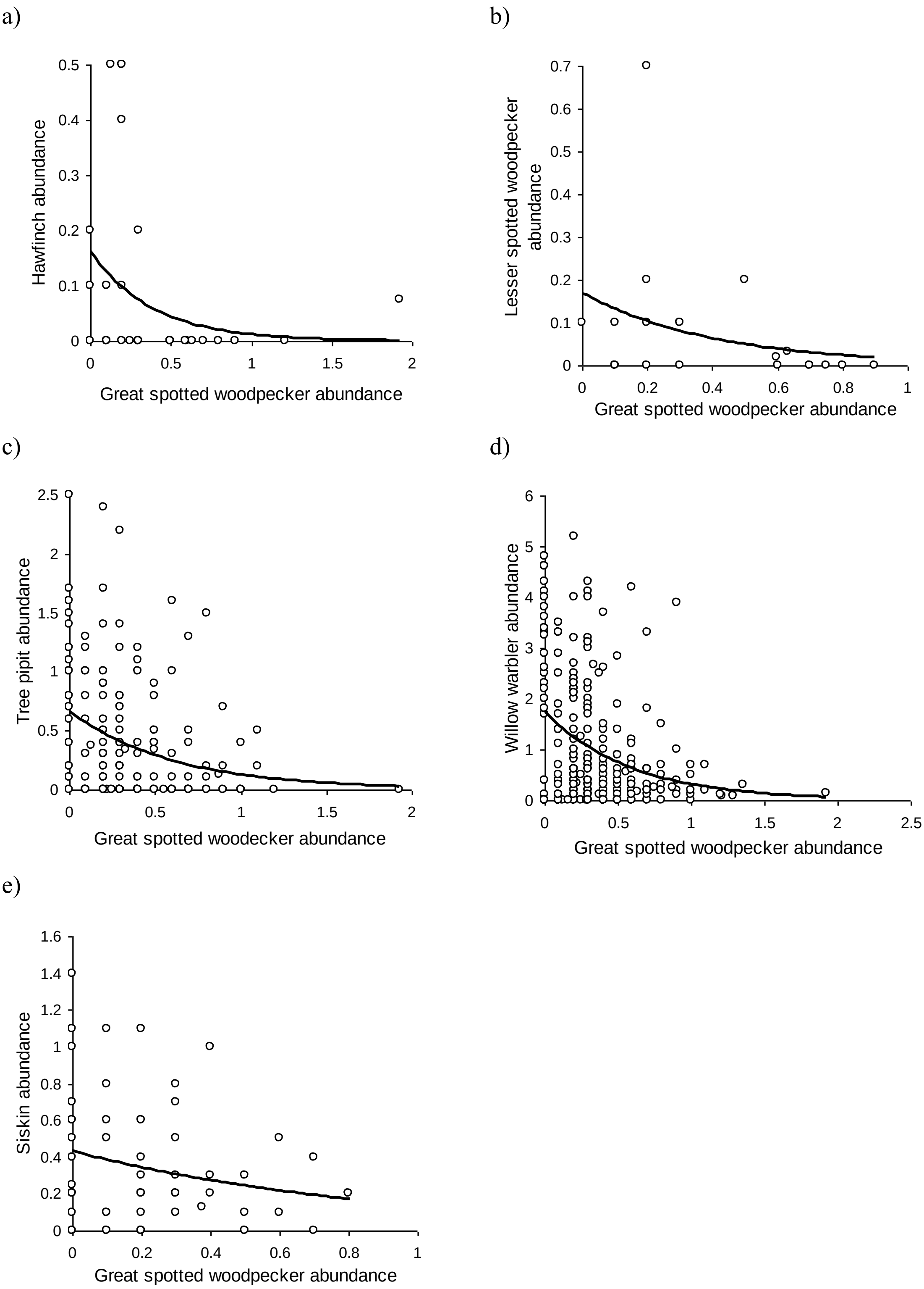

Figure 4.3.2.2.2 Relationship between Great Spotted Woodpecker abundance and a) Hawfinch abundance ($F_{1,34} = 5.50$, $P = 0.03$, $R^2 = 0.14$), b) Lesser Spotted Woodpecker abundance ($F_{1,19} = 3.16$, $P = 0.09$, $R^2 = 0.14$), c) Tree Pipit abundance ($F_{1,178} = 19.73$, $P < 0.0001$, $R^2 = 0.10$), d)Willow Warbler abundance ($F_{1,249} = 36.88$, $P < 0.0001$, $R^2 = 0.13$) and e) Siskin abundance ($F_{1,63} = 3.69$, $P = 0.06$, $R^2 = 0.06$).

4.3.2.3 Population change of woodland birds in relation to avian predators

Additional methods

Data for the abundance of each avian predator was collected at the same time as for all other bird species in the field data collection for the RWBS. Therefore, we simply used this data in our analyses and tested for relationships with bird population change.

Results

Of the 17 species included in the analyses, only two correlations were found between woodland bird population change and avian predators. The Goldcrest was more likely to have increased at sites with high Great Spotted Woodpecker abundance ($F_{1,216} = 4.41$, $P = 0.04$, Figure 4.3.2.3.1 a), whereas the Willow Warbler was more likely to have declined at sites with high Great Spotted Woodpecker abundance ($F_{1,248} = 3.99$, $P = 0.05$, Figure 4.3.2.3.1 b).

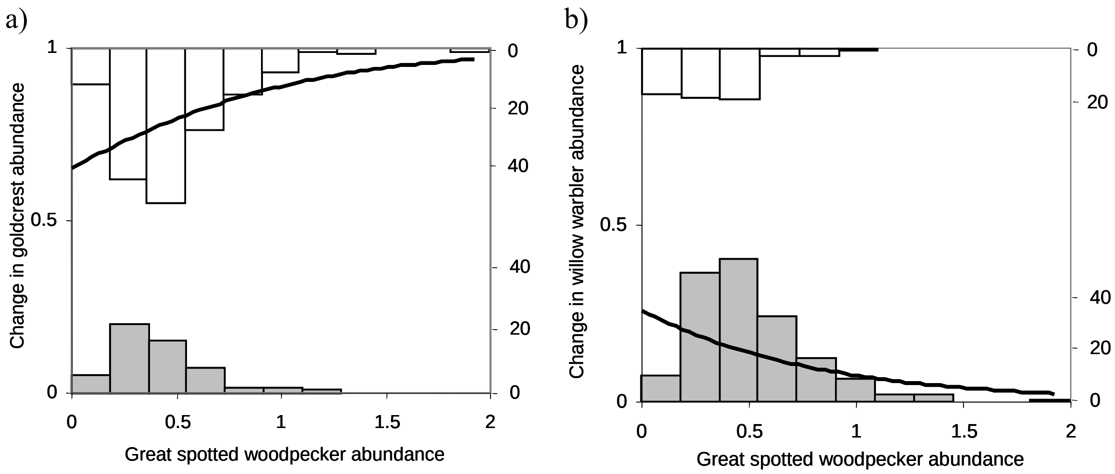

Figure 4.3.2.3.1 Relationship between the change in a) Goldcrest abundance and b) Willow Warbler abundance and Great Spotted Woodpecker abundance (Change in Goldcrest/Willow Warbler abundance 0 = population declined, 1 = population stable or increased).

4.3.2.4 Conclusion

Several correlations were found between bird presence and abundance and predator abundance. However, most of these were positive and so do not suggest this is a cause for concern. Indeed, no negative associations were found with Jay abundance. However, further detailed study of breeding success, and causes of nest failure, at the species level would be required to be sure of this, particularly given that Stevens *et al.* (2008) did find an effect when a detailed study was carried out on Spotted Flycatchers.

Tree Pipit presence and abundance was negatively correlated with Great Spotted Woodpecker abundance, and the abundance of a further four species was negatively correlated with Great Spotted Woodpecker abundance. Furthermore, population change of one species, the Willow Warbler, was negatively associated with Great Spotted Woodpecker abundance. Further detailed study into the species affected would be highly worthwhile.

4.3.3 Climate change

4.3.3.1 Introduction

The original RWBS (Amar *et al.* 2006) looked at the impact of summer climate variables on woodland birds. However, no winter climate variables were included, yet winter climate could also be of crucial importance to woodland birds, particularly resident species (due to influences on survival). But conditions in the UK can also reflect conditions in wintering grounds for migrants (Goodenough *et al.* 2009).

Here, we have correlated bird presence, abundance and population change with a number of winter climate variables, to assess the possible importance of winter climate to woodland bird species. We chose not to amalgamate the different measures using a Principal Components Analysis, as although this would have shown overall trends it would have hidden underlying relationships with specific winter variables.

4.3.3.2 Methods

We calculated the change in mean monthly temperature and rainfall (cm), and number of rainy days in January, February and March 1980-2004. Data were obtained for the 5km square containing each of our sites from the UKCIP website. Measures of change were defined as the slope of a linear regression fitted to these data (Amar *et al.* 2006). These were then correlated with bird presence, abundance and population change.

4.3.3.3 Results

Table 4.3.3.4.1 shows the results of analyses of bird presence, abundance and population change with the mean temperature in January, February and March. Table 4.3.3.4.2 shows the results of analyses of bird presence, abundance and population change with rainfall in January, February and March. Table 3.3.3 shows the results of analyses of bird presence, abundance and population change with the number of rainy days in January, February and March.

4.3.3.4 Conclusion

Many associations were found between bird presence, abundance and population change and winter climate variables. The large amount of information contained in the results tables makes it difficult to summarise the results across species. Instead, further discussion of species by species results are given in the discussion.

However, the number of relationships detected demonstrates the potential importance of winter climate change to woodland, and other, bird populations. Here, we have carried out a preliminary investigation only, yet this work suggests that changes in winter climate are already impacting on woodland bird populations. A clear conclusion of this work, therefore, is that this is an area in urgent need of further investigation and monitoring.

Table 4.3.3.4.1 Summary of results of correlations between bird presence, abundance and population change and mean temperature January-March. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = $P < 0.05$, ++ = $P < 0.01$, +++ = $P < 0.001$) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected. dnc = model did not converge.

		Presence		Abundance				Population change			
		Wald		R2	DF	F	P	R2	DF	F	P
Jan	Blackbird	4.74	-	0.16	2,240	22.85	+++	0.18	2,226	24.11	+++
	Bullfinch				dnc				dnc		
	Dunnock			0.07	2,240	8.91	- - -		dnc		
	Garden Warbler			0.06	2,212	6.55	- -		dnc		
	Goldcrest										
	Hawfinch				dnc				dnc		
	Jay			0.03	2,212	3.24	+		dnc		
	Lesser redpoll			0.11	2,222	13.76	+++	0.10	2,116	6.48	- -
	Lesser Spotted W'pecker				dnc				dnc		
	Marsh Tit				dnc				dnc		
	Song Thrush							0.07	2,239	8.46	+++
	Spotted Flycatcher			0.03	2,240	3.21	-		dnc		
	Tree pipit			0.33	2,240	59.12	+++		dnc		
	Treecreeper							0.03	2,235	3.59	-
	Willow Tit	3.74	+		dnc				dnc		
	Willow Warbler	5.98	- -	0.38	2,240	74.45	+++	0.21	2,239	30.82	+++
	Wood Warbler			0.16	2,240	22.82	- - -				
Feb	Blackbird	31.07	+++	0.4	2,240	78.98	+++	0.18	2,226	24.25	- - -
	Bullfinch	6.37	- -		dnc				dnc		
	Dunnock			0.07	2,240	8.87	- - -		dnc		
	Garden Warbler	4.23	+	0.03	2,212	3.24	+		dnc		
	Goldcrest	25.64	+++	0.13	2,240	17.75	+++	0.06	2,219	7.65	- - -
	Hawfinch	8.33	- -		dnc				dnc		
	Jay	11.52	+++	0.06	2,212	7.32	+++		dnc		
	Lesser redpoll			0.12	2,222	14.97	- - -	0.12	2,116	7.74	+++
	Lesser Spotted W'pecker				dnc				dnc		
	Marsh Tit				dnc				dnc		
	Song Thrush	7.86	++	0.09	2,240	12.61	+++	0.05	2,239	6.53	++
	Spotted Flycatcher			0.03	2,240	3.52	-		dnc		
	Tree pipit			0.48	2,240	113.10	- - -		dnc		
	Treecreeper	9.29	++	0.09	2,240	12.72	+++	0.04	2,235	5.85	- -
	Willow Tit				dnc				dnc		
	Willow Warbler	13.60	- - -	0.66	2,240	237.20	- - -	0.30	2,239	50.01	- - -
	Wood Warbler	22.29	+++	0.23	2,240	35.20	+++	0.04	2,183	3.43	+
Mar	Blackbird			0.165	2,240	23.71	+++	0.22	2,226	31.37	- - -
	Bullfinch				dnc				dnc		
	Dunnock	4.72	-	0.09	2,240	12.82	- - -		dnc		
	Garden Warbler	11.23	- - -	0.08	2,212	8.88	- - -		dnc		
	Goldcrest			0.05	2,240	5.87	++	0.03	2,219	3.49	-
	Hawfinch	14.98	+++		dnc				dnc		
	Jay								dnc		
	Lesser redpoll			0.11	2,222	13.51	+++	0.10	2,116	6.15	++
	Lesser Spotted W'pecker				dnc				dnc		
	Marsh Tit				dnc				dnc		
	Song Thrush							0.06	2,239	7.70	+++
	Spotted Flycatcher			0.03	2,240	3.21	-		dnc		
	Tree pipit			0.33	2,240	59.21	- - -		dnc		
	Treecreeper			0.03	2,240	4.12	+	0.04	2,235	5.10	- -
	Willow Tit				dnc				dnc		
	Willow Warbler	6.48	- -	0.4	2,240	80.80	- - -	0.21	2,239	30.95	- - -
	Wood Warbler	4.53	+	0.15	2,240	20.93	+++				

Table 4.3.3.4.2 Summary of results of correlations between bird presence, abundance and population change and rainfall January-March. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected. dnc = model did not converge.

		Presence		Abundance				Population change			
		Wald	**P**	**R2**	**DF**	**F**	**P**	**R2**	**DF**	**F**	**P**
Jan	Blackbird	24.97	+++	0.17	2,240	24.59	- - -	0.20	2,226	28.71	- - -
	Bullfinch				dnc				dnc		
	Dunnock	10.46	- - -	0.08	2,240	11.09	- - -		dnc		
	Garden Warbler	12.52	- - -	0.07	2,212	8.43	- - -		dnc		
	Goldcrest	9.89	- - -								
	Hawfinch				dnc				dnc		
	Jay	3.95	-	0.04	2,212	3.92	-		dnc		
	Lesser redpoll			0.13	2,222	15.92	+++	0.11	2,116	7.17	+++
	Lesser Spotted W'pecker				dnc				dnc		
	Marsh Tit				dnc				dnc		
	Song Thrush							0.05	2,239	6.11	++
	Spotted Flycatcher	13.59	- - -	0.06	2,240	7.70	- - -		dnc		
	Tree pipit			0.36	2,240	66.74	+++		dnc		
	Treecreeper							0.05	2,235	5.65	- -
	Willow Tit				dnc				dnc		
	Willow Warbler			0.39	2,240	77.73	+++	0.21	2,239	31.45	+++
	Wood Warbler			0.15	2,240	20.74	- - -	0.04	2,183	4.16	-
Feb	Blackbird	12.79	- - -	0.28	2,240	45.77	- - -	0.18	2,226	24.1	- - -
	Bullfinch				dnc				dnc		
	Dunnock			0.07	2,240	9.05	- - -		dnc		
	Garden Warbler			0.03	2,212	3.21	+		dnc		
	Goldcrest	20.60	- - -	0.09	2,240	11.55	- - -	0.03	2,219	3.36	+
	Hawfinch				dnc				dnc		
	Jay			0.03	2,212	3.00	-		dnc		
	Lesser redpoll			0.11	2,222	13.39	+++	0.09	2,116	6.24	- -
	Lesser Spotted w'pecker				dnc				dnc		
	Marsh Tit	17.79	- - -		dnc				dnc		
	Song Thrush			0.06	2,240	6.99	- - -	0.04	2,239	5.45	++
	Spotted Flycatcher			0.03	2,240	4.26	-		dnc		
	Tree pipit	20.69	+++	0.40	2,240	81.88	+++		dnc		
	Treecreeper							0.05	2,235	5.93	++
	Willow Tit	4.90	-		dnc				dnc		
	Willow Warbler	13.82	+++	0.43	2,240	91.78	+++	0.26	2,239	43.59	- - -
	Wood Warbler			0.15	2,240	20.72	- - -				
Mar	Blackbird	24.36	+++	0.19	2,240	27.97	- - -	0.18	2,226	24.43	- - -
	Bullfinch	6.26	++		dnc				dnc		
	Dunnock			0.07	2,240	9.02	+++		dnc		
	Garden Warbler			0.04	2,212	4.63	- -		dnc		
	Goldcrest	23.92	- - -	0.02	2,240	3.05	-	0.03	2,219	3.11	+
	Hawfinch	4.70	-		dnc				dnc		
	Jay	7.01	- -						dnc		
	Lesser redpoll			0.13	2,222	17.17	+++	0.09	2,116	6.06	- -
	Lesser Spotted W'pecker				dnc				dnc		
	Marsh Tit	12.24	+++		dnc				dnc		
	Song Thrush	4.64	-					0.05	2,239	5.96	- -
	Spotted Flycatcher			0.04	2,240	5.01	++		dnc		
	Tree pipit			0.36	2,240	67.69	+++		dnc		
	Treecreeper	5.90	-	0.03	2,240	3.46	-	0.03	2,235	3.67	-
	Willow Tit				dnc				dnc		
	Willow Warbler			0.46	2,240	100.70	+++	0.21	2,239	31.38	+++
	Wood Warbler	31.36	- - -	0.20	2,240	29.60	- - -	0.04	2,183	4.11	-

Table 4.3.3.4.3 Summary of results of correlations between bird presence, abundance and population change and the number of rainy days January-March. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected. dnc = model did not converge.

		Presence		Abundance				Population change			
		Wald	P	R2	DF	F	P	R2	DF	F	P
Jan	Blackbird			0.16	2,240	22.82	- - -	0.19	2,226	26.24	- - -
	Bullfinch				dnc				dnc		
	Dunnock			0.07	2,240	9.28	- - -		dnc		
	Garden Warbler	9.60	- - -	0.09	2,212	10.44	- - -		dnc		
	Goldcrest										
	Hawfinch	10.93	+++		dnc				dnc		
	Jay								dnc		
	Lesser redpoll			0.13	2,222	16.38	+++	0.10	2,116	6.48	++
	Lesser Spotted W'pecker				dnc				dnc		
	Marsh Tit				dnc				dnc		
	Song Thrush							0.05	2,239	6.39	++
	Spotted Flycatcher			0.03	2,240	3.38	-		dnc		
	Tree pipit			0.35	2,240	64.44	+++		dnc		
	Treecreeper							0.07	2,235	9.61	- - -
	Willow Tit				dnc				dnc		
	Willow Warbler	8.96	- -	0.39	2,240	77.21	+++	0.21	2,239	30.95	+++
	Wood Warbler			0.16	2,240	23.53	- - -	0.04	2,183	4.34	- -
Feb	Blackbird	31.07	- - -	0.29	2,240	50.42	- - -	0.19	2,226	25.64	+++
	Bullfinch				dnc				dnc		
	Dunnock			0.07	2,240	9.47	+++		dnc		
	Garden Warbler			0.03	2,212	3.23	+		dnc		
	Goldcrest	24.34	- - -	0.10	2,240	13.42	- - -	0.06	2,219	7.49	+++
	Hawfinch	11.76	+++		dnc				dnc		
	Jay	4.25	-	0.03	2,212	3.17	-		dnc		
	Lesser redpoll			0.11	2,222	13.39	+++	0.17	2,116	11.56	- - -
	Lesser Spotted W'pecker				dnc				dnc		
	Marsh Tit				dnc				dnc		
	Song Thrush			0.05	2,240	6.92	- - -	0.05	2,239	5.71	- -
	Spotted Flycatcher			0.04	2,240	5.30	++		dnc		
	Tree pipit	4.08	+	0.42	2,240	87.01	+++		dnc		
	Treecreeper	9.17	- -	0.04	2,240	4.52	- -	0.05	2,235	5.59	++
	Willow Tit				dnc				dnc		
	Willow Warbler	12.40	+++	0.51	2,240	127.20	+++	0.27	2,239	45.62	+++
	Wood Warbler	4.14	-	0.16	2,240	22.01	- - -				
Mar	Blackbird	20.31	- - -	0.29	2,240	49.53	- - -	0.18	2,226	24.21	- - -
	Bullfinch	5.51	+		dnc				dnc		
	Dunnock			0.07	2,240	9.08	- - -		dnc		
	Garden Warbler			0.03	2,212	3.27	-		dnc		
	Goldcrest	31.73	- - -	0.08	2,240	11.44	- - -				
	Hawfinch	8.93	++		dnc				dnc		
	Jay	11.45	- - -	0.06	2,212	6.32	- -		dnc		
	Lesser redpoll			0.12	2,222	15.21	+++	0.10	2,116	6.51	- -
	Lesser Spotted w'pecker				dnc				dnc		
	Marsh Tit				dnc				dnc		
	Song Thrush	7.61	- -	0.08	2,240	9.82	- - -	0.04	2,239	5.39	- -
	Spotted Flycatcher			0.03	2,240	3.69	+		dnc		
	Tree pipit			0.40	2,240	80.65	+++		dnc		
	Treecreeper	10.15	- - -					0.03	2,235	3.49	+
	Willow Tit				dnc				dnc		
	Willow Warbler	6.01	++	0.51	2,240	124.90	+++	0.25	2,239	39.11	+++
	Wood Warbler	5.09	-	0.16	2,240	23.08	- - -	0.03	2,183	2.95	-

4.3.4 Landscape effects

4.3.4.1 Introduction

The original RWBS (Amar *et al.* 2006) included some landscape information, in the form of Principal Components Analyses of habitat type in the 3km surrounding each woodland. Here, we further investigate the hypothesis that woodland birds are suffering due to factors operating at the landscape scale, outside of woods. Various measures of landscape type surrounding woodlands have been used, and correlated with bird presence, abundance and population change.

4.3.4.2 Methods

Data on woodland size and contiguous area were extracted from the National Inventory of Woodland and Trees (NIWT). Data on habitat surrounding the woodland were extracted from the Landcover 2000 dataset using ArcGIS.

The categories used in the current analyses are as follows:

1. The percentage of total woodland surrounding the surveyed wood at 1km
2. The percentage of broadleaved woodland surrounding the surveyed wood at 1km
3. The percentage of total woodland surrounding the surveyed wood at 3km
4. The percentage of broadleaved woodland surrounding the surveyed wood at 3km
5. Wooded or non-wooded landscape at 1km: 1 = non-wooded; the percentage woodland surrounding the surveyed wood was less than the mean of all sites (37%), 2 = wooded; the percentage woodland surrounding the surveyed wood was equal to or more than the mean of all sites (37%)
6. Wooded or non-wooded landscape at 3km: 1 = non-wooded; the percentage woodland surrounding the surveyed wood was less than the mean of all sites (27%), 2 = wooded; the percentage woodland surrounding the surveyed wood was equal to or more than the mean of all sites (27%)
7. Area of contiguous woodland (ha), not necessarily just that surveyed
8. Size class (ha): each wood was assigned a size class as follows: 1 = < 20, 2 = 20 - 50, 3 = 50 - 100, 4 = 100 - 500, 5 => 500
9. Ancient semi-natural woodland: classifies the woodland as ASNW (1) or not (0)
10. Connectivity category at 1km: This is based on the relationship between contiguous area and the amount of woodland at the landscape level. 1 = less connected, 2 = more connected
11. Connectivity category at 3km: This is based on the relationship between contiguous area and the amount of woodland at the landscape level. 1 = less connected, 2 = more connected
12. Isolation: 0 = not isolated, 1 = isolated

These were correlated with bird presence, abundance and population change as in the other analyses.

4.3.4.3 Results

Table 4.3.4.3.1 shows the results of correlating bird presence, abundance and population change with the percentage of total woodland surrounding the surveyed wood up to 1km. Nine species showed relationships between bird presence and surrounding woodland; 11 species showed relationships between bird abundance and surrounding woodland; and five species showed relationships between population change and surrounding woodland.

Table 4.3.4.3.1 Summary of results of correlations between bird presence, abundance and population change and percentage of total woodland surrounding the surveyed wood up to 1km. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird	15.96	+++	1,241	0.04	10.91	+++	1,227	0.06	13.37	- - -
Bullfinch										
Dunnock										
Garden Warbler	12.03	- - -	1,213	0.07	16.50	- - -	1,173	0.10	18.75	- - -
Goldcrest	19.59	+++	1,241	0.11	30.24	+++	1,220	0.02	4.98	-
Hawfinch			1,81	0.05	4.73	+				
Jay	6.92	++	1,213	0.02	4.20	+				
Lesser Redpoll	9.55	- -	1,223	0.03	6.06	- -				
Lesser Spotted W'pecker	13.16	+++	1,39	0.13	5.90	++				
Marsh Tit										
Song Thrush			1,241	0.02	4.89	+				
Spotted Flycatcher										
Tree Pipit	13.48	- - -	1,241	0.06	15.40	- - -	1,175	0.04	7.38	- -
Treecreeper	4.58	+	1,241	0.05	12.63	+++				
Willow Tit										
Willow Warbler	9.85	- -	1,241	0.11	29.31	- - -				
Wood Warbler							1,184	0.02	3.93	-

Table 4.3.4.3.2 shows the results of correlating bird presence, abundance and population change with the percentage of broadleaved woodland surrounding the surveyed wood up to 1km. Nine species showed relationships between bird presence and surrounding broadleaved woodland; nine species showed relationships between bird abundance and surrounding broadleaved woodland; and six species showed relationships between population change and surrounding broadleaved woodland.

Table 4.3.4.3.2 Summary of results of correlations between bird presence, abundance and population change and percentage of broadleaved woodland surrounding the surveyed wood up to 1km. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	**P**	**DF**	**R2**	**F**	**P**	**DF**	**R2**	**F**	**P**
Blackbird	31.44	+++	1,241	0.08	19.79	+++	1,227	0.06	15.44	- - -
Bullfinch										
Dunnock										
Garden Warbler	6.84	- -	1,213	0.05	12.29	- - -	1,173	0.09	18.92	- - -
Goldcrest	16.77	+++	1,241	0.09	22.48	+++	1,220	0.06	14.67	- - -
Hawfinch										
Jay	9.10	++	1,213	0.02	4.86	+				
Lesser Redpoll	13.53	- - -	1,223	0.03	6.64	- -				
Lesser Spotted W'pecker	6.65	++								
Marsh Tit										
Song Thrush	12.00	+++	1,241	0.02	4.92	+				
Spotted Flycatcher										
Tree Pipit	34.75	- - -	1,241	0.11	30.60	- - -	1,175	0.07	13.29	- - -
Treecreeper			1,241	0.06	15.17	+++				
Willow Tit										
Willow Warbler	16.70	- - -	1,241	0.18	53.79	- - -	1,240	0.05	13.94	- - -
Wood Warbler							1,184	0.02	4.06	-

Table 4.3.4.3.3 shows the results of correlating bird presence, abundance and population change with the percentage of total woodland surrounding the surveyed wood up to 3km. Ten species showed relationships between bird presence and surrounding total woodland; seven species showed relationships between bird abundance and surrounding total woodland; and two species showed relationships between population change and surrounding total woodland.

Table 4.3.4.3.4 shows the results of correlating bird presence, abundance and population change with the percentage of broadleaved woodland surrounding the surveyed wood up to 3km. Ten species showed relationships between bird presence and surrounding broadleaved woodland; ten species showed relationships between bird abundance and surrounding broadleaved woodland; and seven species showed relationships between population change and surrounding broadleaved woodland.

Table 4.3.4.3.3 Summary of results of correlations between bird presence, abundance and population change and percentage of total woodland surrounding the surveyed wood up to 3km. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird	4.07	+++					1,227	0.06	15.71	- - -
Bullfinch										
Dunnock			1,241	0.03	7.56	- -				
Garden Warbler	20.91	- - -	1,213	0.09	20.69	- - -	1,173	0.08	15.95	- - -
Goldcrest	13.52	+++	1,241	0.11	31.12	+++				
Hawfinch	7.56	++	1,81	0.10	9.49	++				
Jay										
Lesser Redpoll	4.06	-								
Lesser Spotted W'pecker	14.62	+++	1,39	0.14	6.34	+				
Marsh Tit										
Song Thrush	5.94	++								
Spotted Flycatcher	4.05	+								
Tree Pipit										
Treecreeper	5.42	+	1,241	0.06	15.09	+++				
Willow Tit										
Willow Warbler	8.73	- -	1,241	0.02	5.71	-				
Wood Warbler										

Table 4.3.4.3.4 Summary of results of correlations between bird presence, abundance and population change and percentage of broadleaved woodland surrounding the surveyed wood up to 3km. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird	25.30	+++	1,241	0.09	23.32	+++	1,227	0.10	25.73	- - -
Bullfinch										
Dunnock										
Garden Warbler	20.46	- - -	1,213	0.09	21.43	- - -	1,173	0.14	28.46	- - -
Goldcrest	17.94	+++	1,241	0.15	41.25	+++	1,220	0.07	17.59	- - -
Hawfinch	5.46	+	1,81	0.07	6.24	++				
Jay										
Lesser Redpoll	13.53	- - -	1,223	0.03	5.99	-				
Lesser Spotted W'pecker	8.85	++								
Marsh Tit			1,184	0.02	4.49	+				
Song Thrush	9.95	++								
Spotted Flycatcher							1,173	0.02	4.30	+
Tree Pipit	44.98	- - -	1,241	0.10	27.90	- - -	1,175	0.08	15.42	- - -
Treecreeper	5.99	++	1,241	0.07	18.76	+++				
Willow Tit										
Willow Warbler	23.48	- - -	1,241	0.18	53.52	- - -	1,240	0.05	13.61	- - -
Wood Warbler			1,241	0.02	3.96	-	1,184	0.03	6.08	- -

Table 4.3.4.3.5 shows the results of correlating bird presence, abundance and population change with the amount of wooded/non-wooded landscape up to 1km. Nine species showed relationships between bird presence and the amount of wooded landscape; eight species showed relationships between bird abundance and the amount of wooded landscape; and five species showed relationships between population change and the amount of wooded landscape.

Table 4.3.4.3.5 Summary of results of correlations between bird presence, abundance and population change and the amount of wooded/non-wooded landscape up to 1km. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird	9.11	++	1,241	0.02	4.08	+	1,227	0.06	13.83	- - -
Bullfinch										
Dunnock										
Garden Warbler	7.38	- -	1,213	0.04	9.78	- -	1,173	0.07	13.44	- - -
Goldcrest	10.70	+++	1,241	0.06	15.04	+++	1,220	0.02	4.34	-
Hawfinch										
Jay	6.34	++								
Lesser Redpoll	6.50	- -	1,223	0.02	5.33	-				
Lesser Spotted W'pecker	6.30	++								
Marsh Tit										
Song Thrush	7.17	++	1,241	0.03	7.16	++				
Spotted Flycatcher										
Tree Pipit	9.35	- -	1,241	0.05	11.98	- - -	1,175	0.03	4.86	-
Treecreeper			1,241	0.02	4.50	+				
Willow Tit										
Willow Warbler	7.87	- -	1,241	0.08	20.18	- - -	1,240	0.02	4.52	-
Wood Warbler										

Table 4.3.4.3.6 shows the results of correlating bird presence, abundance and population change with the amount of wooded/non-wooded landscape up to 3km. Five species showed relationships between bird presence and the amount of wooded landscape; five species showed relationships between bird abundance and the amount of wooded landscape; and just one species showed relationships between population change and the amount of wooded landscape.

Table 4.3.4.3.6 Summary of results of correlations between bird presence, abundance and population change and the amount of wooded/non-wooded landscape up to 3km. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	**P**	**DF**	**R2**	**F**	**P**	**DF**	**R2**	**F**	**P**
Blackbird							1,227	0.05	12.40	- - -
Bullfinch										
Dunnock	4.15	-	1,241	0.03	7.53	- -				
Garden Warbler	9.60	- - -	1,213	0.04	8.16	- - -				
Goldcrest	5.59	+	1,241	0.06	14.29	+++				
Hawfinch	5.65	+	1,81	0.06	4.85	+				
Jay										
Lesser Redpoll										
Lesser Spotted W'pecker	6.96	++								
Marsh Tit										
Song Thrush										
Spotted Flycatcher										
Tree Pipit										
Treecreeper			1,241	0.03	6.77	++				
Willow Tit										
Willow Warbler										
Wood Warbler										

Table 4.3.4.3.7 shows the results of correlating bird presence, abundance and population change with the area of contiguous woodland (ha). Few significant associations were found. Just one species showed a relationship between bird presence and contiguous woodland area; two species showed relationships between bird abundance and contiguous woodland area; and just one species showed a relationship between population change and contiguous woodland area.

Table 4.3.4.3.8 shows the results of correlating bird presence, abundance and population change with woodland size class. Three species showed relationships between bird presence and woodland size class; two species showed relationships between bird abundance and woodland size class; and four species showed relationships between population change and woodland size class.

Table 4.3.4.3.7 Summary of results of correlations between bird presence, abundance and population change and the area of contiguous woodland (ha). The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird										
Bullfinch										
Dunnock										
Garden Warbler							1,173	0.03	5.27	-
Goldcrest	5.09	+	1,241	0.04	10.29	++				
Hawfinch										
Jay										
Lesser Redpoll										
Lesser Spotted W'pecker										
Marsh Tit										
Song Thrush										
Spotted Flycatcher										
Tree Pipit										
Treecreeper			1,241	0.02	5.01	+				
Willow Tit										
Willow Warbler										
Wood Warbler										

Table 4.3.4.3.8 Summary of results of correlations between bird presence, abundance and population change and woodland size class. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird										
Bullfinch										
Dunnock	10.17	*	4,238	0.05	3.36	**				
Garden Warbler							4,170	0.07	3.20	**
Goldcrest			4,238	0.04	2.55	*				
Hawfinch										
Jay										
Lesser Redpoll										
Lesser Spotted W'pecker	9.29	*								
Marsh Tit							4,146	0.07	2.82	*
Song Thrush										
Spotted Flycatcher	10.30	*								
Tree Pipit										
Treecreeper							4,233	0.06	3.50	**
Willow Tit										
Willow Warbler										
Wood Warbler							4,181	0.07	3.58	**

Table 4.3.4.3.9 shows the results of correlating bird presence, abundance and population change with Ancient Semi-Natural Woodland (ASNW) classification. Few relationships were found, with just one species from each of bird presence, abundance and population change showing a relationship with ASNW classification.

Table 4.3.4.3.9 Summary of results of correlations between bird presence, abundance and population change and ASNW classification. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird										
Bullfinch							1,76	0.05	3.83	+
Dunnock										
Garden Warbler										
Goldcrest										
Hawfinch										
Jay										
Lesser Redpoll										
Lesser Spotted W'pecker										
Marsh Tit										
Song Thrush										
Spotted Flycatcher										
Tree Pipit			1,241	0.03	7.33	++				
Treecreeper										
Willow Tit										
Willow Warbler										
Wood Warbler	8.86	++								

Table 4.3.4.3.10 shows the results of correlating bird presence, abundance and population change with the connectivity of woodlands at 1km. Three species showed relationships between bird presence and woodland connectivity; four species showed relationships between bird abundance and woodland connectivity; and just one species showed a relationship between population change and woodland connectivity.

Table 4.3.4.3.11 shows the results of correlating bird presence, abundance and population change with the connectivity of woodlands at 3km. Few relationships were found. No relationships were found between bird presence and woodland connectivity; two species showed relationships between bird abundance and woodland connectivity; and two species showed relationships between population change and woodland connectivity.

Table 4.3.4.3.10 Summary of results of correlations between bird presence, abundance and population change and the connectivity of woodland at 1km. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird			1,241	0.02	5.19	-				
Bullfinch										
Dunnock	8.77	- -	1,241	0.05	12.46	- - -				
Garden Warbler	4.59	-								
Goldcrest										
Hawfinch										
Jay										
Lesser Redpoll										
Lesser Spotted W'pecker	3.96	+								
Marsh Tit										
Song Thrush										
Spotted Flycatcher										
Tree Pipit			1,241	0.02	5.68	+				
Treecreeper										
Willow Tit										
Willow Warbler			1,241	0.03	6.31	++				
Wood Warbler							1,184	0.02	3.84	-

Table 4.3.4.3.11 Summary of results of correlations between bird presence, abundance and population change and the connectivity of woodland at 3km. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird										
Bullfinch										
Dunnock										
Garden Warbler										
Goldcrest										
Hawfinch							1,30	0.14	4.77	-
Jay										
Lesser Redpoll										
Lesser Spotted W'pecker										
Marsh Tit			1,184	0.03	5.07	+				
Song Thrush			1,241	0.02	4.11	+				
Spotted Flycatcher										
Tree Pipit										
Treecreeper										
Willow Tit										
Willow Warbler										
Wood Warbler							1,184	0.03	5.78	- -

Table 4.3.4.3.12 shows the results of correlating bird presence, abundance and population change with woodland isolation. Three species showed relationships between bird presence and woodland isolation; three species showed relationships between bird abundance and woodland isolation; and two species showed relationships between population change and woodland isolation.

Table 4.3.4.3.12 Summary of results of correlations between bird presence, abundance and population change and woodland isolation. The R^2 value, degrees of freedom (DF = 1 in all cases in presence analysis), test statistic (Wald or F Value) and P Value category (+ = P < 0.05, ++ = P < 0.01, +++ = P < 0.001) along with the direction of the effect (+ or -) are shown for any significant association. Blank cell = no relationship detected.

	Presence		Abundance				Population change			
	Wald	P	DF	R2	F	P	DF	R2	F	P
Blackbird										
Bullfinch										
Dunnock	5.37	+	1,241	0.04	9.22	++				
Garden Warbler	8.86	++	1,213	0.03	5.73	+				
Goldcrest	3.88	-	1,241	0.03	8.62	- -				
Hawfinch										
Jay										
Lesser Redpoll										
Lesser Spotted W'pecker										
Marsh Tit										
Song Thrush										
Spotted Flycatcher							1,173	0.04	7.00	- -
Tree Pipit										
Treecreeper							1,236	0.02	4.37	+
Willow Tit										
Willow Warbler										
Wood Warbler										

4.3.4.4 Conclusion

Many relationships were found between woodland birds and landscape scale effects. However, some landscape effects appeared more important than others; they were associated with more bird species, and associations were stronger. The amount of total woodland and broadleaved woodland, both at the 1km and 3km scale, were often associated with bird presence, abundance and population change. This was reflected in the wooded/non-wooded classification, which also had several associations at both scales. The other categories had fewer associations, and so perhaps are less important for declining woodland bird species.

However, overall it seems there is considerable support for the hypothesis that landscape scale effects are having some impact on some declining woodland bird species. See individual species discussion for detailed information.

4.4 Discussion

Each species is taken in turn, below, and the results of correlations with the four drivers are discussed, conclusions drawn, and areas for further work noted.

4.4.1 Blackbird

The Blackbird is currently green listed, although the woodland bird indicator showed a decline of 18% in the last 25 years. Of the four drivers investigated Blackbird abundance and population change were not related to soil moisture (presence could not be tested), and presence and abundance were positively related to both Great Spotted Woodpecker and Jay abundance. This suggests these drivers are unlikely to be important in Blackbird decline, although further work on soil moisture, at a national scale, is required.

The results with climate change variables were mixed. Birds were more likely to be present in woods where January mean temperature had decreased over time, but where February mean temperature had increased. They were more likely to be abundant in woods where mean temperature January-March had increased. The species' population increased in woods where January mean temperature increased, but where February and March mean temperature decreased. Overall, no clear pattern appears to exist with mean temperature, and indeed the population change results seem to contrast with the abundance results.

Birds were more likely to be present in woods where January and March rainfall had increased, but February rainfall had decreased. In all cases for abundance and population change, the relationship was negative; abundance was lower where rainfall had increased, and the population was more likely to have declined where rainfall had increased. All relationships with the number of rainy days were negative, except for bird presence in January, where no relationship was detected, and population change in February, where a positive relationship was found. Overall, however, it seems that increasing rainfall, in terms of amount of rain and number of rainy days per month, has had a detrimental impact on the species. This is a key finding and suggests this species may be vulnerable to changes brought by a changing climate.

Landscape effects were found for total woodland surrounding the wood at 1 km and 3 km, broadleaved woodland surrounding the wood at 1 km and 3 km, and the amount of wooded/non-wooded landscape up to 1 km. The same pattern was found in each case; a positive association with bird presence and abundance, but a negative association with population change. This suggests that although birds were more likely to be present, and more abundant, in woods with more woodland in the surrounding landscape, the species' population has actually declined more at these sites. There was also a negative association found between population change and the amount of wooded/non-wooded landscape up to 3km, further supporting these other negative population change associations. This negative relationship with population change, alongside positive associations with presence and abundance, is a confusing result. It could suggest another factor is causing population decline at the sites, but one which is also correlated with the landscape variables. It could also suggest that areas are acting as sinks for Blackbird populations due to other factors operating at the landscape scale. The only other association found with landscape variables was a negative association between Blackbird abundance and woodland connectivity at 1km. This suggests that Blackbirds are less likely to be abundant at sites which are more connected to woodland in the surrounding 1km.

4.4.2 Bullfinch

The Bullfinch is currently amber listed, and the woodland bird indicator showed a decline of 55% between 1970 and 2007. Of the four drivers investigated, Bullfinch presence, abundance and population change were not related to soil moisture, although it should be noted that the soil moisture analysis was limited to one geographical region. They also were not related to the abundance of Great Spotted Woodpeckers or Jays. This suggests these two drivers are not important in Bullfinch decline, although Proffit (2002) suggests that predation is likely to be a contributing factor to decline. However, Proffit *et al.* (2004) suggest this may be due to Sparrowhawks, and this, along with the evidence provided here, suggests the Great Spotted Woodpecker and Jay are perhaps not a key driver in the species decline.

Unfortunately, the models for relating climate variables to Bullfinch presence, abundance and population change did not converge, so no information is currently available for this species and this driver. This is likely to be because of small sample sizes for the Bullfinch, and the fact that climate variables were obtained at the 5km x 5km square level, meaning multiple woods had the same climate information, reducing the sample size further. However, given the species' severe decline and small population size, further investigation of this driver in a way more suitable to the available data for the species should be seen as high priority. This is particularly so as information provided in Carpenter *et al.* (2009b) suggests climate change could be an important factor in this species decline.

The only association found with all of the landscape variables tested was a weak ($P < 0.05$) positive association between Bullfinch population change and ancient semi-natural woodland (ASNW) classification. This suggests that the Bullfinch population was more likely to have increased at sites classified as an ASNW. This could be linked to the species requirement for thick understorey and field layer cover, as discussed in Carpenter *et al.* (2009b), as older semi-natural woodlands might be expected to be more heterogeneous in their understorey and field layer cover. This is further evidence that woodland management to encourage woodland understorey, including a return of coppice woodland, would perhaps be of benefit to this species.

4.4.3 Dunnock

The Dunnock is currently amber listed, and the woodland bird indicator showed a decline of 32% between 1970 and 2007. Of the four drivers investigated, relationships with soil moisture could not be tested due to a lack of bird data. Further investigation of this driver is still required. Dunnock presence and abundance were positively associated with Great Spotted Woodpecker and Jay abundance. No association was found between the two avian predators and population change. This initial evidence suggests the Dunnock decline is not being driven by predation by Great Spotted Woodpeckers or Jays. However, Carpenter *et al.* (2009b) suggest further work is still required on predation, both by avian and non-avian predators.

Although none of the population change models with winter climate converged, several relationships were found between Dunnock presence and abundance and winter climate variables. Mean temperature January – March was negatively associated with Dunnock abundance, as was mean March temperature with Dunnock presence. Therefore, Dunnock abundance (and presence in March) was lowest at sites where mean winter temperature had increased. Dunnock presence in January, and abundance in January and February, was negatively associated with rainfall. However, in March the association with abundance was positive. The relationships with rainy days are slightly conflicting. Dunnock abundance in January and March were negatively associated with rainy days, but in February the association was positive. However, again, overall the relationships with rainfall were negative, suggesting that Dunnock abundance (and presence in some cases) is lowest at sites where winter rainfall has increased. This is a worrying finding, as both mean temperature and rainfall in winter are predicted to rise as a result of climate change (as shown on the MetOffice website), suggesting this species is vulnerable to its impacts. However, this result slightly conflicts with information presented in the review by Carpenter *et al.* (2009), which suggests a negative relationship with snow cover, and hence a possible positive effect of climate change. Overall, further investigation and monitoring of the impacts of climate change on this species are of high importance, particularly given the results presented here.

The Dunnock did not show many correlations between presence, abundance and population change and woodland in the surrounding landscape at 1 or 3 km, or amount of wooded landscape at 1 or 3 km. The three relationships that were found were all negative, between abundance and total woodland at 3 km, and between presence and abundance and amount of wooded landscape at 3 km. This suggests that Dunnocks are more likely to be present and abundant in woods with little woodland in the surrounding 3 km. This idea is supported by the fact that Dunnock presence and abundance were negatively correlated with woodland connectivity at 1 km, and were positively related to woodland isolation. This suggests that the Dunnock actually prefers isolated woodland patches interspersed with non-wooded habitat; in most cases presumably farmland. It is possible that the species uses surrounding farmland for foraging, and is therefore selecting heterogeneous landscape rather than isolated woodlands, which could explain this trend. However, the findings reported here were not found during the literature search by Carpenter *et al.* (2009), and hence further work to investigate these relationships, and why they exist, is recommended.

4.4.4 Garden Warbler

The Garden Warbler is currently green listed, and the woodland bird indicator showed a decline of 6% between 1970 and 2007. Of the four drivers investigated, it was not possible to test Garden Warbler variables with soil moisture, and none of the variables were related to abundance of Great Spotted Woodpecker and Jay. Work to test for the possible importance of soil moisture to the Garden Warbler should be carried out, but it seems that predation by avian predators may not be a driver of this species decline.

Unfortunately, none of the climate models relating to population change converged. However, some associations were found between winter climate variables and Garden Warbler presence and abundance. Garden Warbler abundance in January, and presence and abundance in March, were negatively associated with mean temperature, although in February the association with abundance was positive. This pattern was repeated for both rainfall and number of rainy days. The species' presence and abundance in January, and abundance in March, was negatively associated with rainfall, but in February, the association with abundance was positive. Garden Warbler abundance was negatively associated with rainy days in January and March, but positively associated with rainy days in February. Thus, it seems that Garden Warblers are less likely to be present or abundant in woods where climate variables have increased in January and March, but are more likely to be abundant in woods where they have increased in February. This pattern is difficult to understand, and in all cases, the positive associations in February are weak ($P < 0.05$) compared to stronger negative associations in the other months. Perhaps overall, it appears that at sites where temperature and rainfall have increased, the Garden Warbler has declined. Information in Carpenter *et al.* (2009b) states that the Garden Warbler advanced its lay date by 7 days in the period 1968-2005, and this is likely to be due to changes in climate. It is possible that in sites where winter climate has increased the most, the Garden Warbler has been unable to advance its lay date far enough, leading to lower presence and abundance at these sites. Unfortunately, population change models did not converge, so it not possible to see if the species had declined more at these sites. Nonetheless, these findings are of concern, particularly in combination with the finding of advancing lay dates, and further work to monitor the species' response to a changing climate is of high priority.

Garden Warbler presence, abundance and population change were negatively associated with woodland in the surrounding landscape at 1 and 3 km, and with the amount of wooded landscape at 1 and 3 km (except for no relationship detected between population change and amount of wooded landscape at 3 km). This is strong evidence that the species is less likely to be found, less likely to be abundant, and more likely to have declined, at sites with plenty of woodland in the surrounding landscape. The species' presence was also negatively related to woodland connectivity at 1 km, and presence and abundance were positively related to woodland isolation, providing more evidence of this general relationship. This is similar to a finding reported in the original RWBS (Amar *et al.* 2006). The species also showed a relationship between population change and woodland size. A negative association with the area of contiguous woodland area was found, and a significant association with woodland size class was found. Investigation of relationships with specific size classes showed a positive association with the smallest size class, and negative associations with the two largest size classes. Therefore, the Garden Warbler has declined in large woodlands, and increased in small woodlands. In summary, the Garden Warbler has increased in small woodlands, and is more likely to be present, abundant, and have an increasing population at sites which are isolated from other woodland areas, with little woodland in surrounding landscape.

4.4.5 Goldcrest

The Goldcrest is currently green listed, and the woodland bird indicator showed a decline of 21% between 1970 and 2007.

The Goldcrest was the only species to show a relationship with soil moisture; it was less likely to be abundant in woodlands with high soil moisture content. This could be related to the species' association with conifer woodlands, as these woodlands tend to be drier than deciduous woods. Further work on this relationship, firstly to extend the test beyond a single geographical area, and secondly to look for this relationship with conifer plantations being drier, is recommended.

Goldcrest presence in woods was positively associated with Great Spotted Woodpecker abundance. Furthermore, the Goldcrest was one of only two species to show associations between population change and Great Spotted Woodpecker abundance, and again this relationship was positive. This suggests that predation by Great Spotted Woodpecker is unlikely to be important in Goldcrest decline, and the lack of any relationship with Jay abundance suggests neither avian predator is important in Goldcrest decline.

No relationships were found between Goldcrest presence, abundance and population change and mean January temperature. In February, both presence and abundance were positively associated with mean temperature, whereas population change was negatively correlated. In March, abundance was positively correlated, where as population change was negatively correlated. This supports the suggestion in Carpenter *et al.* (2009b) that the Goldcrest is vulnerable to low winter temperature, as this suggests that Goldcrests are most likely to be present and abundant at sites where mean temperature has increased. However, this is also where the species' population is likely to have declined. Goldcrest presence January – March was negatively correlated with rainfall, as was their abundance in February and March. However, population change in February and March was positively correlated with rainfall. A similar pattern was found with rainy days. No relationships were detected in January, in February and March presence and abundance were negatively related to the number of rainy days, but in February, there was a positive association between population change and rainy days. This suggests that birds are more likely to be present and abundant at sites where rainfall and rainy days have decreased, but these are also the sites at which they are likely to have declined.

A similar relationship is found between Goldcrest presence, abundance and population change with woodland in the surrounding landscape at 1 and 3 km, and the amount of wooded landscape at 1 and 3 km. In all cases, the relationship with presence and abundance is positive, but with population change is negative (except total woodland up to 3 km and amount of wooded landscape at 3 km, where no relationship was detected with population change). A positive association was also found with presence and abundance and contiguous area, and an association was found with size class. A negative association was found between presence and abundance and woodland isolation. It seems, therefore, that Goldcrests are more likely to be abundant in woods with more woodland in the surrounding landscape, and less isolation. It is also at these sites, however, that the species is declining. Carpenter *et al.* (2009b) report of the importance of habitat fragmentation to Goldcrest decline, and the results we present here support this finding. It is of concern, however, that the species appears to be declining at sites where it is currently most abundant, and which appears to be its favoured habitat type.

4.4.6 Hawfinch

The Hawfinch is currently red listed, and the woodland bird indicator showed a decline of 19% between 1970 and 2007. No association was found between Hawfinch presence, abundance and population change and soil moisture. It seems unlikely, therefore, that this driver is important in Hawfinch decline, although the current analysis was limited to a single geographical area.

Although no association was found between Hawfinch presence, abundance and population change and Jay abundance, a negative association was found between Hawfinch abundance and Great Spotted Woodpecker abundance. No association was found with species' presence or population change. This finding, however, is of concern; although it is not sufficient evidence of a relationship between the two, it is evidence that further investigation is of a high priority. Amar *et al.* (2006) also found evidence that the Hawfinch was being predated by the grey squirrel, and hence it appears this species may be vulnerable to predation from both avian and non-avian predators. However, due to the sparsity of data in general on Hawfinch populations, there is no available information on nest survival over the period of the species' decline. It is clear that detailed work investigating the relationship between predation and Hawfinch decline is of a high priority.

Unfortunately, none of the models of abundance and population change with winter climate variables converged, presumably to due the paucity of data for the Hawfinch generally. Only presence can therefore be considered. There was no relationship between presence and January mean temperature, a negative association with February mean temperature, and a positive association with March mean temperature. These data are a little conflicting and difficult to interpret, but suggest that the species prefers colder Februaries and warmer March temperatures. The only association with rainfall was a weak negative association with March rainfall. However, there was a positive association with rainy days in all three months, perhaps suggesting that damp conditions are preferable for the species.

Results of the landscape analyses suggest that woodland in the surrounding landscape is of high importance to the Hawfinch. Positive associations were found with abundance and total woodland in the surrounding area at 1 km, and with presence and abundance and woodland in the surrounding area at 3 km, and the amount of wooded landscape at 3 km. However, this is slightly conflicted by a negative association with population change and woodland connectivity at 3 km, suggesting the species has declined at sites with more connectivity. Carpenter *et al.* (2009b) also point to the importance of woodland in the surrounding landscape, suggesting that overall this is an important feature for the Hawfinch. Increasing woodland isolation and fragmentation could, therefore, be a factor in the species' decline.

4.4.7 Jay

The Jay is currently green listed, and the woodland bird indicator showed a decline of 9% between 1970 and 2007. Of the four drivers considered, no relationship was found between Jay presence, abundance and population change and soil moisture, and only positive associations were found with Great Spotted Woodpecker abundance. It seems unlikely that these two drivers are important in Jay decline.

Unfortunately, models of population change and climate variables did not converge. However, relationships were detected between Jay presence and abundance and climate variables. Jay abundance in January, and presence and abundance in February were positively associated with mean temperature. This suggests that Jays are more likely to be present and abundant in woods where mean temperature has increased over time, and that the species could therefore benefit from impacts of climate change. Negative associations were found between Jay presence and rainfall in January and March, and Jay abundance in January and February. Negative associations were also found between presence and abundance of Jays and rainy days in February and March. This suggests that Jays are more likely to be present and abundant in woods where rainfall has decreased over time. In contrast to results with mean temperature, this suggests the species could suffer from the impacts of climate change. Therefore, these results are a little conflicting in terms of understanding the impact of climate on Jays. Perhaps only monitoring over time will show whether the relationship with mean temperature, or that with rainfall, is the most important for the species, and hence whether climate change will have a negative impact. However, Carpenter *et al.* (2009b) reports that climate simulations suggest little impact of climate change on the species in the future.

Landscape results suggest that the amount of woodland in surrounding landscape up to 1 km, but not 3 km, is important to the Jay. Positive associations were found between presence and abundance and surrounding woodland at 1km, but no associations were found for 3km. Similarly, a positive association between presence and amount of wooded landscape was found at 1 km, but not at 3km. No other associations with landscape variables were found. This relationship between Jays and the amount of surrounding wooded landscape up to 1 km has not been reported before, although Carpenter *et al.* (2009a) found that the species preferred woods surrounded by more natural, rather than agricultural, land. It is possible, therefore, that landscape scale effects such as fragmentation and isolation could have played a role in the species' decline, and further work to understand these relationships is desirable.

4.4.8 Lesser Redpoll

The Lesser Redpoll is currently red listed, and the woodland bird indicator showed a decline of 96% between 1970 and 2007. Of the four drivers considered, Lesser Redpoll variables could not be tested with soil moisture, due to a lack of bird data. Further work is therefore recommended. No relationships were detected with avian predators, suggesting this driver is unlikely to be important in the species' decline.

Results with climate variables are somewhat conflicting. No associations between bird presence and any climate variables were found. Mean temperature was positively associated with Lesser Redpoll abundance in January and March, but negatively related in February. Population change was negatively associated with mean temperature in January, but positively associated in February and March. Although associations exist, it is difficult to ascertain a pattern in these with mean temperature. Lesser Redpoll abundance was positively associated with rainfall and rainy days January – March, and population change was positively associated with rainfall and rainy days in January. However, in February and March the relationship with both variables was negative. This suggests that in all months abundance was higher at sites where rainfall had increased over time, but the population change results were conflicting. Given the number of results, and their conflicting nature, further work investigating the effect of winter climate change would be beneficial, particularly as work outlined in Carpenter *et al.* (2009b) suggests the species could be highly vulnerable to climate change.

Landscape results suggest that the species prefers woods which have little woodland in the surrounding landscape. Presence and abundance were negatively related to woodland in the surrounding landscape at both 1 and 3 km (no abundance relationship was found for total woodland at 3 km), and amount of wooded landscape at 1 km. No other relationships were found. This suggests that woodland in the surrounding landscape is actually a hindrance to the species, but could point to the fact that the species requires a heterogeneous habitat. This has not been highlighted in previous work. Carpenter *et al.* (2009b) recommend further investigation into the species' use of farmland habitat, and this finding supports this recommendation.

4.4.9 Lesser Spotted Woodpecker

The Lesser Spotted Woodpecker is currently red listed, and the woodland bird indicator showed a decline of 72% between 1970 and 2007. Of the four drivers considered, no relationships were detected with soil moisture, suggesting this driver is unlikely to be important in the species' decline. However, further work covering a larger geographical area is recommended.

No relationships were detected between the Lesser Spotted Woodpecker variables and Jay abundance. However, a very weak ($P < 0.1$) negative association was found between Lesser Spotted Woodpecker abundance and Great Spotted Woodpecker abundance. Although weak, this could be due to the small sample size available. Competition between the two species is a possibility. That a relationship has been detected, even though it is weak, is therefore of high concern.

Unfortunately, winter climate models with Lesser Spotted Woodpecker abundance and population change did not converge, presumably due to small sample sizes. No relationships were detected between species' presence and any winter climate variables, but again this could be due to small sample sizes leading to a failure to detect relationships which are present. Further investigation of the potential for winter climate change to impact the species is recommended, as so little is currently known.

Woodland in the surrounding landscape appears to be an important factor in determining Lesser Spotted Woodpecker presence and abundance. Species presence was positively related to woodland in the surrounding landscape at 1 and 3 km, and amount of wooded landscape and 1 and 3 km. Species abundance was positively related to total woodland in the surrounding landscape at both 1 and 3 km. Furthermore, a weak positive association was found between presence and woodland connectivity at 1 km, and an association was found between presence and woodland size (more likely to be present in larger woodlands), further supporting these results. It seems, therefore, that species decline may be driven, at least in part, by changes in habitat at the landscape scale, including fragmentation and loss of woodland in the surrounding landscape.

4.4.10 Marsh Tit

The Marsh Tit is currently red listed, and the woodland bird indicator showed a decline of 76% between 1970 and 2007. Of the four drivers considered, no relationship was detected between Marsh Tit abundance and population change and soil moisture. It was not possible to test for a relationship with bird presence. This might suggest that soil moisture is not important in driving this species decline, but the current study was limited to a single geographical area, and Carpenter *et al.* (2009b) point to soil moisture as a possible factor. Further investigation at a national scale is therefore recommended.

No relationships were detected between Marsh Tit variables and avian predator abundance. This suggests that predation by these species may not be driving decline, and evidence provided in Carpenter *et al.* (2009b) supports this. However, continued monitoring of predation on Marsh Tits is recommended; as a hole-nesting species, they are vulnerable to predation by both Great Spotted Woodpeckers and Jays.

Unfortunately, climate models with Marsh Tit abundance and population change did not converge, presumably due to limited sample sizes. Only two relationships were detected between Marsh Tit presence and winter climate; a negative association with rainfall in February, and a positive association with rainfall in March. This suggests that the species prefers sites where rainfall has decreased in February, but increased in March. Overall, further work on the relationship with climate variables, including winter climate, is highly recommended, as some work outlined in Carpenter *et al.* (2009b) has shown that the species may be highly vulnerable to impacts of climate change.

Few relationships were found between Marsh Tit variables and landscape scale effects, and those that were found were weak. Marsh Tit abundance was positively associated with broadleaved woodland in the surrounding landscape at the 3 km level, and with connectivity of woodland at 3 km. This suggests that the species shows some preference for presence of woodland, particularly broadleaved, in the surrounding landscape. This is some evidence that changes in landscape surrounding woodlands could be driving species decline, although given the weak nature of these results this is unlikely to explain the severe decline of the species fully. The only other relationship detected was between Marsh Tit population change and woodland size. The Marsh Tit was more likely to have declined at small woodland sites, particularly the smallest category. Carpenter *et al.* (2009b) include information on this species' sensitivity to woodland size, and the current data supports this. This, alongside the species' highly sedentary nature, could also be a factor in the species decline.

4.4.11 Song Thrush

The Song Thrush is currently red listed, and the woodland bird indicator showed a decline of 51% between 1970 and 2007. Of the four drivers considered, no relationship was found with soil moisture, although it was not possible to test this driver with Song Thrush presence. It was not possible to test Song Thrush presence with avian predator abundance, but Song Thrush abundance was positively associated with both avian predators. It seems unlikely that these two drivers are important in this species' decline.

Song Thrush presence and abundance were positively associated with February mean temperature, and population change was positively associated with mean temperature January – March. This suggests that the species is more likely to be present and abundant at sites where temperature has increased, and the population is more likely to have increased at such sites. This suggests that climate change could be beneficial to this species. Rainfall results are slightly more conflicting. In January, population change was positively related to rainfall and to the number of rainy days. In February, abundance was negatively related to both rainfall and rainy days, but population change was positively related to rainfall and negatively related to rainy days. In March, all relationships with rainfall and rainy days were negative (although no relationship was detected between abundance and rainfall). Overall, the pattern appears to be negative, although more so in February and March than January. This suggests that at least for the latter two months, birds are more likely to be present and abundant, and to have increased, at sites where rainfall has decreased. This contrasts with the mean temperature results, and suggests that climate change could be detrimental to the species. Carpenter *et al.* (2009b) found little evidence for a negative impact of climate change on the species, but given the current results with rainfall, further monitoring is recommended.

Woodland in the surrounding landscape appears to be an important factor in determining Song Thrush presence and abundance. Song Thrush presence was positively related to surrounding broadleaved woodland at 1 and 3 km, and surrounding total woodland at 3 km. Abundance was related to surrounding woodland at 1 km. Both presence and abundance were related to amount of wooded landscape at 1 km. The only other association was positive with woodland connectivity at 3 km, further supporting these results. It seems possible that changes at the landscape scale, such as loss of woodland from the surrounding landscape, could be a factor driving this species' decline. Carpenter *et al.* (2009b) highlight the possible importance of agricultural intensification of surrounding land, which could also cause loss of woodland in such areas. Further work to test these relationships is essential.

4.4.12 Spotted Flycatcher

The Spotted Flycatcher is currently red listed, and the woodland bird indicator showed a decline of 87% between 1970 and 2007. Of the four drivers considered, no relationships were found with soil moisture. This suggests this driver is unlikely to be important in the species' decline. However, analyses were limited to a single geographical location.

In the current work, no relationships were found with avian predators. However, Stevens *et al.* (2008) found that avian predators were the cause of most predation of Spotted Flycatcher nests, with the Jay the commonest predator. Furthermore, clutch size and brood size have both decreased between 1968 and 2005 and daily failure rates have increased, which could be due to such predation. This suggests that our analyses may have failed to detect relationships which do exist, and hence further investigation is highly recommended.

None of the climate models with population change converged. However, relationships were found with Spotted Flycatcher presence and abundance. Mean temperature January – March was negatively associated with Spotted Flycatcher abundance. Birds were therefore less abundant in woods where winter temperature had increased. This is a worrying finding and suggests the Spotted Flycatcher could be vulnerable to changes caused by climate change. In January, both rainfall and rainy days were negatively associated with Spotted Flycatcher presence (rainfall only) and abundance. In February, the association between abundance and rainfall was negative, but with rainy days was positive. In March, both relationships with abundance were positive. This suggests that in January, bird presence and abundance was more likely at sites where rainfall had decreased, but in March, abundance was more likely at sites where rainfall had increased. In February, data were conflicting. Overall, further monitoring and investigation of impacts of winter climate on this species are recommended, as the relationships found with winter temperature, at least, are of concern.

Few relationships were detected with landscape variables. The Spotted Flycatcher was more likely to be present in woods with more total woodland in the surrounding landscape at 3 km, and the population was more likely to have increased at sites with more broadleaved woodland in the surrounding landscape at 3 km. This suggests that changes at the landscape scale, such as loss of woodland in surrounding habitat, could have played a part in the species' decline. This relationship has not been reported elsewhere, and is therefore worth further investigation.

4.4.13 Tree Pipit

The Tree Pipit is currently red listed, and the woodland bird indicator showed a decline of 86% between 1970 and 2007. Of the four drivers studied, it was not possible to run the soil moisture model for the Tree Pipit, due to a lack of bird data in the New Forest. The Tree Pipit was the only species for which a negative correlation was found between bird presence and Great Spotted Woodpecker abundance. Tree Pipit abundance was also negatively correlated. This is a worrying finding, and has not been reported elsewhere, suggesting there could be a negative impact of the Great Spotted Woodpecker, although further detailed work would be required to confirm this. This is highly recommended.

None of the population change climate models converged for the Tree Pipit. However, relationships were found for bird presence and abundance. In January, Tree Pipit abundance was positively related to mean temperature, but in February and March, the association was negative. This suggests that in January, birds were more likely to be abundant in woods where temperature had increased, but in February and March in woods where temperature had decreased. The situation for rainfall is clearer; positive associations with rainfall and rainy days were found for bird presence in February and bird abundance January – March. This suggests that birds were more likely to be present and abundant in woods where winter rainfall has increased, and therefore suggests climate change could be beneficial to this species.

Little woodland in the surrounding landscape appears to be important for Tree Pipits. The species showed negative associations between presence, abundance and population change for woodland in surrounding landscape at 1 km, and for broadleaved woodland in the surrounding landscape at 3 km. Negative associations were also found for amount of wooded landscape at 1 km. However, a positive association found with woodland connectivity at 1 km slightly contradicts these results. Overall, it seems the species prefers woods with little woodland in the surrounding landscape, a results also found by Smart *et al.* (2007). The only other association found was a positive correlation with ASNW classification. The Tree Pipit was likely to be more abundant in woods which are classified as ASNW. This suggests that although the species is found in conifer plantations, and various other types of woodland habitat, the preferred type is that which is classified as ASNW.

4.4.14 Treecreeper

The Treecreeper is currently green listed, and the woodland bird indicator showed a decline of 28% between 1970 and 2007. Of the four drivers considered, no associations were found with soil moisture (although presence analysis could not be carried out), and positive associations were found with Great Spotted Woodpecker abundance. This suggests that these two drivers may not be important in the species decline, although more work on soil moisture over a larger geographical area is required.

Treecreeper presence was positively associated with mean temperature in February, and abundance was positively correlated in February and March. However, population change was negatively associated with mean temperature January – March. The situation with rainfall is even less clear. In January, population change is negatively associated with rainfall, in February, the association is positive, but in March, presence, abundance and population change are negatively associated. In January, population change is negatively associated with rainy days. In February, presence and abundance are negatively associated, but population change is positively associated. In March, presence is positively associated with rainy days, but population change is negatively associated. The number of conflicting results for both mean temperature and rainfall make it difficult to draw conclusions. Therefore, further monitoring and research is recommended, to understand the impact of climate change on this species.

Woodland in the surrounding landscape appears to be an important requirement for Treecreepers. Positive associations were found between bird presence and abundance and woodland in the surrounding landscape at 1 and 3 km (except for no association found between presence and broadleaved woodland at 1 km). Positive associations between abundance and amount of wooded landscape at 1 and 3 km further support this result. Woodland size was also shown to be important, with a positive association between abundance and contiguous area, and an association between size class and population change. Interestingly, however, a weak positive association was found with woodland isolation, conflicting with these results. Overall, however, it seems that changes at the landscape scale, including woodland fragmentation, could be involved in driving this species' decline. Further detailed work is recommended.

4.4.15 Willow Tit

The Willow Tit is currently red listed, and the woodland bird indicator showed a decline of 90% between 1970 and 2007. Of the four drivers considered, no association was found with soil moisture. However, this has been highlighted elsewhere (see Carpenter *et al.* 2009b) as a potential driver for this species, and the current analysis was limited to a single geographical area. Therefore, further work on this relationship is highly recommended. No association was found between Willow Tit presence and Great Spotted Woodpecker abundance, and a positive association was found with Jay abundance. However, given that the sample size in this analysis was low, and the species nests in holes, particularly in rotten stumps, further monitoring of these relationships is important.

Unfortunately, the climate models with bird abundance and population change did not converge; therefore, only those with bird presence can be assessed. Only two associations were found. A weak positive association was found with mean temperature in January, and a weak negative association was found with rainfall in February. This is some evidence that changes in winter climate could work either in the species favour, or not. Further work to increase sample sizes, and make more meaningful analysis possible, is essential. This is particularly important as work outlined in Carpenter *et al.* (2009) suggests the species is highly vulnerable to climate change.

No associations were found between Willow Tit presence, abundance and population change and landscape variables. However, this is likely to be due to small sample sizes making it impossible to detect such relationships, rather than the relationships not existing. Again, further work to increase sample sizes, and make more meaningful analysis possible, is essential.

4.4.16 Willow Warbler

The Willow Warbler is currently amber listed, and the woodland bird indicator showed a decline of 58% between 1970 and 2007. Of the four drivers considered, no association was found with soil moisture (although this was limited to one geographical area) or with Jay abundance. However, a strong negative association between abundance and population change and Great Spotted Woodpecker abundance was found, suggesting this species could be having an impact on the Willow

Warbler population. Further work to investigate this is of a high priority, particularly as this relationship has not been detected previously.

In general, negative associations were found between Willow Warbler presence, abundance and population change and mean winter temperature. The exceptions were positive associations with abundance and population change in January. Overall, however, it appears that birds were less likely to be present or abundant, and were more likely to have declined, at sites where winter temperature has increased. This is a worrying finding and suggests the species could be vulnerable to the impacts of climate change, which has also been suggested by climate modelling (see Carpenter *et al.* 2009b for a summary). The relationships between presence, abundance and population change and rainfall were generally positive. The exceptions were January and March rainfall and January rainy days with presence (no relationship), and February rainfall with population change (negative). This suggests that climate change could be beneficial to the species, as it is more likely to be present, abundant and to increase population at sites where rainfall has increased; which is predicted to occur under climate change (as shown on the MetOffice website). Therefore, results with winter temperature and rainfall contradict each other, making further investigation and monitoring of high priority for this species.

Little woodland in the surrounding landscape appears to be important for the Willow Warbler. The species' presence, abundance and population change were negatively associated with woodland in the surrounding area at 1 and 3 km (except for population change with total woodland at 1 and 3 km where no association was found). This result is further supported by negative associations between presence abundance and population change and amount of wooded landscape at 1 km. However, a positive association with woodland connectivity at 1 km perhaps slightly contradicts these results. No other associations were found. Overall, therefore, it seems that the Willow Warbler is more likely to be present, abundant, and increasing in population in areas with little woodland in the surrounding area. Smart *et al.* (2007) reported a similar result.

4.4.17 Wood Warbler

The Wood Warbler is currently red listed, and the woodland bird indicator showed a decline of 59% between 1970 and 2007. Of the four drivers considered, no associations were found with soil moisture, and the only association with an avian predator (Great Spotted Woodpecker) was weakly positive. It seems unlikely that these two drivers are important in Wood Warbler decline.

Relationships between Wood Warbler presence, abundance and population change and winter temperature in February and March were positive (except for population change in March where no relationship was detected). In January, however, the only association, with abundance, was negative. Overall, it seems that the relationship with temperature is positive, suggesting that climate change could be beneficial to the species. Several relationships were detected with rainfall and rainy days, however, all of which were negative. This suggests that birds have suffered at sites where rainfall has increased. This relationship is of high concern, particularly as simulations (summarised in Carpenter *et al.* 2009b) also suggest a negative impact of climate change.

There is some evidence of a negative relationship between Wood Warblers and woodland in the surrounding landscape. Negative associations were found between population change and woodland in the surrounding landscape at 1 km, and between abundance and population change and broadleaved woodland at 3 km. These relationships are further supported by negative associations between population change and woodland connectivity at both 1 and 3 km. The only other association found was between population change and wood size class. The population was more likely to have increased in small woodlands. These results suggests that Wood Warblers prefer small woodlands set in a non wooded landscape, and this latter result was also found by Amar *et al.* (2006).

4.5 Conclusion

Several relationships were found between potential contributory drivers of declines and species presence, abundance and population change. Results are summarised in Table 4.5.1. Many relationships exist, partly because of the exploratory modelling approach, and further work is recommended. Individual species summaries should be read to fully understand the results summarised in the table, and the table should be used as a guide only.

Many of the relationships found in the current analyses back up ideas or evidence from other studies. Some relationships found in other work are not backed up here. Although only one such relationship was found for soil moisture, this analysis was limited to one geographical area. Other relationships, particularly those with winter climate variables, are only beginning to be explored. Hewson *et al* (2008) looked at the relationship between woodland bird community changes and climate change. There was evidence of many species being affected. Resident gleaners benefited from warmer winters, as did middle distance migrants. There was evidence that long distance migrants had done worse where winters had warmed more. This was thought to possibly be a result of interactions with residents. Thrushes did best where spring rainfall increased most and where winter temperatures and rainfall increased. Resident insectivores did better where winter temperatures had increased most and spring temperatures increased least. There were also some positive relationships between winter warming and changes in some declining hole-nesters.

It is important to point out that the modelling approach was designed to be exploratory and are initial analyses designed to highlight areas for further study and research. Results found here should not be regarded as absolute, but instead as pointing to areas where further, more detailed, research is urgently required. In particular, further analysis of the affect of winter temperatures and landscape issues are required to help isolate primary effects. Research recommendations are discussed in subsequent parts of this report.

Table 4.5.1 Summarising the results of analyses to investigate some potential drivers of population change in woodland bird populations. ✓✓ = Strong evidence presented that the driver could be involved in species decline. ✓ = Some evidence presented that the driver could be involved in species decline. +/- = Conflicting results found, further investigation necessary. x = No evidence found in current analyses of driver being important in species decline. NB An absence of effect in current work does not guarantee that a relationship does not exist, and in many cases, further study is recommended in the text. Please see text for full information. * = Low sample size, results to be interpreted with caution. ** = Data available for one geographical area only; results reflect the situation in this area only. 'Wooded surrounds' category combines woodland in the surrounding landscape, amount of wooded landscape, and connectivity analyses.

	Soil moisture**	**Avian predators**	**Winter climate**		**Landscape**			
		Great Spotted W'pecker	**Temperature**	**Rainfall**	**Wooded surrounds**	**ASNW**	**Isolation**	**Area or size**
Blackbird	x	x	+/-	✓✓	+/-	x	x	x
Bullfinch	x	x	na	na	x	✓	x	x
Dunnock	na	x	✓✓	✓✓	x	x	x	x
Garden Warbler	na	x	✓✓	✓✓	x	x	x	x
Goldcrest	✓	x	+/-	+/-	+/-	x	✓	✓
Hawfinch	x	✓✓	+/-	x	✓✓	x	x	x
Jay	x	x	x	✓✓	✓	x	x	x
Lesser Redpoll	na	x	+/-	+/-	x	x	x	x
Lesser Spotted W'pecker*	x	✓	x	x	✓✓	x	x	✓✓
Marsh Tit	x	x	x	+/-	✓	x	x	✓
Song Thrush	x	x	x	✓✓	✓✓	x	x	x
Spotted Flycatcher	x	x	✓✓	+/-	✓	x	✓	x
Tree Pipit	na	✓✓	+/-	x	x	✓	x	x
Treecreeper	x	x	+/-	+/-	✓✓	x	x	✓
Willow Tit*	x	x	x	✓	x	x	x	x
Willow Warbler	x	✓✓	✓✓	x	x	x	x	x
Wood Warbler	x	x	x	✓✓	x	✓	x	x

Summary Table Summarising the results of analyses to investigate some potential drivers of population change in woodland bird populations. ✓✓ = Strong evidence presented that the driver could be involved in species decline. ✓ = Some evidence presented that the driver could be involved in species decline. +/- = Conflicting results found, further investigation necessary. x = No evidence found in current analyses of driver being important in species decline. NB An absence of effect in current work does not guarantee that a relationship does not exist, and in many cases, further study is recommended in the text. Please see text for full information. * = Low sample size, results to be interpreted with caution. ** = Data available for one geographical area only; results reflect the situation in this area only. 'Wooded surrounds' category combines woodland in the surrounding landscape, amount of wooded landscape, and connectivity analyses.

	Soil	**Avian predators**	**Winter climate**		**Landscape**			
	moisture**	**Great Spotted W'pecker**	**Temperature**	**Rainfall**	**Wooded surrounds**	**ASNW**	**Isolation**	**Area or size**
Blackbird	x	x	+/-	✓✓	+/-	x	x	x
Bullfinch	x	x	na	na	x	✓	x	x
Dunnock	na	x	✓✓	✓✓	x	x	x	x
Garden Warbler	na	x	✓✓	✓✓	x	x	x	x
Goldcrest	✓	x	+/-	+/-	+/-	x	✓	✓
Hawfinch	x	✓✓	+/-	x	✓✓	x	x	x
Jay	x	x	x	✓✓	✓	x	x	x
Lesser Redpoll	na	x	+/-	+/-	x	x	x	x
Lesser Spotted W'pecker*	x	✓	x	x	✓✓	x	x	✓✓
Marsh Tit	x	x	x	+/-	✓	x	x	✓
Song Thrush	x	x	x	✓✓	✓✓	x	x	x
Spotted flycatcher	x	x	✓✓	+/-	✓	x	✓	x
Tree Pipit	na	✓✓	+/-	x	x	✓	x	x
Treecreeper	x	x	+/-	+/-	✓✓	x	x	✓
Willow Tit*	x	x	x	✓	x	x	x	x
Willow Warbler	x	✓✓	✓✓	x	x	x	x	x
Wood Warbler	x	x	x	✓✓	x	✓	x	x

4.6 References

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5. ANALYSES OF FARMLAND BIRDS

Simon Butler (CAER)

5.1 Introduction

The rate of farmland bird declines has increased over recent years. The key gap in our understanding of the processes driving these continued declines is the relationship between field scale resource availability and national population dynamics. Bridging this scaling gap is crucial if we are to quantify the level of resources required to deliver biodiversity targets such as the UK Government's Public Service Agreement of reversing farmland bird declines by 2020. Butler et al (2007) used a trait-based approach to develop a generic risk assessment framework and link land-use change with population change. Whilst this approach can be used to assess the impact of novel, widespread land-use changes and to guide the delivery of key resources back into the agricultural landscape, it is limited in a number of respects. Firstly, it focuses only on the detrimental impacts of an agricultural change and cannot take into account population responses to potential benefits, such as any resultant increases in resource availability (Bignal & McCracken 2000; Robinson, Wilson & Crick 2001). Secondly, it relies on simple but crude assumptions about the spatial congruence of agricultural change and species' ranges in order to estimate national population trends. Furthermore, it cannot be used to predict the consequence of changes in the intensity of management of existing habitats and or to identify threshold levels of resource provision likely to deliver stable or increasing populations. Here we develop a farm-scale model which overcomes many of the limitations of the national model, can provide a rapid assessment of the impacts of land-use change on bird populations and can be used to explore spatial variation in the threshold levels of resource availability associated with stable/increasing populations. These analyses are based on bird abundance and habitat data collected from the 601 1km squares covered by both the Breeding Bird Survey (BBS) and Winter Farmland Bird Survey (WFBS).

5.2 Methods

5.2.1 Population trend

The population trend of each farmland bird species between 1994 and 2007 was calculated for all squares in which the species had been recorded by BBS in at least three years during that period using General Linear Mixed modelling approaches. The population trajectory of each species was then classified as either declining (population trend <0) or stable/increasing (population trend ≥ 0).

5.2.2 Defining niche space

For each farmland bird index species, we identified all the BBS and WFBS habitat codes which defined habitats or land-uses which were expected to provide high or low quality summer foraging and/or nesting habitat (BBS data) and high or low quality winter foraging habitat (WFBS data) - see Table 5.4.1 for details of the codes assigned to each category. Habitats and land-uses were assigned to each niche space category on the basis of the species' key ecological requirements (Butler *et al.* 2007) and previously reported evidence of habitat preference or selection and resource availability (e.g. Defra report BD1618; BTO research report 485; Fuller *et al*. 1995; Pain & Pienkowski 1997; Cramp 1998; Siriwardena *et al*. 1998; Wilson *et al*. 1999; Aebischer *et al*. 2000; Chamberlain *et al*. 2000; Henderson *et al*. 2000a; Henderson *et al*. 2000b; Boatman *et al*. 2002; Newton 2004; Vickery *et al*. 2004). Sufficient data were available to confidently define high and low quality niche space for all species except woodpigeon for which it was not possible to determine the features which differentiate high and low quality breeding habitat.

5.2.3 Quantifying niche space availability

The average area of each niche space category available in each square over three years was estimated from habitat data collected during WFBS (1999/2000, 2000/2001, 2002/2003) and BBS (2000, 2001, 2003). The methods of habitat data recording differed between BBS and WFBS so different approaches were used for quantifying niche space availability in summer and winter.

5.2.3.1 Summer foraging and breeding habitat

For each species and each year's data, we recorded whether or not the primary and, where applicable, secondary habitat codes recorded for each 200m section were expected to provide high or low quality summer foraging habitat. A number of potential outcomes were possible and transect sections were scored as follows:

Primary habitat code		Secondary habitat code		HQ score	LQ score
High quality	Low quality	High quality	Low quality		
No	No	-	-	**0**	**0**
Yes	No	-	-	**1**	**0**
No	Yes	-	-	**0**	**1**
No	No	No	No	**0**	**0**
Yes	No	No	No	**0.5**	**0**
Yes	No	Yes	No	**1**	**0**
No	No	Yes	No	**0.5**	**0**
No	Yes	No	No	**0**	**0.5**
No	Yes	No	Yes	**0**	**1**
No	No	No	Yes	**0**	**0.5**
Yes	No	No	Yes	**0.5**	**0.5**
No	Yes	Yes	No	**0.5**	**0.5**

High quality and low quality scores were then summed across transect sections within a square and divided by the total number of transect sections in the square for which data were available to identify the proportion of transect sections contributing to each niche space category. On the assumption that the habitat recorded along the transects was representative of that available throughout the square, this was multiplied by the area of farmland available in the square to estimate the total area of high and low quality summer foraging habitat available. Finally, these areas were averaged across the three years. This process was repeated to identify the average area of high and low quality breeding habitat available in each square. Given that high and low quality breeding habitat for woodpigeon could not be differentiated, the total area of breeding habitat available was calculated for this species.

5.2.3.2 Winter foraging habitat

WFBS habitat data were recorded for individual patches within a square rather than along transects, with the area associated with each patch also recorded. To quantify winter niche space availability, the habitat in each patch was redefined as providing either high quality winter foraging habitat, low quality winter foraging habitat or making no contribution to winter niche space. The summed areas of patches defined as high quality foraging habitat and low quality foraging habitat were calculated for each square and multiplied by the proportion of the square that had been surveyed to estimate the total area of high quality and low quality winter foraging habitat available in each square. Again, these calculations were performed on data from each winter and then averaged across the three winters.

It is important to note that the habitat recorded within a single transect section could potentially contribute to both the area of high and low quality niche space and the area of summer foraging and breeding habitat. Niche space availability could also be linked temporally i.e. land-use in the winter could influence both winter foraging habitat availability but also summer foraging and breeding habitat in the subsequent year because of the impact on crop rotation. Furthermore, the area of niche space available reflects land-use as recorded under BBS and WFBS and interpreted as outlined above. This is particularly important when evaluating the provision of niche space associated with linear features such as hedgerows or tree lines. The results of the analyses below must therefore be considered with this in mind.

5.2.4 Data analyses

The relationship between population trend and niche space availability was explored using classification and regression tree analysis (CART) using the RPART package in R (Breiman et al 1984). Population trend (declining or stable/increasing) was defined as the dependent variable. For all resident species, the areas of high and low quality summer and winter foraging habitat and breeding habitat were included as predictor variables, for migrant species (Turtle dove, Whitethroat and Yellow wagtail), only high and low quality summer foraging and breeding habitat were included. This process constructs a set of decision rules based on predictor variables by recursively partitioning data into successively smaller groups until a set of homogenous groups, in terms of the response variable, is achieved (De'ath & Fabricious 2000) or until the data cannot be divided any further based on the explanatory variables employed. At each stage, splits for all of the predictors are examined by an exhaustive search procedure before the best split is chosen. The best split is chosen as the one which maximises the homogeneity of each subgroup and is based on a measure of model impurity which is defined in terms of the proportion of responses in each category (Breiman et al 1984). This approach has the advantage over more traditional multiple and logistic regression techniques in that it can accommodate nonlinear relationships and high-order interactions. Furthermore, the output is a tree diagram which represents the set of decision rules that can be easily interpreted. A number of steps were taken to prevent over-fitting the models to the data which could reduce their generality. Firstly, the minimum split level was set at 10% of total number of squares i.e. only groups with this number of squares in could be further sub-divided. Secondly, the minimum bucket was set at 5% of number of squares in the set which, when squares were grouped by trajectory, had the lowest number i.e. if a group was split, each sub-group had to have at least this number of squares assigned to it. Thirdly, a maximum tree depth of 6 splits was set as this was the maximum number of variables included. Finally, we used 10-fold cross-validation to estimate prediction error associated with a range of tree sizes. This process works by dividing the data into 10 mutually exclusive subsets of approximately equal size, dropping out each subset in turn, building a tree using data from the remaining subsets and using it to predict the responses for the omitted subset. This process was repeated for a range of tree sizes (number of splits) to provide an estimated prediction error (± 1SE) for each tree size. We limited final tree size to the largest tree that had an estimated prediction error that fell within the 95% confidence interval of the tree with the lowest estimated prediction error.

The results of CART analyses for each species are presented below. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat respectively. A number of details are provided in each tree. Firstly, the decision rule associated with each split is provided; squares with niche space availability agreeing with the rule move to the left and those which do not move to the right. At each endnode (labelled A, B, C etc) the number of squares with declining and stable/increasing population trajectories are shown and the endnode is classified as declining (0) or stable/increasing (1) accordingly (i.e. whichever has the greater number of squares).These data can be used to determine the probability that a species will decline or be stable/increasing given the niche space available within a square defined by the path to that endnode.

Taking the Corn Bunting tree as an example, the first split is based on the availability of SLQ habitat. There were 9 squares with less than 4.186ha SLQ, six with stable/increasing populations and 3 with declining populations (endnode F). Thus if a square has less than 4.186ha SLQ it has a 66.7% probability of having a stable/increasing Corn Bunting population trend. If it has more than 4.186ha SLQ and more than 68.3ha BLQ there is a 66.7% probability of it having a stable/increasing population (endnode E). If the square has more than 4.186ha SLQ, less than 68.3ha BLQ and less than 6.21ha WLQ (endnode A), there is an 83.6% probability of it having a declining population. If a square has less than 16.76ha SLQ, less than 68.3 ha BLQ but more than 6.21ha WLQ, there is a 94.4% probability of it having a declining population (endnode B) and so on.

Below the tree for each species, a table outlining the relative distribution of squares from each Government Office Region between the endnodes is provided. The results from a contingency table analysis which tests for regional variation in this distribution are also provided.

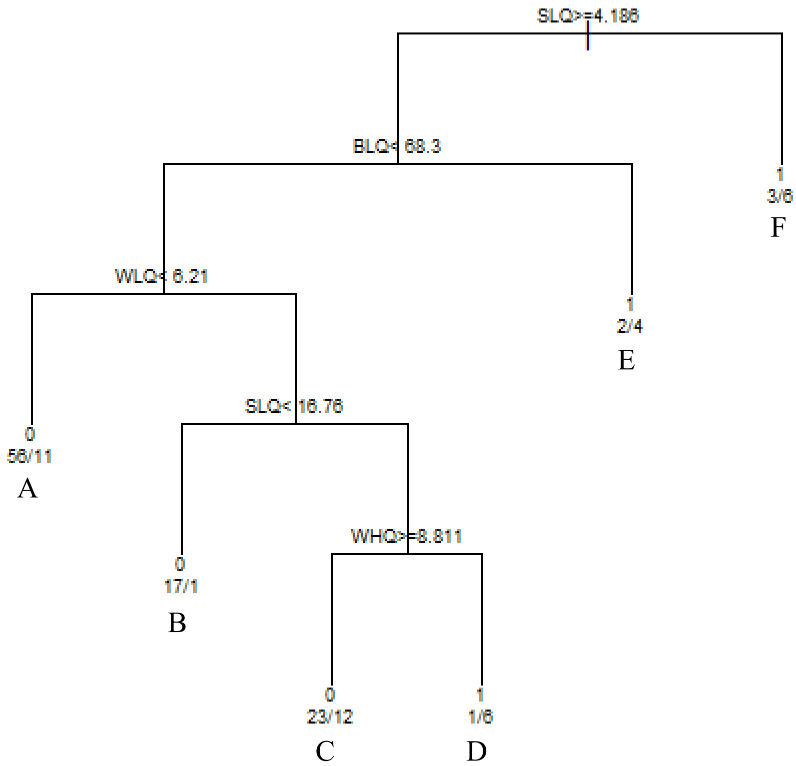

Figure 5.2.4.1 Classification and regression tree showing results for Corn Bunting. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.1 The relative distribution of squares from each Government Office Region between endnodes, for Corn Bunting.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)					
GOR	**A↓**	**B↓**	**C↓**	**D↑**	**E↑**	**F↑**
Northwest	8	2	2	2	0	2
Northeast	2	0	2	0	1	0
Yorkshire & Humber	3	1	5	0	0	1
East Midlands	11	0	3	0	1	1
East England	23	3	6	0	2	0
West Midlands	1	2	2	1	0	0
Southeast	11	6	4	2	2	4
Southwest	7	2	10	2	0	0

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 47.8$, df = 35, P = 0.07

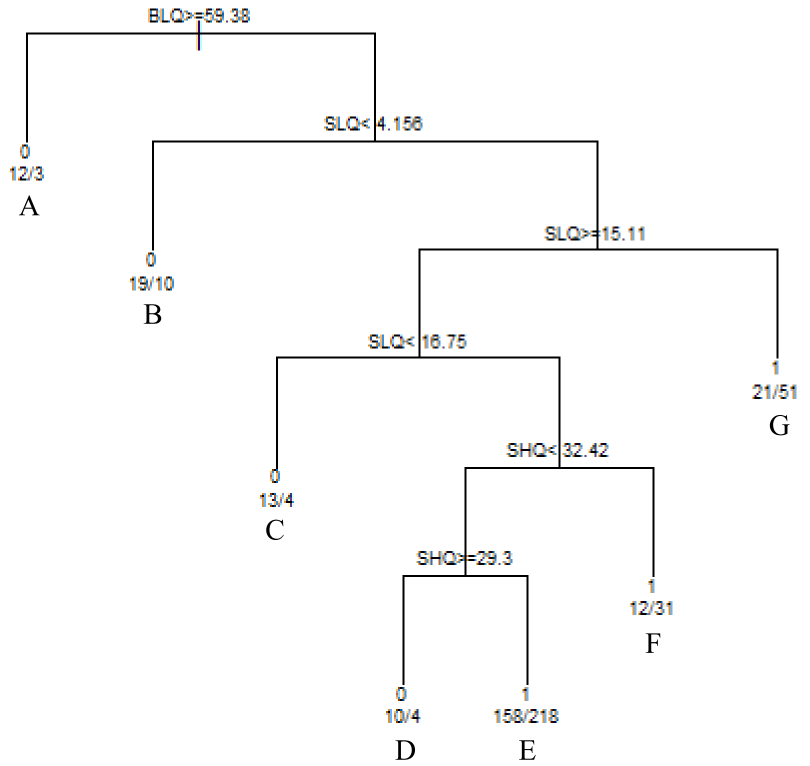

Figure 5.2.4.2 Classification and regression tree showing results for Goldfinch. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.2 The relative distribution of squares from each Government Office Region between endnodes, for Goldfinch.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)						
GOR	**A↓**	**B↓**	**C↓**	**D↓**	**E↑**	**F↑**	**G↑**
Northwest	0	2	2	2	27	6	14
Northeast	2	3	1	0	16	1	0
Yorkshire & Humber	0	2	1	0	21	3	5
East Midlands	5	0	0	2	26	2	1
East England	0	4	1	1	76	3	3
West Midlands	1	1	1	2	26	1	7
Southeast	2	7	7	2	70	3	11
Southwest	5	4	2	2	62	17	15

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 90.8$, df = 42, $P < 0.001$

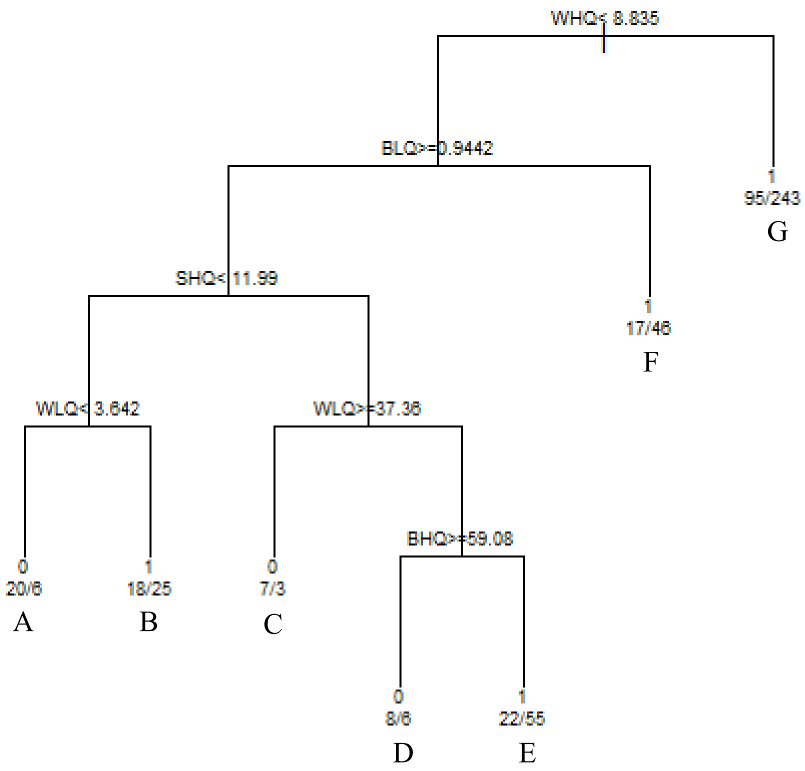

Figure 5.2.4.3 Classification and regression tree showing results for Greenfinch. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.3 The relative distribution of squares from each Government Office Region between endnodes, for Greenfinch.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)						
GOR	**A↓**	**B↑**	**C↓**	**D↓**	**E↑**	**F↑**	**G↑**
Northwest	1	6	0	3	8	14	21
Northeast	1	1	0	0	6	5	10
Yorkshire & Humber	2	2	1	0	4	4	21
East Midlands	0	1	0	0	5	2	28
East England	4	4	0	3	5	6	66
West Midlands	1	6	0	0	5	5	24
Southeast	5	11	5	1	17	9	57
Southwest	4	7	3	3	15	8	67

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 64.5$, df = 42, P = 0.014

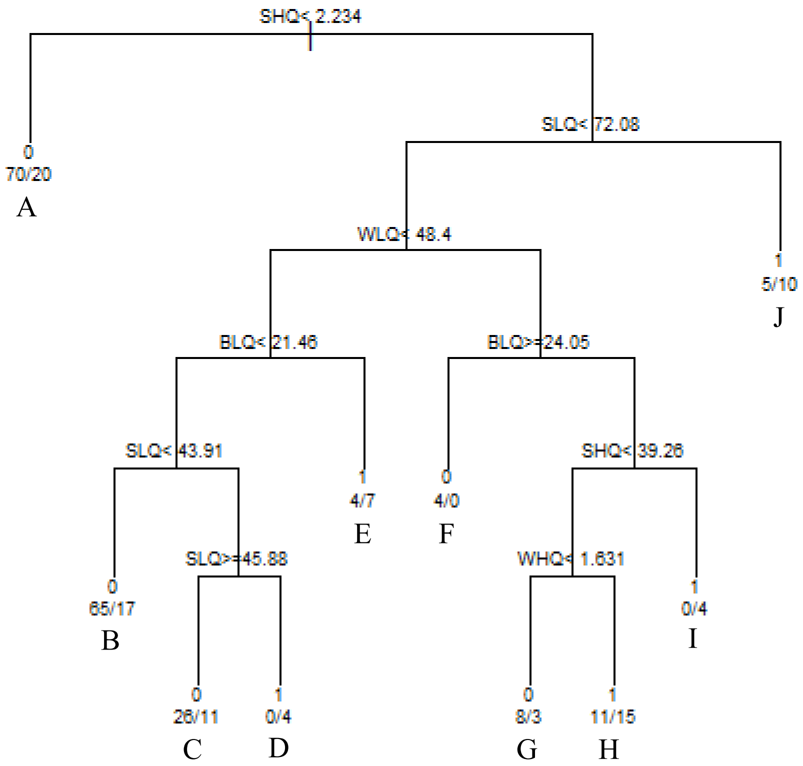

Figure 5.2.4.4 Classification and regression tree showing results for Grey Partridge. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.4 The relative distribution of squares from each Government Office Region between endnodes, for Grey Partridge.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)									
GOR	**A↓**	**B↓**	**C↓**	**D↑**	**E↑**	**F↓**	**G↓**	**H↑**	**I↑**	**J↑**
Northwest	12	13	1	1	2	0	1	2	0	0
Northeast	5	1	3	1	0	0	1	4	0	4
Yorkshire & Humber	9	8	4	1	0	1	0	2	0	0
East Midlands	6	7	4	0	0	1	1	5	1	1
East England	15	12	6	0	6	1	4	4	1	4
West Midlands	7	4	3	0	0	0	0	0	0	1
Southeast	26	15	7	1	0	0	2	4	0	2
Southwest	2	10	3	0	2	1	1	3	1	2

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 74.1$, df = 63, P = 0.16

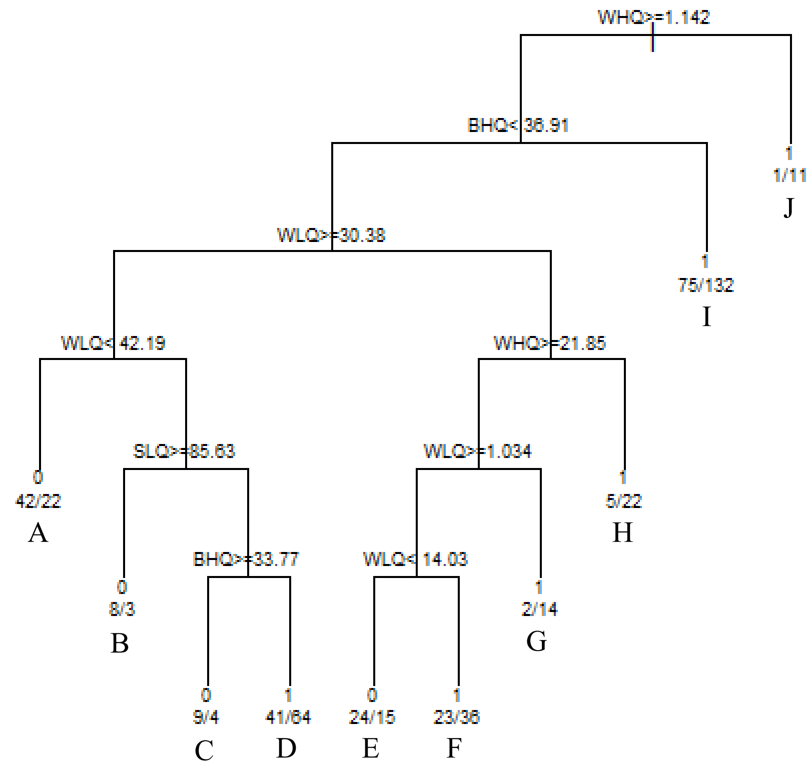

Figure 5.2.4.5 Classification and regression tree showing results for Jackdaw. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.5 The relative distribution of squares from each Government Office Region between endnodes, for Jackdaw.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)									
GOR	**A↓**	**B↓**	**C↓**	**D↑**	**E↓**	**F↑**	**G↑**	**H↑**	**I↑**	**J↑**
Northwest	5	0	0	5	7	8	3	4	19	1
Northeast	3	1	0	6	0	3	2	1	7	1
Yorkshire & Humber	1	1	1	6	1	1	0	6	13	1
East Midlands	4	1	1	11	0	3	0	0	9	2
East England	12	4	2	16	1	3	1	3	34	5
West Midlands	4	1	1	7	3	4	1	2	17	0
Southeast	14	1	3	27	8	9	2	4	35	1
Southwest	7	2	2	14	10	11	2	2	54	1

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 87.1$, df = 63, P = 0.024

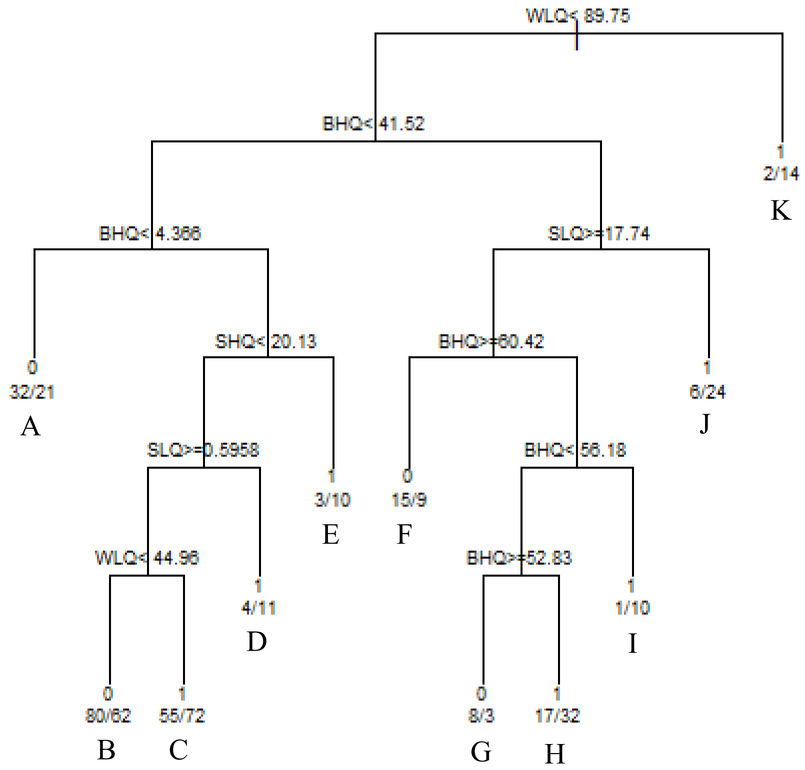

Figure 5.2.4.6 Classification and regression tree showing results for Kestral. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.6 The relative distribution of squares from each Government Office Region between endnodes, for Kestral.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)										
GOR	**A↓**	**B↓**	**C↑**	**D↑**	**E↑**	**F↓**	**G↓**	**H↑**	**I↑**	**J↑**	**K↑**
Northwest	5	9	16	0	3	2	2	2	2	1	6
Northeast	3	10	3	0	1	1	0	5	1	0	0
Yorkshire & Humber	5	13	6	1	0	1	0	0	0	2	1
East Midlands	5	12	8	0	3	2	0	2	1	2	0
East England	14	25	12	6	0	4	2	9	1	11	0
West Midlands	1	11	8	1	1	2	3	5	1	1	2
Southeast	8	38	26	3	2	2	1	8	0	8	1
Southwest	2	14	28	2	2	9	2	13	5	4	4

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 120.5$, df = 70, P < 0.001

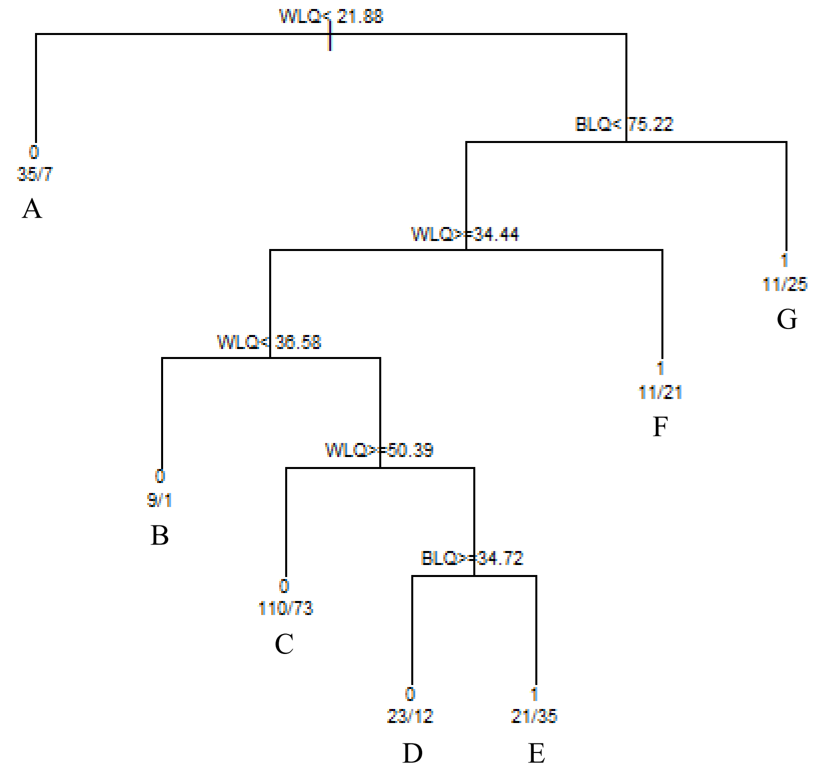

Figure 5.2.4.7 Classification and regression tree showing results for Lapwing. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.7 The relative distribution of squares from each Government Office Region between endnodes, for Lapwing.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)						
GOR	**A↓**	**B↓**	**C↓**	**D↓**	**E↑**	**F↑**	**G↑**
Northwest	10	0	26	2	6	5	1
Northeast	6	1	10	1	1	1	2
Yorkshire & Humber	5	1	14	4	3	3	3
East Midlands	1	1	11	5	6	0	10
East England	3	2	25	9	5	4	11
West Midlands	2	1	17	3	3	2	2
Southeast	6	0	33	8	17	7	3
Southwest	1	0	23	3	3	5	2

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 72.4$, df = 42, P = 0.002

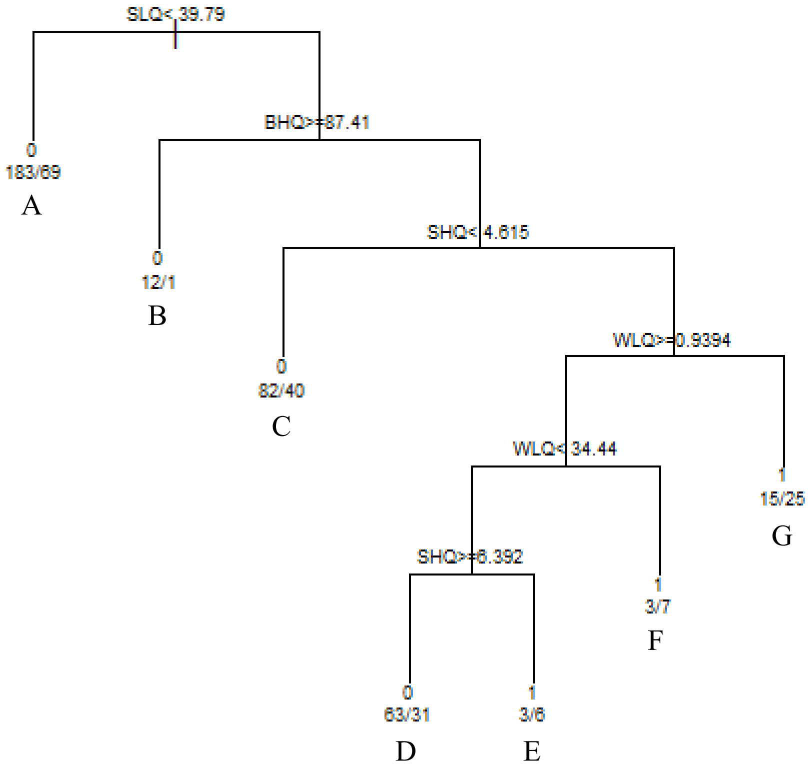

Figure 5.2.4.8 Classification and regression tree showing results for Linnet. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.8 The relative distribution of squares from each Government Office Region between endnodes, for Linnet.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)						
GOR	**A↓**	**B↓**	**C↓**	**D↓**	**E↑**	**F↑**	**G↑**
Northwest	29	2	9	5	0	1	1
Northeast	8	1	5	5	0	1	4
Yorkshire & Humber	16	0	6	5	0	1	4
East Midlands	15	2	5	10	0	1	3
East England	33	0	11	21	2	1	16
West Midlands	18	2	9	3	0	0	3
Southeast	58	2	17	17	0	3	2
Southwest	33	4	36	19	5	2	4

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 78.8$, df = 42, $P < 0.001$

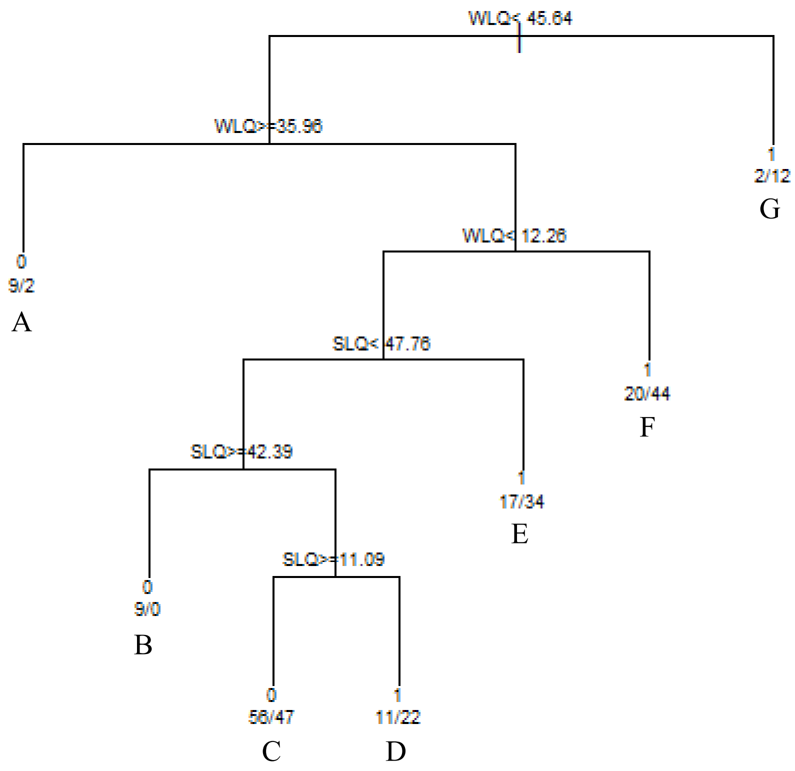

Figure 5.2.4.9 Classification and regression tree showing results for Reed Bunting. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.9 The relative distribution of squares from each Government Office Region between endnodes, for Reed Bunting.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)						
GOR	**A↓**	**B↓**	**C↓**	**D↑**	**E↑**	**F↑**	**G↑**
Northwest	2	0	15	9	1	10	3
Northeast	0	0	7	1	5	3	1
Yorkshire & Humber	1	1	3	4	2	6	0
East Midlands	1	0	10	1	12	4	0
East England	1	3	21	1	17	7	1
West Midlands	0	0	6	4	2	5	0
Southeast	4	4	18	5	5	7	4
Southwest	1	1	8	3	3	4	1

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 62.8$, df = 42, P = 0.02

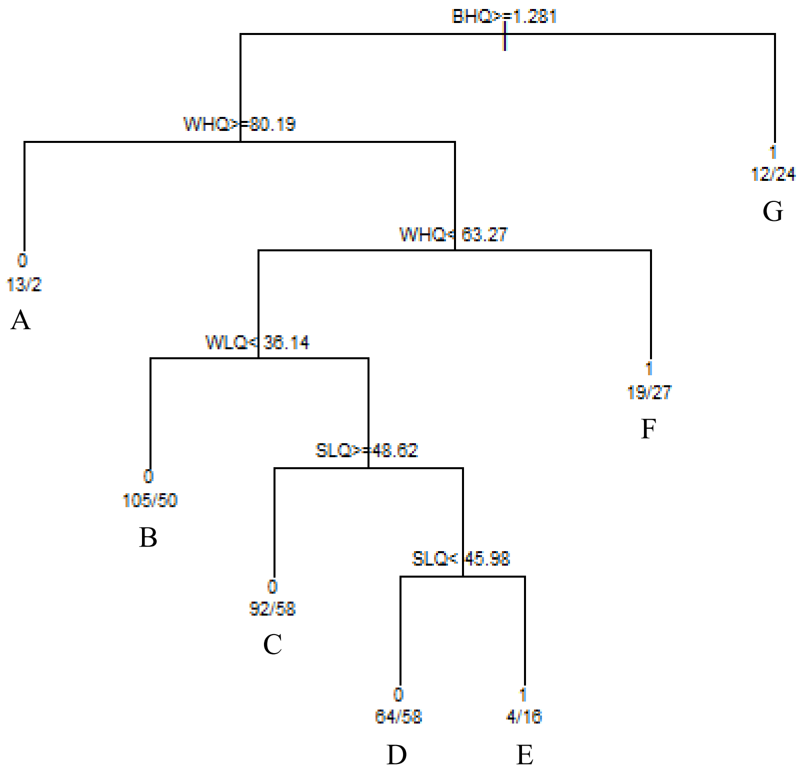

Figure 5.2.4.10 Classification and regression tree showing results for Rook. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.10 The relative distribution of squares from each Government Office Region between endnodes, for Rook.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)						
GOR	**A↓**	**B↓**	**C↓**	**D↓**	**E↑**	**F↑**	**G↑**
Northwest	4	11	3	11	2	11	3
Northeast	0	6	9	4	1	2	2
Yorkshire & Humber	0	7	16	5	2	1	2
East Midlands	0	5	20	6	0	2	2
East England	2	15	37	16	4	1	10
West Midlands	0	15	7	8	5	2	1
Southeast	0	27	19	40	5	5	4
Southwest	6	36	31	20	1	11	2

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 119.9$, df = 42, P < 0.001

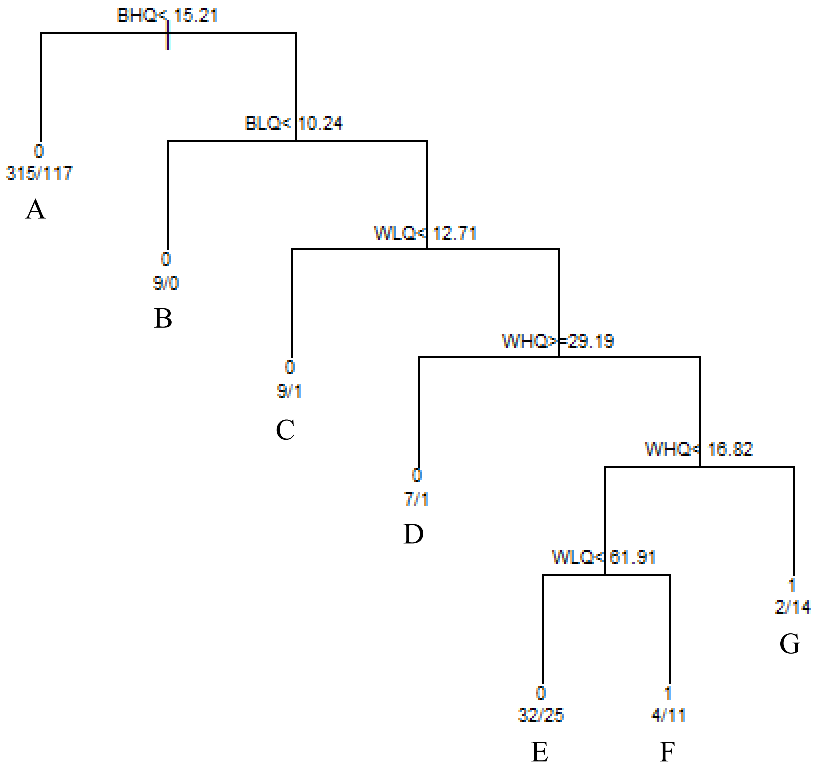

Figure 5.2.4.11 Classification and regression tree showing results for Skylark. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.11 The relative distribution of squares from each Government Office Region between endnodes, for Skylark.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)						
GOR	**A↓**	**B↓**	**C↓**	**D↓**	**E↓**	**F↑**	**G↑**
Northwest	39	1	2	1	3	2	0
Northeast	16	0	0	1	5	1	0
Yorkshire & Humber	25	0	1	1	3	1	2
East Midlands	24	0	0	1	6	4	1
East England	69	3	1	0	11	4	1
West Midlands	36	0	0	0	2	0	2
Southeast	88	2	1	2	7	1	3
Southwest	76	1	4	1	13	1	3

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 44.3$, df = 42, P = 0.37

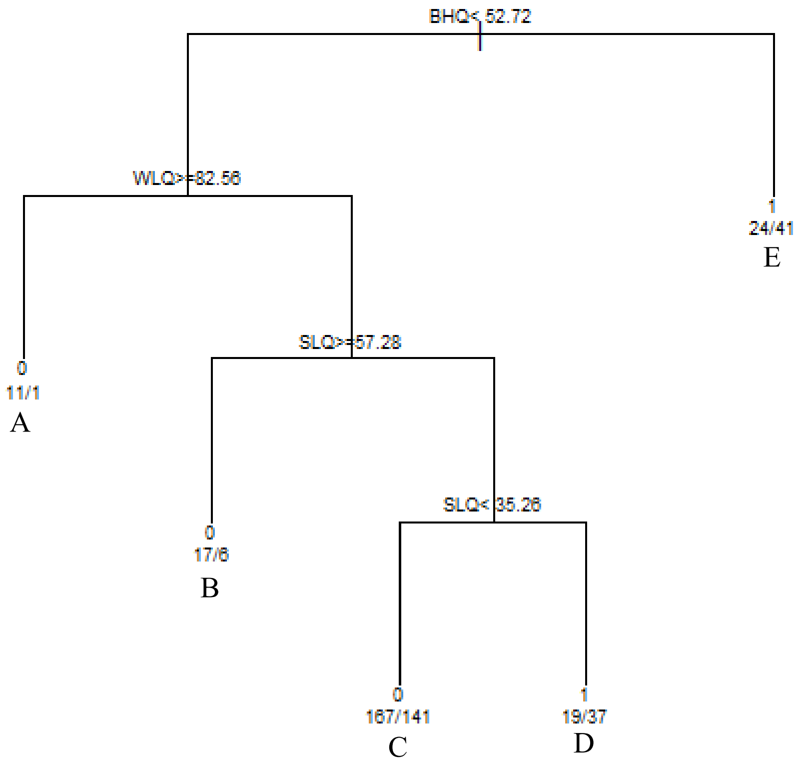

Figure 5.2.4.12 Classification and regression tree showing results for Stock Dove. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat

Table 5.2.4.12 The relative distribution of squares from each Government Office Region between endnodes, for Greenfinch

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)				
GOR	**A↓**	**B↓**	**C↓**	**D↑**	**E↑**
Northwest	0	0	32	0	9
Northeast	1	1	13	2	2
Yorkshire & Humber	0	1	19	5	2
East Midlands	1	5	18	6	4
East England	6	10	31	18	10
West Midlands	0	0	22	3	8
Southeast	2	2	72	13	7
Southwest	0	2	60	8	20

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 75.2$, df = 28, P < 0.001

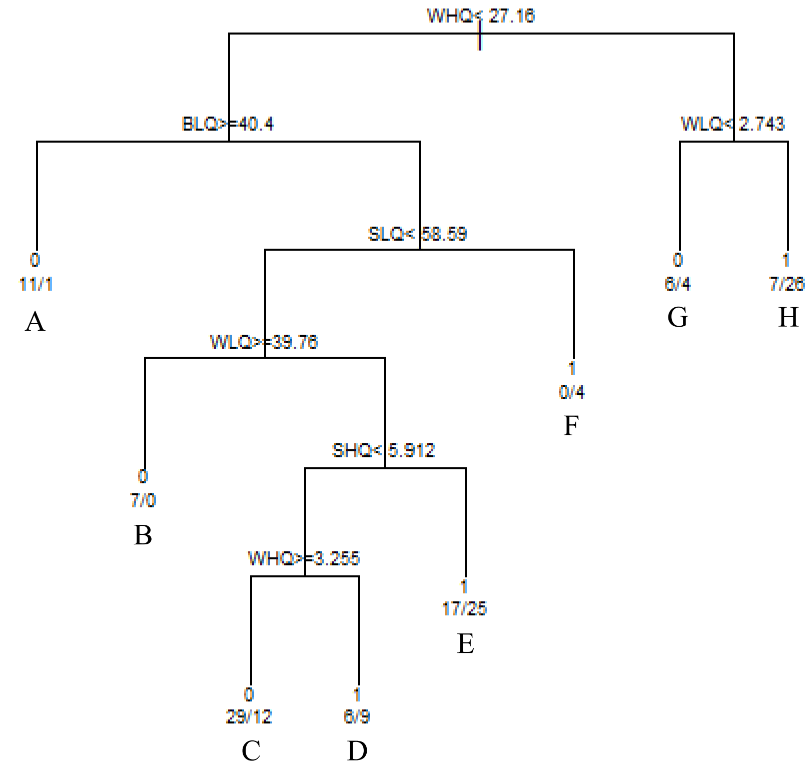

Figure 5.2.4.13 Classification and regression tree showing results for Tree Sparrow. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.13 The relative distribution of squares from each Government Office Region between endnodes, for Tree Sparrow.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)							
GOR	**A↓**	**B↓**	**C↓**	**D↑**	**E↑**	**F↑**	**G↓**	**H↑**
Northwest	0	1	6	7	12	0	1	2
Northeast	2	0	2	0	2	0	1	3
Yorkshire & Humber	2	1	5	1	4	1	3	6
East Midlands	3	0	3	1	6	1	2	8
East England	1	1	5	0	3	1	0	2
West Midlands	2	1	4	4	3	1	0	2
Southeast	1	0	8	1	3	0	2	0
Southwest	1	0	1	0	1	0	0	0

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 53.8$, df = 49, P = 0.29

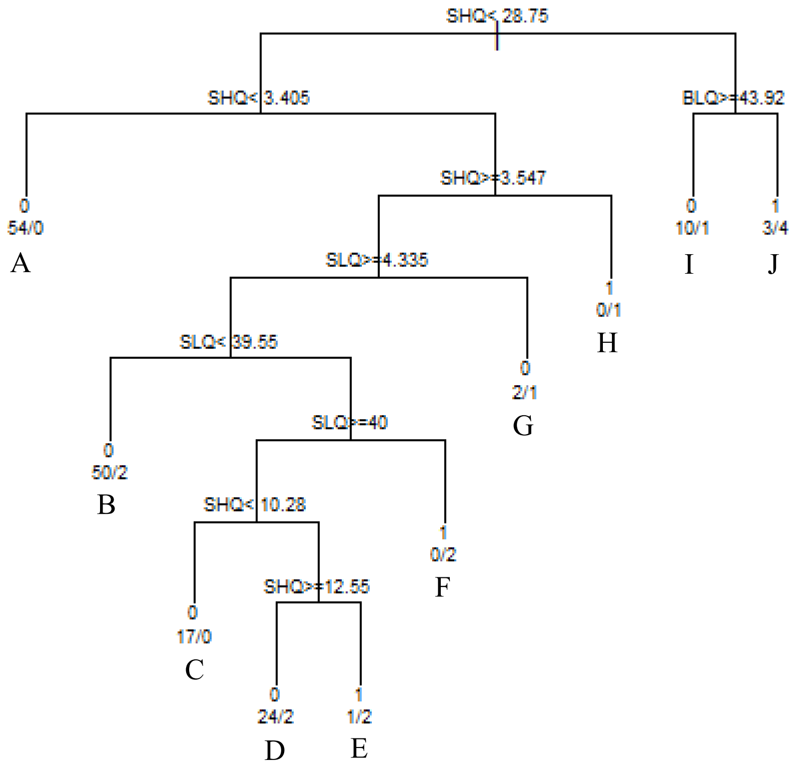

Figure 5.2.4.14 Classification and regression tree showing results for Turtle Dove. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.14 The relative distribution of squares from each Government Office Region between endnodes, for Turtle Dove.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)									
GOR	**A↓**	**B↓**	**C↓**	**D↓**	**E↑**	**F↑**	**G↓**	**H↑**	**I↓**	**J↑**
Yorkshire & Humber	2	2	2	1	0	0	0	0	2	0
East Midlands	3	6	4	2	0	0	0	0	1	1
East England	19	15	7	15	2	0	1	0	6	6
West Midlands	2	5	1	0	0	0	0	0	1	0
Southeast	21	16	3	7	0	1	1	1	1	0
Southwest	5	7	0	1	1	1	0	0	0	0

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 46.7$, df = 45, P = 0.4

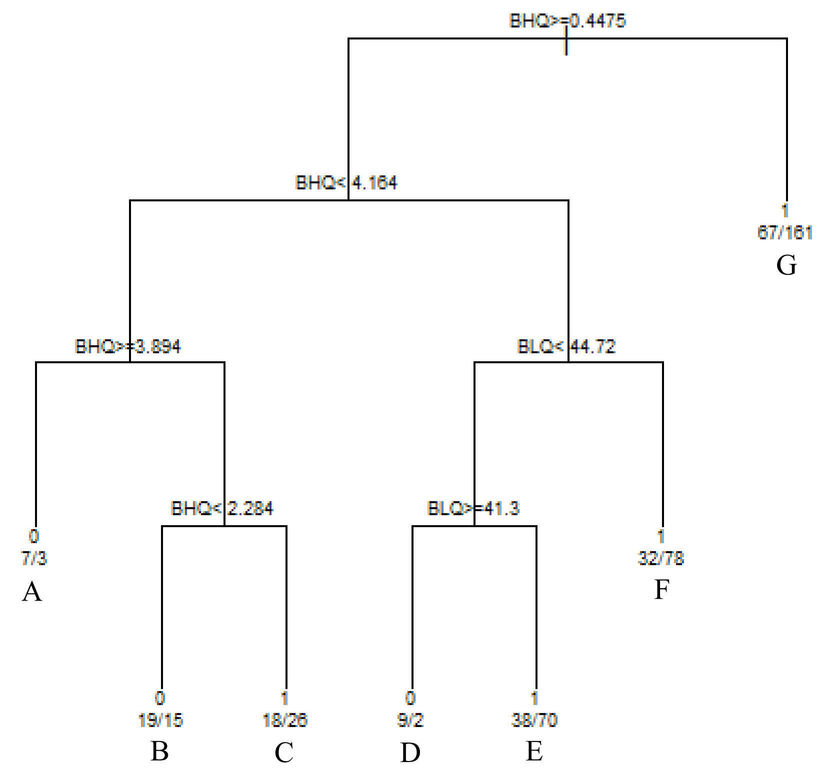

Figure 5.2.4.15 Classification and regression tree showing results for Whitethroat. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.15 The relative distribution of squares from each Government Office Region between endnodes, for Whitethroat.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)						
GOR	**A↓**	**B↓**	**C↑**	**D↓**	**E↑**	**F↑**	**G↑**
Northwest	0	1	6	2	9	7	23
Northeast	0	6	0	0	3	8	6
Yorkshire & Humber	1	2	5	1	5	8	12
East Midlands	2	1	0	0	5	6	22
East England	1	5	8	2	9	9	52
West Midlands	0	0	4	1	6	7	20
Southeast	2	9	8	0	28	24	30
Southwest	1	7	7	3	22	29	34

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 78.1$, df = 42, P < 0.001

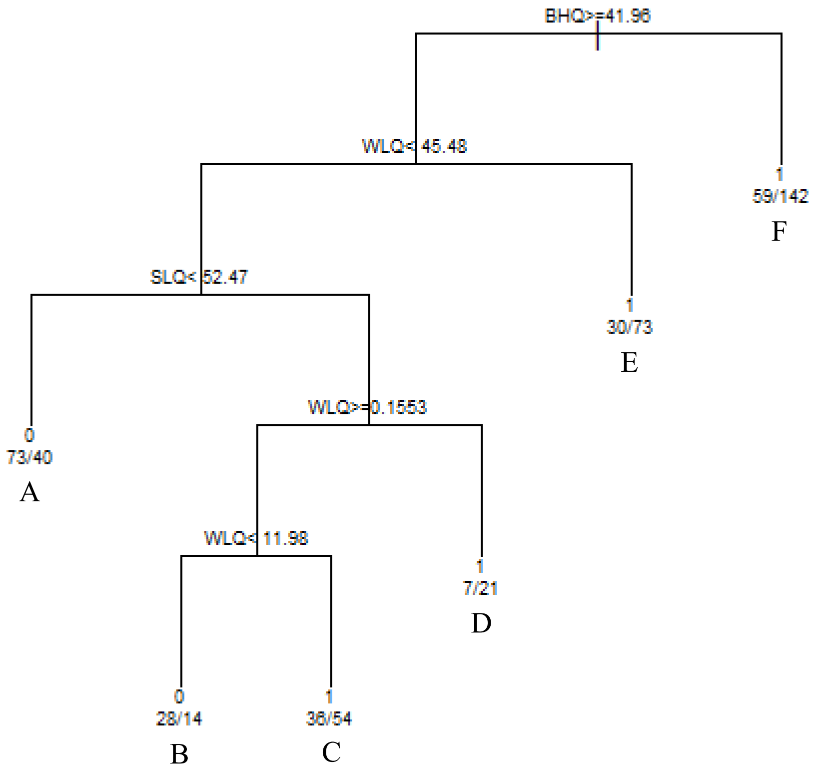

Figure 5.2.4.16 Classification and regression tree showing results for Woodpigeon. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.16 The relative distribution of squares from each Government Office Region between endnodes, for Woodpigeon.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)					
GOR	**A↓**	**B↓**	**C↑**	**D↑**	**E↑**	**F↑**
Northwest	9	5	4	6	1	28
Northeast	2	1	3	1	9	8
Yorkshire & Humber	7	0	3	0	11	13
East Midlands	6	0	5	0	13	13
East England	13	1	11	1	32	31
West Midlands	9	5	10	2	5	10
Southeast	26	1	18	1	21	39

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 135.6$, df = 35, P < 0.001

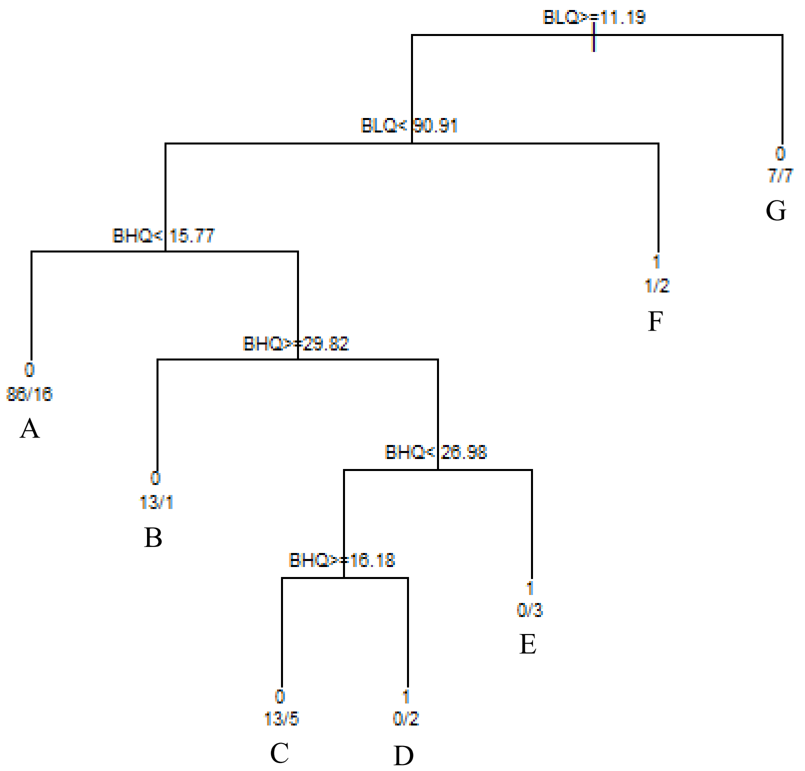

Figure 5.2.4.17 Classification and regression tree showing results for Yellow Wagtail. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.17 The relative distribution of squares from each Government Office Region between endnodes, for Yellow Wagtail.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)						
GOR	**A↓**	**B↓**	**C↓**	**D↑**	**E↑**	**F↑**	**G↓**
Northwest	6	1	2	1	0	0	3
Northeast	5	0	1	1	1	1	0
Yorkshire & Humber	12	0	0	0	1	0	1
East Midlands	14	4	6	0	1	1	1
East England	25	8	6	0	0	0	3
West Midlands	8	0	1	0	0	0	2
Southeast	24	0	1	0	0	1	2
Southwest	7	1	1	0	0	0	1

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 55.5$, df = 42, P = 0.08

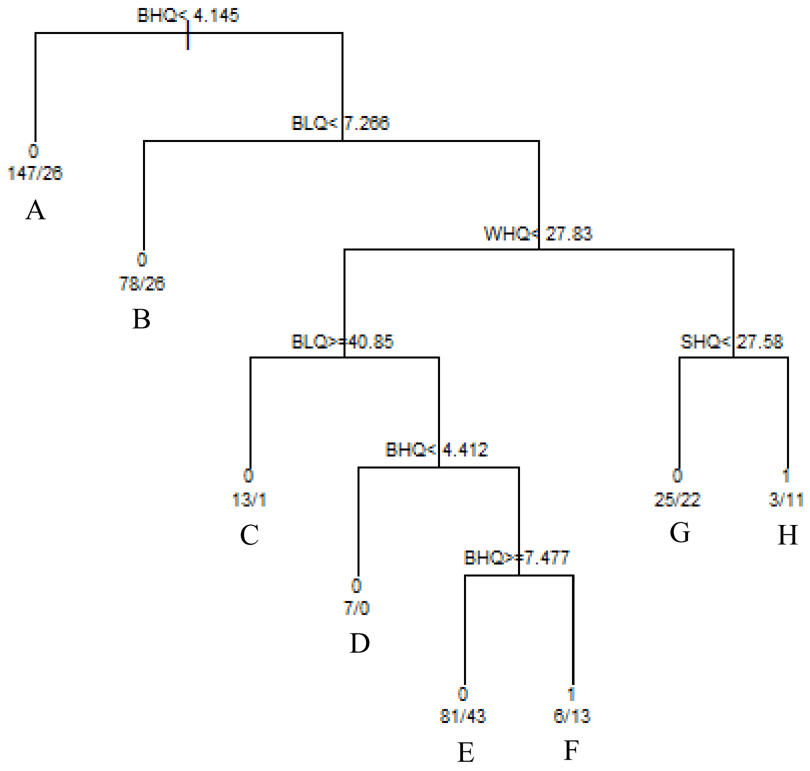

Figure 5.2.4.18 Classification and regression tree showing results for Yellowhammer. BHQ, BLQ, SHQ, SLQ, WHQ and WLQ refer to high and low quality breeding, summer foraging and winter foraging habitat.

Table 5.2.4.18 The relative distribution of squares from each Government Office Region between endnodes, for Yellowhammer.

	Number of squares at each end node (predicted direction of trend: ↓ - declining; ↑ - stable/increasing)							
GOR	**A↓**	**B↓**	**C↓**	**D↓**	**E↓**	**F**	**G↓**	**H**
Northwest	19	13	0	0	5	2	2	0
Northeast	9	6	0	0	7	0	1	1
Yorkshire & Humber	8	3	2	0	9	2	7	0
East Midlands	6	9	4	1	7	2	7	0
East England	20	19	1	1	30	1	11	1
West Midlands	15	3	1	1	17	0	2	1
Southeast	37	13	3	2	27	5	9	2
Southwest	32	19	3	1	19	5	6	5

Test for regional variation in distribution of squares between nodes:
$\chi^2 = 71.9$, df = 49, P = 0.018

5.3 Results and Discussion

These results show that, for each species, there are a number of different combinations of niche space availability that are associated with declining or stable/increasing population trends, suggesting that there are a number of potential drivers of decline. Furthermore, for 12 of the 19 farmland bird index species there is evidence that the distribution of squares between the possible endnodes varies between Government Office Regions, indicating that there is regional variation in the drivers of population trajectory and therefore that targeted delivery of specific management options may be beneficial.

As outlined in the methods, it is crucial that the threshold areas of niche space categories identified are interpreted with data collection and analytical methods in mind rather than being taken as definitive values; the areas of niche space identified are methodological and analytical interpretations of the habitat and land-uses that are actually available. Thus, if a threshold level of 10 ha of BHQ is identified for species, the required area of BHQ in a 1x1km square is such that if BBS was carried out on that square, and similar analytical approached were applied to the resulting data, the area of BHQ would be recorded as 10 ha.

These trees offer a platform for identifying the most appropriate management for altering the population trajectory of a given species and identify critical thresholds in the availability of each niche space category. Ultimately, the goal should be to provide sufficient additional habitat to a square so that the path it takes down the tree is altered in such a way that it ends up at an endnode associated with stable/increasing population trends. So, taking the Corn Bunting as an example again, altering niche space availability in squares that currently end up in endnodes A, B or C so that their path is altered and they subsequently fall in endnodes D, E or F. Table 5.3.1 outlines the particular habitat and land-use types associated with each niche space category and can therefore be used to translate the results of these trees back into practical management options.

The translation of habitat into niche space and the assessment of niche space quality were based on a coarse categorisation of each species' key resource requirements and on a range of autecological studies and habitat assessments that have investigated habitat selection, food availability and nesting success in agricultural landscapes. The analyses presented also rely on the spatially and temporally contemporaneous population trend and habitat data generated by BBS and WFBS. Whilst this depth of understanding and knowledge is currently limited to farmland birds, we believe the approach should be applicable to both woodland and wetland birds in the future. The key resource requirements for most of these species are already known and, for woodland birds, the Repeat Woodland Bird Survey (RWBS) has already generated spatially and temporally contemporaneous habitat and abundance data which could be used to link population change and niche space availability. This approach therefore has the potential to provide valuable insights into the links between local-scale land use and national population trends for these two species groups.

Table 5.3.1 BBS and WFBS habitat codes defined as providing high and low quality summer and winter foraging habitat and breeding habitat for each farmland bird index species.

Species	HQ Summer				LQ Summer			
	L1	**L2**	**L3**	**L4**	**L1**	**L2**	**L3**	**L4**
LAPWING	E	3	ALL EXCEPT 6	2-6,8,13-15	E	ALL EXCEPT 1	ALL EXCEPT 6	ALL
SKYLARK	C	1-5	2,4,6,9,10	2-7	C	1-5	ALL EXCEPT 7,8	ALL EXCEPT 8
	E	2,3,4	2,4,7,8	2-5,8,13-15	E	1-4	ALL EXCEPT 6	ALL EXCEPT 6
KESTREL	C	1-5	1-5,9,10	2-7	C	1-5	1-6,9-10	1-9
	E	2	ALL EXCEPT 8	2-5,13-15	E	ALL	ALL	1-5,13-16
TURTLE DOVE	E	ALL	6	ALL	E	2	1-5,7,8	ALL
	E	3,4	1-5,7,8	11-15	E	3,4	ALL EXCEPT 6	1-10,16
YELLOW WAGTAIL	C	6	4,6,9,10	2-7	C	1-6	ALL EXCEPT 8	2-7
	E	2,3,4	4,7,8	2-5,8,9,13-15	E	2,3,4	ALL EXCEPT 6	ALL EXCEPT 6
WHITETHROAT	A	ALL	2,3,5	1,2,4,5,8-10	A	ALL	2,3,5	ALL
	B	ALL	ALL EXCEPT 7	2-9	B	ALL	ALL EXCEPT 7	ALL
	C	1-6	2	1	C	1-6	1,2,4,5	ALL
	E	ALL	2	1	E	ALL	1,2,4,5	ALL
LINNET	E	1-4	ALL EXCEPT 6	11,14,15	E	1-4	ALL EXCEPT 6	ALL
	E	2,3	ALL EXCEPT 6	1				
GOLDFINCH	E	ALL	ALL	1,14,15	E	ALL	ALL	ALL
GREENFINCH	E	ALL	ALL	1,11,14,15	E	ALL	ALL	ALL
					F	ALL	ALL	ALL EXCEPT 1,3

Species	HQ Summer				LQ Summer			
	L1	L2	L3	L4	L1	L2	L3	L4
REED BUNTING	B	ALL	4,6	ALL	B	ALL	1,3,8,9	ALL
	C	ALL	1,2,4	1,9	C	ALL	1,2,4	ALL
	E	ALL	1,2,4	1,11,14,15	E	ALL	1,2,4	ALL
	G	ALL	ALL	10				
TREE SPARROW	B	ALL	4,6	ALL	B	ALL	1,3,8	ALL
	E	2,3,4	1,2,4	1,14,15	E	2,3,4	1,2,4	ALL
	G	ALL	ALL	10				
CORN BUNTING	C	1-5	ALL EXCEPT 8	1,9	C	1-5	ALL EXCEPT 8	ALL
	E	2,3,4	ALL EXCEPT 6	1,8,14,15	E	2,3,4	ALL EXCEPT 6	ALL
YELLOWHAMMER	C	1-5	ALL EXCEPT 8	1,9	C	1-5	ALL EXCEPT 8	ALL
	E	2,3,4	ALL EXCEPT 6	1,8	E	1-4	ALL EXCEPT 6	ALL
ROOK	C	1-5	ALL	2-7	C	1-5	ALL	ALL
	E	1-3	ALL	2-6,13-16	E	1-4	ALL	ALL
JACKDAW	C	1-5	ALL	2-7	C	1-5	ALL	ALL
	E	1-3	ALL	2-6,13-16	E	1-4	ALL	ALL
STARLING	C	1,5,6	ALL EXCEPT 8	2,3,4	C	1-5	ALL EXCEPT 8	ALL
	E	2,3	ALL	2-5,16	E	1-3	ALL	1-5,13-16
					F	1,2,3	2,3	2,4-10
STOCK DOVE	E	3,4	ALL EXCEPT 6	11,12,14,15	E	3,4	ALL EXCEPT 6	7-10,13
WOODPIGEON	E	ALL	ALL	9-12,14,15	E	ALL	ALL	ALL
					F	ALL	2,3	2-10
GREY PARTRIDGE	C	1-5	2,4,6,9,10	2-7,9	C	1-5	ALL EXCEPT 7,8	ALL EXCEPT 8
	E	2,3,4	2,4,7,8	2-5,8,13-15	E	1-4	ALL EXCEPT 6	ALL EXCEPT 6

Table 5.3.1 Continued.

Species	HQ Winter			LQ Winter		
	L1	**L2**	**L3**	**L1**	**L2**	**L3**
LAPWING	M	2	ALL EXCEPT 10	M	ALL	
	P	8	ALL	N	1,2,3	1-3,9-12
				Q	1,2,3	ALL EXCEPT 7
				P	4,5,6,9	ALL
SKYLARK	P	ALL	2	P	ALL	ALL
	M	2	10	M	2,4	ALL
	Q	1,3,8	ALL EXCEPT 7	N	1,2,3	ALL EXCEPT 5
KESTREL	M	2	2-6,8,9,11	M	2,4	ALL
	N	ALL	6-8	M	1	ALL
				P	ALL	ALL
				Q	1,2,3	ALL EXCEPT 7
LINNET	P	ALL	2,10	P	ALL	ALL
	M	2	2-6,8	M	2,4	ALL
	N	ALL	6-8			
	Q	1-3	ALL			
GOLDFINCH	P	ALL	2,10	P	ALL	ALL
	M	2	1,10	M	2,4	ALL
	N	ALL	6,7,8	Q	4,7	ALL
	Q	1-3,8	ALL			
GREENFINCH	P	ALL	2,10	P	ALL	ALL
	M	2	1,10	M	2,4	ALL
	N	1-16	6-8	Q	ALL	ALL
	Q	1-4,8	ALL			
REED BUNTING	P	ALL	2,10	P	ALL	ALL
	M	2	1,10,11	M	2,4	ALL
	N	ALL	6-8,12			
	Q	1-3,8	ALL			
TREE SPARROW	P	ALL	2,10	P	ALL	ALL
	P	1-3	4	M	2,4	ALL
	M	2	1,10,11			
	N	ALL	6-8,12			
	Q	1-3,8	ALL			

Table 5.3.1 Continued

Species	HQ Winter L1	HQ Winter L2	HQ Winter L3	LQ Winter L1	LQ Winter L2	LQ Winter L3
CORN BUNTING	P	ALL	2,10	P	ALL	ALL
	M	2	1,10,11	M	2,4	ALL
	N	ALL	6-8,12			
	Q	1-3,8				
YELLOWHAMMER	P	ALL	2,10	P	ALL	ALL
	M	2	1,10,11	M	2,4	ALL
	Q	1-3,8				
ROOK	M	ALL	2-6,8	M	ALL	ALL
	P	ALL	2,8,9	P	ALL	ALL
	Q	1-4,8		N	1-11,14-16	ALL EXCEPT 5
JACKDAW	M	ALL	2-6,8	M	ALL	ALL
	P	ALL	2,8,9	P	ALL	ALL
	Q	1-4,7,8		N	1-11,14-16	ALL EXCEPT 5
STARLING	M	2	2-6,8	M	ALL	ALL
				P	ALL	2
				Q	1-4,6-8	ALL
STOCK DOVE	P	ALL	2	P	ALL	ALL
	N	4-7	ALL EXCEPT 5	N	1,2,3	ALL EXCEPT 5
				Q	1-3,8	ALL
WOODPIGEON	P	ALL	2	P	ALL	ALL
	N	4-7	ALL EXCEPT 5	N	1-3	ALL EXCEPT 5
	Q	3	ALL	Q	1,4-8	ALL
GREY PARTRIDGE	P	ALL	2	P	ALL	ALL
	M	2	1,10	M	2	ALL
	N	1,2,3,10	6,7,8	N	1,2,3,10	ALL
	Q	3				

Table 5.3.1 Continued

Species	HQ Breeding				LQ Breeding			
	L1	L2	L3	L4	L1	L2	L3	L4
LAPWING	E	3	ALL EXCEPT 6	2-6,8,13-15	E	ALL EXCEPT 1	ALL EXCEPT 6	ALL
SKYLARK	C	1-5	2,4,6,9,10	2-7	C	1-5	ALL EXCEPT 7,8	ALL EXCEPT 8
	E	2,3,4	2,4,7,8	2-5,8,13-15	E	1-4	ALL EXCEPT 6	ALL EXCEPT 6
KESTREL	C	1-5	1,3,5	ALL	A	1,3,4,6	1,4,6,8,9	ALL
	E	ALL	1,3,5	ALL	F	3	ALL	3
TURTLE DOVE	B	1-5	ALL EXCEPT 7,9	1-4	E	ALL	1,2	ALL
					A	ALL	1,4,5,8,9	ALL
YELLOW WAGTAIL	C	6	4,6,9,10	2-7	C	1-6	ALL	2-7
	E	2,3,4	4,7,8	2-5,8,9,13-15	E	2,3,4	ALL EXCEPT 6	ALL EXCEPT 6
WHITETHROAT	A	ALL	2,3,5	1,2,4,5,8-10	A	ALL	2,3,5	ALL
	B	ALL	ALL EXCEPT 7	2-9	B	ALL	ALL EXCEPT 7	ALL
	C	1-6	2	1	C	1-6	1,2,4,5	ALL
	E	ALL	2	1	E	ALL	1,2,4,5	ALL
LINNET	B	ALL	1,3,4,6,8,9	2,3	B	ALL	1,3,4,6,8,9	4,5
	C	1-5	1,2	ALL				
	E	ALL	1,2	ALL				
GOLDFINCH	A	ALL	1,4-6,8,9	2,3	A	ALL	1,4-6,8,9	ALL
	B	ALL	ALL EXCEPT 7	1	B	ALL	ALL EXCEPT 7	2-5
	C	1-5	1,3,5	ALL	C	1-5	2	ALL
	E	ALL	1,3,5	ALL	E	ALL	2	ALL

Table 5.3.1 Continued

Species	HQ Breeding				LQ Breeding			
	L1	L2	L3	L4	L1	L2	L3	L4
GREENFINCH	A	ALL	1,4-6,8,9	2,3	A	ALL	1,4-6,8,9	ALL
	B	ALL	ALL	1	B	ALL	ALL	2-5
			EXCEPT 7				EXCEPT 7	
	C	1-5	1,3,5	ALL	C	1-5	2	ALL
	E	ALL	1,3,5	ALL	E	ALL	2	ALL
REED BUNTING	B	ALL	1,3,4,6,8	3,7	B	ALL	1,3,4,6,8	1,2,4,6,8
	C	ALL	1,2,4	1,9	C	ALL	1,2,4	ALL
		EXCEPT 9				EXCEPT 9		
	E	ALL	1,2,4	1,11,15	E	ALL	1,2,4	ALL
	G	ALL	ALL	10				
TREE SPARROW	A	4,6	6	ALL	A	1,3	6	ALL
	B	ALL	4,6	1	B	ALL	1,3,8	1
	E	ALL	1,3,5	ALL	E	ALL	2	ALL
CORN BUNTING	C	1-5	ALL	1,9	C	1-5	ALL	ALL
			EXCEPT 8				EXCEPT 8	
	E	2,3,4	ALL	1,8,14,15	E	1-4	ALL	1,7,8,11,12,14,15
			EXCEPT 6				EXCEPT 6	
YELLOWHAMMER	C	1-5	2,4	ALL	C	1-5	1	ALL
	E	2,3,4	2,4	6-15	E	2,3,4	1,2,4	ALL
ROOK	C	1-5	1,3,5	ALL	A	1,3,4,6	1,4,6,8,9	ALL
	E	ALL	1,3,5	ALL	F	3	ALL	3
JACKDAW	C	1-5	1,3,5	ALL	A	1,3,4,6	1,4,6,8,9	ALL
	E	ALL	1,3,5	ALL	F	2,3	ALL	2,3
STARLING	A	1,3,4,6	1,4,6,8,9	ALL	C	1-5	2	ALL
	C	1-5	1,3,5	ALL	E	ALL	2	ALL
	E	ALL	1,3,5	ALL				
	F	2,3	ALL	2,3				
STOCK DOVE	C	1-5	1,3,5	ALL	A	1,3,4,6	1,4,6,8,9	ALL
	E	ALL	1,3,5	ALL	F	3	ALL	3
WOODPIGEON	C	1-5	1,2,3,5	ALL				
	E	ALL	1,2,3,5	ALL				
	A	ALL	1,4,6,8,9	ALL				
	F	ALL	ALL	3				
GREY PARTRIDGE	C	1-5	2,4	1,9	C	1-5	1,2,4	ALL
	E	2-4	2,4	1,8,13-15	E	2-4	1,2,4	ALL

5.4 References

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6. PRIORITY ACTIONS TO REVERSE DECLINES

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6.1 Introduction

In this chapter, we present the results of an objective assessment of drivers in the breeding declines of species in the wetland and woodland bird indicator and make links, where possible, between key drivers and appropriate conservation actions to mitigate the effects of these drivers. The first step was to quantify each of the proposed drivers of decline and, using a matrix analysis, rank their relative importance. For the second step, the information collated in the literature reviews and the analyses carried out in Objective Two provides a detailed evidence base to inform decisions about potential conservation actions to reverse the declines, such as habitat management options and possible policy changes. Using this information, consultation with experts, and drawing on other relevant work, the key drivers identified by the matrix analysis can then be related to actions to reverse the population declines. This includes those currently available under agri-environment initiatives, as well as actions identified as priorities for future development and implementation.

6.2 Methods

Based on evidence uncovered by the literature review, we produced a list of potential drivers for each declining species in the wetland and woodland bird indictors. Each driver was assigned two scores. One score reflects the importance of the driver in the decline of each species, and is calculated by assessing the overall evidence base. Driver could be assessed as primary (i.e. there as general agreement that this was the main driver in the decline), important (at least in some studies), contributory, or not a driver. The second score reflects the quality of the evidence supporting this, based on the original source of information. The scoring system is summarised as follows;

Scoring system for quality of evidence

0.5 = no evidence/unknown
1 = anecdotal evidence
2 = expert opinion
3 = grey literature
4 = Studies from 'popular journals' or peer-reviewed journals that were undertaken outside of UK
5 = Studies from peer reviewed journals that were carried out in the UK

Scoring system for importance of driver

0 = not a driver
1 = unknown
2 = contributory driver
3 = important driver
4 = primary driver

The overall score of each driver for each species was determined by multiplying the scores for importance by the score for quality of evidence. Overall scores can be summed across species to provide a total score (Table 6.3c and 6.6c) for each driver (on the suite of declining wetland bird species). For woodland birds this score was then divided by the number of species which the driver was potentially valid for (e.g. problems on wintering grounds were only valid for migrants). To provide an example, if there was only anecdotal evidence that predation has had an impact on the population decline of Dipper, this driver would be allocated a score of 1 for the 'quality of evidence' score. If the anecdotal evidence suggested that predation has had a minor, but not substantial, impact on Dipper populations, then this would get a score of 2 (contributory driver) for the 'importance of driver' score. These two scores would then be multiplied together to give an overall score of 2 for the impact of predation on Dippers.

For the second part of this chapter, for each declining species, we provide a list of potential conservation actions that could be undertaken to reverse the decline. These are based on the literature review and also on expert opinion. We expect that this section will be augmented subsequently following input from external experts and other stakeholders. New publications, not all focused on the declining species in this review, may also help identify other potential actions.

6.3 Key Drivers for Declines in Wetland Birds

The results of the scoring process for wetland birds are provided in Tables 6.3a, 6.3b and 6.3c.
The overall total score per driver provides the most objective method of assessing the importance of potential causes of declines in wetland bird species. Based on the available information and the strength of the evidence, the most important driver of declines in this group of wetland bird species is drainage, followed by changes in grazing patterns, breeding failure due to predation and the increased use of fertilizers and pesticides. Breeding failure due to destruction by farm machinery, by trampling by livestock, habitat loss due to afforestation in uplands, changes in the timing of crop sowing, and hunting had intermediate scores, whereas disturbance, pollution, acidification, and three possible effects of climate change had the lowest scores.

Whilst interpreting these results, it is important to consider the issue of bias. Some of these drivers have benefited from extensive study and hence there is a great deal of information available. Other issues have been considered in less detail and for these drivers it is difficult to draw as many conclusions. The number of 0.5 scores (unknown) in Table 6.3a illustrates this issue, which is discussed further in the section on gaps in knowledge. The evaluation of impacts of different drivers are derived from studies covering several decades, over which time the drivers and population trajectories of these species could have changed markedly. There are also factors that have not been covered, such as eutrophication. This is an area that has received relatively little study in relation to effects on the species considered in this review although it has been hypothesized to have both positive and negative effects on other wetland species.

Table 6.3a Quality of Evidence Scores. For scoring system refer to text.

Driver	**Common Sandpiper**	**Curlew**	**Dipper**	**Lapwing**	**Redshank**	**Reed Bunting**	**Sedge Warbler**	**Snipe**	**Yellow Wagtail**
Climate change - drought in African wintering grounds	5	0.5	0.5	0.5	0.5	0.5	5	0.5	0.5
Climate change - loss of coastal habitat to sea level rise	0.5	0.5	0.5	0.5	5	0.5	0.5	0.5	0.5
Climate change - unpredictable summer rainfall	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Changes in grazing patterns	5	5	0.5	5	5	5	0.5	5	5
Afforestation - habitat loss in uplands	0.5	5	0.5	5	5	0.5	0.5	5	0.5
Afforestation - acidification of water courses	5	0.5	5	0.5	0.5	0.5	0.5	0.5	0.5
Breeding failure - destruction by machinery	0.5	4	0.5	5	4	5	0.5	5	5
Breeding failure - trampling	0.5	4	0.5	4	4	0.5	0.5	5	5
Breeding failure - predation	5	5	4	5	4	5	0.5	5	4
Hunting	3	4	3	4	3	3	3	4	3
Drainage	0.5	5	0.5	5	5	5	5	5	5
Disturbance	4	5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
changes in timing of crops	0.5	0.5	0.5	5	0.5	5	0.5	0.5	5
acidification of water courses	5	0.5	5	0.5	0.5	0.5	0.5	0.5	0.5
Pollution of water courses	5	4	5	0.5	4	0.5	5	0.5	0.5
habitat loss to development	0.5	5	0.5	0.5	5	0.5	0.5	0.5	0.5
increased use of fertilisers	0.5	5	0.5	5	5	5	0.5	5	5
increased use of pesticides	0.5	5	5	5	5	5	4	5	5

Table 6.3b Importance of Driver Scores. For scoring system refer to text.

Driver	Common Sandpiper	Curlew	Dipper	Lapwing	Redshank [1]	Reed Bunting	Sedge Warbler	Snipe	Yellow Wagtail
Climate change - drought in wintering grounds	2	0	0	0	0	0	4	0	1
Climate change - loss of coastal habitat to sea level rise	0	1	0	1	3	1	1	1	1
Climate change - unpredictable summer rainfall	1	1	1	1	1	1	1	1	1
Changes in grazing patterns	1	3	1	3	4	2	1	3	3
Afforestation - habitat loss in uplands	1	2	1	2	2	0	0	2	0
Afforestation - acidification of water courses	0	0	4	0	0	0	0	0	0
Breeding failure - destruction by machinery	1	3	0	3	3	2	1	2	2
Breeding failure - trampling	1	3	0	2	2	1	1	2	2
Breeding failure - predation	2	3	2	3	3	2	1	3	2
Hunting	1	2	1	1	1	1	1	2	1
Drainage	1	4	1	4	4	4	3	4	4
Disturbance	2	2	1	1	1	1	1	1	1
Changes in timing of sowing of crops	0	1	0	3	0	2	1	0	3
acidification of water courses	0	1	4	1	1	1	0	1	0
Pollution of water courses	0	1	2	1	1	1	1	1	1
Habitat loss to development	1	2	0	1	2	0	0	0	0
increased use of fertilisers	1	3	1	3	3	2	1	3	3
increased use of pesticides	1	2	3	2	2	2	2	2	2

[1]Note that there are 2 'primary' drivers for redshank. This is because inappropriate grazing is the primary cause of declines on saltmarsh breeding habitat but drainage is the primary cause of declines in wet grassland habitat.

Table 6.3c Overall Score. This is the product of the scores given in tables 1 and 3. For scoring system refer to text.

Driver	Common Sandpiper	Curlew	Dipper	Lapwing	Redshank	Reed Bunting	Sedge Warbler	Snipe	Yellow Wagtail	Total score
Climate change - drought in wintering grounds	10	0	0	0	0	0	20	0	0.5	**30.5**
Climate change - loss of coastal habitat to sea level rise	0	0.5	0	0.5	15	0.5	0.5	0.5	0.5	**18**
Climate change - unpredictable summer rainfall	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	**4.5**
Changes in grazing patterns	5	15	0.5	15	20	10	0.5	15	15	**96**
Afforestation - habitat loss in uplands	0.5	10	0.5	10	10	0	0	10	0	**41**
Afforestation - acidification of water courses	0	0	20	0	0	0	0	0	0	**20**
Breeding failure - destruction by machinery	0.5	12	0	15	12	10	0.5	10	10	**70**
Breeding failure - trampling	0.5	12	0	8	8	0.5	0.5	10	10	**49.5**
Breeding failure - predation	10	15	8	15	12	10	0.5	15	8	**93.5**
Hunting	3	8	3	4	3	3	3	8	3	**38**
Drainage	0.5	20	0.5	20	20	20	15	20	20	**136**
Disturbance	8	10	0.5	0.5	0.5	0.5	0.5	0.5	0.5	**21.5**
Changes in timing of sowing of crops	0	0.5	0	15	0	10	0.5	0	15	**41**
acidification of water courses	0	0.5	20	0.5	0.5	0.5	0	0.5	0	**22.5**
Pollution of water courses	0	4	10	0.5	4	0.5	5	0.5	0.5	**25**
Habitat loss to development	0.5	10	0	0.5	10	0	0	0	0	**21**
increased use of fertilisers	0.5	15	0.5	15	15	10	0.5	15	15	**86.5**
increased use of pesticides	0.5	10	15	10	10	10	8	10	10	**83.5**

Drainage, the key driver identified by this process has been implicated in the population declines of many wet grassland species, particularly waders due to the resulting loss of breeding habitat in terms of quantity and quality (Newton 2004, Wilson *et al*, 2004, Fuller and Ausden 2008). Moreover, drainage is linked to many of the other drivers affecting birds breeding in wet grassland habitat and the effects may be synergistic. For example, lowering of water levels allows stock and machinery to be brought onto the land earlier, which may increase breeding failure due to nest destruction and trampling. Drainage also permits grasslands to be reseeded with more vigorous growing plant species and combined with increased use of fertilizers and pesticides, can influence sward structure, reduce the abundance and availability of invertebrate prey, and increase susceptibility to nest predation. Drainage can also result in direct loss of wet grassland through conversion to arable land. Figure 6.3a summarizes these issues.

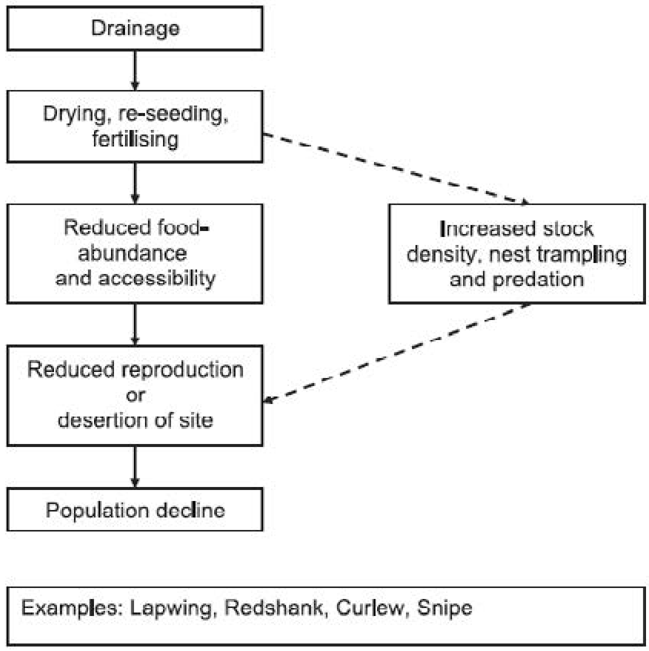

Figure 6.3a Proposed sequence of events through which the draining and re-seeding of wet grassland causes population declines in waders. From Newton 2004.

Changes in grazing patterns was scored as the second most important driver, and changes in stocking levels could have either positive (over-grazed) or negative (under-grazed) effects. This is largely related to the significant impact of livestock on sward height and structure, and nutrient enrichment. Similarly, increases in the use of fertilizers has been documented to affect wet grassland breeding birds through its effects on sward height and structure (Newton 2004). However, because species vary in their sward preferences and many prefer habitat with a mixed sward type, these relationships can be complex and species-specific..Increased pesticide use has been shown to decrease the invertebrate food supplies available directly (by insecticides) or indirectly (by herbicides and reductions in insect food plants).

The impact of nest and chick loss to predation, trampling and destruction by machinery may be higher than identified here. Much of the research described in the literature review gives percentages of nests lost to predation (see Green 1986, Beintema and Muskens 1987, Brickle and Peach 2004) but does not quantify the impact that this has on overall productivity and hence on populations. Information on chick loss is even scarcer, and it is loss at this stage that is likely to have the most impact on populations due to the fact that many species relay if clutches fail but not if chicks are lost.

Habitat loss in the uplands due to intensification of agriculture has also been an issue as drainage and increases in stocking densities have reduced the quantity and quality of habitat available. Afforestation has also had an impact (*e.g.* Newton 2004, Fuller and Ausden 2008). Loss of habitat caused by peat extraction is another potential driver; this was highlighted during consultation with experts, but quantitive evidence in the literature concerning this area is extremely sparse.

The role that hunting has played in the declines of these species has been poorly quantified. This includes the impact of legal hunting in England as well as the often illegal shooting of migrants outside the UK. For most species there are reports of numbers of birds deliberately taken by man, but it is unclear how this has affected population numbers. However, expert opinion is that levels of hunting are declining, so it seems unlikely that this is currently a major driver in population declines.

Pollution of water courses was scored low and although egg-shell thinning as a result of exposure to organochlorine pesticides has been documented in predatory and fish-eating bird species,it seems unlikely to constitute a major threat in the UK where they has been banned for several decades. Pollutants are potentially an issue for migrants (e.g. Common Sandpiper) exposed to these compounds on their wintering grounds. There may also be an indirect negative effect of increased agro-chemical use through increased rates of nest destruction as machinery is brought onto the land more frequenting for spraying (Newton 2004).

The effects of disturbance (i.e. human disturbance in breeding areas) are largely unknown for these species and little quantitative evidence was found on the impact of this driver. There is evidence that recreational disturbance has caused some species such as Curlew (Haworth and Thompson 1990) as well as ground-nesting species not considered here, to alter their distribution by avoding areas with high disturbance, but whether this has any impact on productivity is unknown. Similarly, recreational use and boat traffic in water bodies may affect the distribution or breeding success of other species in the wetland bird indicator, such as grebes and ducks.

Based on current evidence, the role of climate change in the declines of the species considered in this review has been small, apart from the declines suffered several decades ago by Sedge Warbler, a sub-Saharan migrant, due to drought in their wintering areas in the Sahel (Peach *et al* 1991). However, predicted climate change could exacerbate the declines as it may result in loss of coastal habitats to sea level rise and the increased frequency of spring floods or drought are likely to have an impact on water availability and hence habitat quality (Wilson *et al.* 2004). If coastal breeding habitats are lost because of sea level rise, it will be even more important to create new habitat further inland to mitigate these losses. The positioning of new sites needs careful consideration as many of these species are highly site faithful.

6.3.1 Gaps in knowledge of drivers for wetland species

Not surprisingly, there was a fairly strong link between the importance of potential drivers and the extent of our knowledge. Among the potential drivers of declines for this group of wetland birds, the biggest gaps in knowledge were on the effects of climate change (conditions on wintering grounds, breeding season rainfall, and loss of coastal habitat to sea level rise), disturbance, acidification, and habitat loss due to development. Conversely, there were very few gaps in our knowledge on the impact of key drivers such as changes in grazing patterns, drainage, predation, destruction by machinery and increased use of pesticides, and there was some assessment of the impact of hunting for all species, despite its low to intermediate overall score. Because drivers operate at different scales, care must be taken in interpreting these patterns but the gap analysis suggests further attention should be spent on exploring possible effects of aspects of climate change such as sea level rise and breeding season wetness.

6.4 Priority Conservation Actions and Policies for Wetland Birds

The first table in this section identifies the potential for each general policy instrument or initiative to provide benefits to each of the declining wetland bird species included in this study. This is a diverse array of policies or actions operating at different spatial and temporal scales, but most have the capacity to provide benefits for at least some of the species. The polices or actions that scored highest overall across this group of species due to their major potential for benefits were: (i) Biodiversity Action Plans (BAP) to maintain, restore and create key habitat such as grazing marshes, fens, lowland bog, (ii) protection of habitat through the SPA network, (iii) to maintain, restore and create habitat in Environmentally Sensitive Areas (ESAs), (iv) actions related to water management and abstraction, and (v) habitat improvements through the Higher Level Stewardship (HLS) scheme. The Entry Level Stewardship (ELS) and Upland Entry Level Stewardship (UELS) schemes, the BAP for coastal saltmarshes, and the Climate Change Act 2008 showed moderate potential to benefit a large proportion of the species assessed. Other policies, including the Water Framework Directive, showed little potential for benefit overall but have major potential for benefiting riparian species such as Dipper and Common Sandpiper.

The next two tables in this section explore in more detail the benefits provided by specific options within broader categories, in the two main current agri-environment schemes: HLS and ELS. For each option, the potential benefits to any of the nine declining ‘wetland’ bird species, are assessed as major, moderate or minimal. Within HLS, virtually all options for arable land have major or moderate potential to improve conditions for Reed Bunting, reflecting the fact that a large proportion of the population of this species occupies farmland. Of the arable options, undersown cereals provide most benefits, with major potential for five species. Of boundary and buffer options, ditch management and pond buffers show most potential, and low-input pastoral options offer moderate potential in Severely Disadvantaged Areas. Similarly within ELS, most arable options (and especially low input spring cereals) are beneficial to Reed Warblers and some have moderate potential for other essentially birds typical of wet and dry farmland such as Curlew, Lapwing and Yellow Wagtail. Most grassland and moorland options have major potential benefits to the breeding wader suite (Curlew, Lapwing, Redshank and Snipe) and options that maintain, restore or create wet grassland are also beneficial to Reed Bunting, Yellow Wagtail and Sedge Warbler. Intertidal and coastal options have the potential to provide major benefits mainly to Redshank but also other species, and most species benefited from some of the wetland options such as the provision of ponds, reedbeds, gutters and other wet features.

Habitat restoration and creation, and better management of existing habitat, are key to reversing the declines in wetland species. The actions identified here focus on AES, partly because this suite of options are already available and partly because management of agricultural land was assessed as being an important driver of declines in many of the constituent species. The Higher Level Scheme of Environmental Stewardship offers what is probably the best opportunity to do this, as the scheme involves plans specifically tailored to individual sites and includes actions to ensure appropriate levels of grazing and water level management to improve and create habitat for breeding waders. Such actions will also benefit other wet grassland birds such as Reed Bunting, Yellow Wagtail and Sedge Warbler.

The Entry Level Scheme, although broader-scale, offers less potential as this contains little in the way of full-scale habitat creation and the options which may have an impact are mainly those relating to arable land. For many of these agri-environment scheme (AES) options, their success will depend on the finer details. The value of margins and headlands to birds such as Lapwing and Curlew depends on their appropriate deployment, because, for example, their proximity to trees and hedges can limit their utility as these birds prefer open landscapes. Similarly, options must be managed correctly. The creation of gutters (wet features within grazing marsh) can have real benefit for breeding waders by providing wet areas for foraging later in the season. However, if water levels are not managed correctly, these features quickly dry out and their value is greatly reduced.

Table 6.4a Summary of general policy measures and their potential to impact upon population declines in wetland bird species. CS = Common Sandpiper, CU = Curlew, DI = Dipper, L. = Lapwing, RK = Reed Bunting, SW = Sedge Warbler, SN = Snipe, YW = Yellow Wagtail. 0 = no/minimal potential, 1 = moderate potential, 2 = major potential.

Action/Policy	**justification**	**CS**	**CU**	**DI**	**L.**	**RK**	**RB**	**SW**	**SN**	**YW**
Water Framework Directive	Improvement in water quality	1	0	2	0	0	0	0	0	0
Reduction in emissions	Reduce acid depositions in rain	1	0	2	0	0	0	0	0	0
Liming of acidic catchments	Reduce acidity of water courses	1	0	2	0	0	0	0	0	0
BAP - coastal and floodplain grazing marsh	Maintain, restore and recreate habitat	0	2	0	2	2	2	2	2	2
BAP – fens	Maintain, restore and recreate habitat	0	2	0	2	2	2	2	2	2
BAP - lowland raised bog	Maintain, restore and recreate habitat	0	2	0	2	2	2	2	2	2
BAP - reeds	Maintain, restore and recreate habitat	0	0	0	0	0	2	2	0	0
BAP - coastal saltmarsh	Maintain, restore and recreate habitat	0	1	0	1	2	1	1	1	1
BAP - Mudflats	Maintain, restore and recreate habitat	0	1	0	1	1	0	0	1	0
Birds Directive	Protection of habitat through SPA network	1	2	0	2	2	2	2	2	2
Climate change Act 2008	Aims to reduce impacts of climate change	1	1	1	1	1	1	2	1	1
Public Service Agreements - water quality	Aims to improve water quality	1	0	2	0	0	0	0	0	0
Public Service Agreements - farmland bird index	Aims to reverse the decline in farmland birds	0	2	0	2	0	2	2	0	2
ESA scheme	Maintain, restore and recreate habitat	0	2	0	2	2	2	2	2	2
Water act 2003	Aims to regulate and manage water abstraction	1	2	0	2	2	2	2	2	2
Catchment Abstraction Management Strategies	6 year plans to manage water in a given region	1	2	0	2	2	2	2	2	2
HLS	aims to improve habitat quality on farmland	1	2	1	2	2	2	2	2	2
ELS	aims to improve habitat quality on farmland	0	1	0	1	1	1	1	1	1
UELS	aims to improve habitat quality in uplands	1	2	0	1	1	1	1	1	0
Biofuels and loss of setaside	negative impact through habitat loss	0	-1	0	-1	-1	-1	-1	-1	-1

Table 6.4b Environmental Stewardship options within HLS and their potential influence on declining wetland species. CS = Common Sandpiper, CU = Curlew, DI = Dipper, L. = Lapwing, RK = Reed Bunting, SW = Sedge Warbler, SN = Snipe, YW = Yellow Wagtail. 0 = no/minimal potential, 1 = moderate potential, 2 = major potential.

			Species								
	Option	**justification**	**CS**	**CU**	**DI**	**L.**	**RK**	**RB**	**SW**	**SN**	**YW**
Options for arable land	Management of field corners	Provide foraging habitat for birds	0	1	0	1	0	1	1	0	1
	Wild bird seed mixture	provide food resources, esp. in winter	0	0	0	0	0	2	0	0	0
	Overwintered stubbles	provide food resources, esp. in winter, and early breeding sites for ground nesting birds	0	1	0	1	0	2	0	0	0
	Beetle banks	provide food resources	0	1	0	1	0	1	1	0	1
	Skylark plots	provide nesting habitat	0	0	0	0	0	1	1	0	1
	Unfertilised cereal headlands within arable fields	provide food resources	0	1	0	1	0	1	1	0	1
	Unharvested cereal headlands within arable fields	provide food resources	0	1	0	1	0	1	1	0	1
	Wild bird seed mixture in grassland areas	provide food resources for seed eating birds	0	0	0	0	0	1	0	0	0
	Undersown spring cereals	provide breeding habitat	0	2	0	2	0	2	2	0	2
	Cereals for whole-crop silage followed by overwintered stubbles	provides a seed source in winter stubbles	0	0	0	0	0	2	0	0	0
boundary and buffer options	buffer strips on cultivated land	Provide foraging habitat for birds	0	1	0	1	0	1	1	0	1
	buffer strips on intensive grassland	Provide foraging habitat for birds	0	1	0	1	0	1	1	0	1
	Ditch management	provides varied bankside & aquatic vegetation as an undisturbed wildlife habitat	0	0	0	0	0	2	2	0	1
	Buffering in field ponds	provides breeding and foraging habitat	0	1	0	1	0	2	2	0	2
SDA options	Permanent grassland with low or very low inputs	provides breeding and foraging habitat	0	1	0	1	1	1	1	1	1
	Management of rush pastures	provides breeding and foraging habitat	0	1	0	1	1	1	1	1	1
	Enclosed and unenclosed rough grazing	provides breeding and foraging habitat	0	1	0	1	1	1	1	1	1

Table 6.4c Environmental Stewardship options within ELS and their potential influence on declining wetland species. CS = Common Sandpiper, CU = Curlew, DI = Dipper, L. = Lapwing, RK = Reed Bunting, SW = Sedge Warbler, SN = Snipe, YW = Yellow Wagtail. 0 = no/minimal potential, 1 = moderate potential, 2 = major potential. SDA = Severely Disadvantaged Area.

			Species								
	Option	**justification**	**CS**	**CU**	**DI**	**L.**	**RK**	**RB**	**SW**	**SN**	**YW**
Arable options	Floristically enhanced grass margin	provides habitat & foraging area for inverts and birds	0	1	0	1	0	1	1	0	1
	Enhanced wild bird seed mix plots	provides winter food source for granivorous birds	0	0	0	0	0	2	0	0	0
	Fallow plots for ground-nesting birds	provides breeding areas for ground nesting birds. Best when located near grassland	0	1	0	1	0	1	0	0	1
	Unharvested, fertiliser-free conservation headland	provides a year round food source for farmland birds	0	1	0	1	0	1	1	0	1
	Reduced herbicide cereal crop preceding overwintered stubble	provides a year round food source for farmland birds, especially during winter	0	1	0	1	0	2	1	0	1
	Brassica fodder crops followed by overwintered stubble	provides foraging habitat for small seed-eating birds	0	0	0	0	0	2	0	0	0
	Fodder crop management to retain or recreate an arable mosaic	provides foraging habitat for small seed-eating birds	0	0	0	0	0	1	0	0	0
	Low-input spring cereal to retain or recreate an arable mosaic	provides breeding habitats for ground nesting birds and foraging habitats for other species	0	2	0	2	0	2	2	0	2
Grassland options	Maintenance, restoration and creation of wet grassland for breeding waders	provides nesting and foraging habitat	1	2	0	2	2	2	2	2	2
	Maintenance, restoration and creation of wet grassland for wintering waders and wildfowl	provides wintering habitat	0	2	0	2	2	0	0	2	0
	Buffer strips	provides nesting and foraging habitats for species in intensively managed grassland	0	0	0	1	0	1	1	0	1
	Raised water levels supplement	provides foraging habitat for birds	1	2	0	2	2	2	2	2	2
	Cattle grazing supplement	improves nesting and foraging habitat for birds by creating a heterogeneous sward	1	2	0	2	2	2	2	2	2

	Option	justification	Species CS	CU	DI	L.	RK	RB	SW	SN	YW
Moorland options	Maintenance, restoration and creation of moorland	provides habitat for upland birds, especially waders	1	2	0	2	2	0	0	2	0
	Creation of upland heathland	provides habitat for upland birds, especially waders	0	2	0	2	2	0	0	2	0
	Maintenance and restoration of rough grazing for birds	provides habitat for upland birds, especially waders	0	2	0	2	2	0	0	2	0
	Supplement for management of heather, gorse and grass	provides habitat for upland birds, especially waders	0	2	0	2	2	0	0	2	0
	Moorland re-wetting supplement	provides habitat for upland birds, especially waders	0	2	0	2	2	0	0	2	0
Inter-tidal and coastal options	Maintenance and restoration of coastal salt marsh	provides habitat for breeding and wintering birds	0	1	0	1	2	1	1	1	0
	Creation of inter-tidal and saline habitat	provides habitat for breeding and wintering birds	0	2	0	1	2	1	1	2	0
	Supplement for extensive grazing on salt marsh	provides habitat for breeding and wintering birds	0	1	0	1	2	1	1	1	0
	Salt marsh livestock exclusion supplement	provides habitat for breeding and wintering birds	0	1	0	1	2	1	1	1	0
Wetland options	Maintenance of ponds of high wildlife value	Provides foraging habitat	0	0	0	0	0	2	2	0	0
	Maintenance, restoration and creation of reedbeds	provides foraging and nesting habitat	0	0	0	0	0	2	2	0	0
	Maintenance, restoration and creation of lowland raised bog	provides foraging and nesting habitat	0	1	0	1	1	1	1	1	1
	Wetland cutting supplement	provides foraging and nesting habitat	0	1	0	1	1	1	1	1	1
	Wetland grazing supplement	provides foraging and nesting habitat	0	1	0	1	1	1	1	1	1

Table 6.4c Continued.

	Option	justification	Species CS	CU	DI	L.	RK	RB	SW	SN	YW
captial items – wetlands	Creation of ditches	provides foraging habitat	0	1	0	1	1	1	1	1	1
	Creation of gutters	provides foraging habitat	0	2	0	2	2	2	2	2	2
	bund, culvert, sluice, wind pump	will help improve hydrological management on wet grasslands	0	2	0	2	2	2	2	2	2
	Scrape creation	provides foraging habitat	0	2	0	2	2	2	2	2	2
	Pond creation	provides foraging/nesting habitat	0	0	0	0	0	2	2	0	0
Resource protection	Arable reversion to grassland to prevent erosion or run-off	Will improve water quality	1	0	1	0	0	0	0	0	0
	In-field grass areas to prevent erosion or run-off	Will improve water quality	1	0	1	0	0	0	0	0	0
	Preventing erosion or run-off from intensively managed, improved grassland	Will improve water quality	1	0	1	0	0	0	0	0	0
	Seasonal livestock removal on grassland with no input restriction	Will improve water quality	1	0	1	0	0	0	0	0	0
	Nil fertiliser supplement	Will improve water quality	1	0	1	0	0	0	0	0	0

Table 6.4c Continued.

6.4.1 Gaps in conservation actions and policies to address declines in wetland species

Overall, these tables show that declines in most of these wetland species could be addressed by existing policies or actions, the exceptions being Dipper for which only initiatives related to water quality and particularly acidification have major potential, and Common Sandpiper. There are many policies or actions, including the Environmental Stewardship options, that should provide benfits to breeding waders, as well as to Yellow Wagtail, Sedge Warbler and especially Reed Bunting. With respect to the main drivers identified earlier, this range of conservation actions address issues related to drainage, the effects of grazing, the impact of fertilizers and pesticides and destruction by machinery through different mechanisms for managing elements of the agricultural landscape (especially boundaries and wet features) and by initiatives to maintain, restore and create special habitats such as fens, reedbeds, lowland bogs, saltmarshes, wet grasslands and ponds. Predation was also highlighted as an important factor in the declines of many declining wetland species, but is not addressed specifically by any of the conservation actions (and hence a potential gap). Measures to mitigate this, including predator control, need to be considered, but only in the context of maintaining habitat in the best possible condition. In minimising the impact of predation on ground-nesting birds, manipulating surrounding habitat structure to remove cover for predators is crucial.

6.5 Specific Conservation Actions and Policies for Wetland Birds

There is considerable overlap with conservation actions and policies aimed at providing benefits for declining farmland species, including three included here which are also wetland birds (Lapwing, Reed Bunting and Yellow Wagtail) as well as species such as Skylark, Grey Partridge, Turtle Dove, Yellowhammer, Corn Bunting, Tree Sparrow and Starling. For the breeding wader group, priority actions are to modify agricultural practices to provide essential breeding and foraging habitats, and to maintain, restore and create more semi-natural wetland habitats that provide the best conditions. This is best achieved through a combination of targeted agri-environment scheme options and conservation policies to maintain a protected network of suitable habitats. Management of grazing pressure and water levels to provide heterogenous sward conditions and ensure that wet areas are maintained throughout the season is also essential. Details of the conservation action requirements for each of the declining wetland species are described in the following section.

Common Sandpiper

- River management that involves the creation of vegetated islands, shoals and bars will provide nesting and feeding areas.
- The provision of refuge areas (small, fenced, forestry enclosures or zoned sanctuaries) on reservoirs would enable this species to co-exist with recreational users.
- More studies are needed to determine exactly what has been causing the population decline, including studies focussing on over-wintering populations in Africa.

Curlew

- Reducing the intensity of farming will improve conditions on both grassland, moorland and arable breeding habitats. AES are likely to be the best way to do this. Specific options include;
    - Reductions in stocking density on lowland grassland and moorland
    - Delaying grazing turnout or mowing in spring should minimize the effects of trampling and nest/chick loss.
    - Raising water levels, introducing surface flooding, and managing water levels to ensure that wet areas are maintained throughout the season is key to providing high-quality foraging areas.
    - New wet grassland creation schemes will provide additional habitat
    - On arable land, over-wintered cereal or linseed stubble followed by a spring/summer fallow may be beneficial.

- Ensure that all woodland planting proposals avoid the adverse effects of planting on Curlew breeding and feeding sites.
- Protection of wintering habitat from development such as Ports.

Dipper

- Providing pools and riffles with rocks and boulders will help create feeding areas.
- Ensuring that river regulation construction is avoided during the breading season of Dipper will help maintain food supplies.
- Afforestation with coniferous trees should be avoided in areas known to be important breeding areas as this can increase water acidity.
- The liming of rivers may reduce the acidity of water and therefore help food supplies recover. However, research looking at the effectiveness of liming acidic streams concluded that liming had limited success as a restoration measure.

Lapwing

- Agri-environmental measures working aiming to improving conditions across farmland is a realistic approach to aiding population recovery. Specific options include;
    - Reductions in stocking density on lowland grassland but ensuring strong or moderate grazing pressure the previous autumn to maintain short areas of sward.
    - Raising water levels, introducing surface flooding, and managing water levels to ensure that wet areas are maintained throughout the season is key to providing high-quality foraging areas.
    - Wet grassland creation schemes will provide additional habitat.
    - On arable land over-wintered cereal or linseed stubble followed by a spring/summer fallow may be beneficial.
    - Delaying grazing turnout or mowing in spring should minimize the effects of trampling and nest/chick loss.

Redshank

- Agri-environmental measures aimed at improving conditions across farmland, is a realistic approach to aiding population recovery. Specific options include;
    - Reductions in stocking density on lowland grassland.
    - Raising water levels, introducing surface flooding, and managing water levels to ensure that wet areas are maintained throughout the season is key to providing high-quality foraging areas.
    - Wet grassland creation schemes will provide additional habitat. This is particularly important to replace coastal habitat that may be lost to sea level rise.
    - Delaying grazing turnout or mowing in spring should minimize the effects of trampling and nest/chick loss.
- On saltmarshes, the maintenance of cattle grazing, at densities of about one animal per hectare or less should be encouraged to prevent over or under-grazing.
- The introduction of grazing to sites with no history of grazing should be discouraged and there should be an aim to reduce the stocking density of sheep.

Reed Bunting

- Installing small wet features, such as ponds, in farmland will provide foraging areas.
- Ensuring that ditches remain wet all year round and that the emergent rank vegetation is left in place will provide nesting habitat.
- Allowing grasses to set seed over-winter, rather than mowing them, will provide foraging areas.
- Of the measures available under AES in England, the establishment of uncropped, tussocky grass field margins and wildlife strips, pollen and nectar mixes and uncropped field corners should all increase nesting and feeding opportunities for farmland Reed Buntings. Seed-rich habitats should be retained into spring.

- Delaying mowing/grazing dates on grassland to reduce loss of nests and young.
- On arable land over-wintered cereal or linseed stubble followed by a spring/summer fallow may be beneficial.

Sedge Warbler

- Retaining existing stands of emergent vegetation, in larger blocks where possible, will help improve breeding habitat.
- Establishment of new stands by transferring dredged material to areas of shallow water will also help create new breeding habitat.
- Reducing the intensity of farming on breeding areas is also likely to help.
- Delaying mowing dates on marshes to reduce loss of nests and young.
- On arable land over-wintered cereal or linseed stubble followed by a spring/summer fallow may be beneficial.

Snipe

- Agri-environmental measures aimed at improving conditions across farmland, is a realistic approach to aiding population recovery. Specific options include;
    - Reductions in stocking density on grassland and moorland.
    - Raising water levels, introducing surface flooding, and managing water levels to ensure that wet areas are maintained throughout the season is key to providing good foraging areas and thereby increasing the length of the breeding season.
    - Wet grassland creation will provide additional new habitat.
    - Delaying grazing turnout or mowing in spring should minimize the effects of trampling and egg/chick loss.

Yellow Wagtail

- Provision of permanent water features that provide a source of invertebrates with aquatic larval stages will help improve feeding condition.
- Other actions include delaying mowing dates on grassland to reduce loss of nests and young.
- On arable land over-wintered cereal or linseed stubble followed by a spring/summer fallow may be beneficial.

6.6 Key Drivers for Declines in Woodland Species

The results of the scoring process for woodland birds are provided in Tables 6.6a, 6.6b and 6.6c. Overall, despite many gaps in knowledge of drivers for woodland bird species (scores of 1 in Table 6.6a), there were some clear indications of areas of importance. Based on the overall scores in Table 6.6c, seven drivers emerged as being particularly important: climate change, breeding failure by predation, fragmentation and reduced connectivity of woodlands, changes in woodland structure through deer browsing, changes in woodland structure through reduced management, reduction in food availability and factors operating on wintering grounds.

Cessation of forest management and woodland maturation was assessed as being important for six declining species and this factor was the **highest scoring driver overall**. Changes in woodland structure as a result of increased deer browsing also appeared to be an important issue for Nightingale, Blackbird, Bullfinch and Marsh Tit as well as the majority of the early succession species. The effects of both of these drivers is to create a lack of diversity in the ground flora and understory layers resulting in habitat loss for many early successional woodland species. In the Repeat Woodland Bird Survey, these factors were identified as primary drivers of population decline in woodland birds and must continue to be treated as major problems (Amar *et al.* 2006).

Fragmentation and reduced connectivity of woodlands emerges as being of particular relevance to Marsh Tit, Song Thrush, Treecreeper and Goldcrest although high scores were observed for other species too. Species which are not able to disperse far from natal areas are particularly vulnerable to this factor. Loss of hedgerows in farmland is widespread and woods have become increasingly isolated in an agricultural landscape with sharp boundaries between crop and wood. Although the amount of woodland area has increased over recent decades, this mostly represents new plantings. The quality of new plantings and areas connecting woodlands is unknown and remaining hedgerows are often of degraded quality which will limit their usefulness by species.

Climate change was considered a contributory driver for nine species, and emerged as of primary concern for four: Lesser Spotted Woodpecker, Willow Tit, Wood warbler and Treecreeper. The first three of these species have been identified as the predicted biggest 'losers' under climate change (Gregory *et al*. 2009). For the majority of species this is an under-researched area. Factors operating on wintering grounds scored highly for migrants. Further work is required to establish the importance of this driver relative to factors operating on breeding grounds.

Breeding failure by predation was considered a contributory driver for nine species and an important driver for one (Spotted Flycatcher). Combined with the quality of evidence scores, the issue emerges as a primary concern for Blackbird, Bullfinch, Spotted Flycatcher and Wood Warbler. Other species such as Hawfinch and Lesser Spotted Woodpecker attained slightly smaller scores. This is an area which is not well studied for all species and critically rarely do any studies look at impacts at the population level. Furthermore, identification of predators is often ignored. Grey squirrels are often implicated in predation issues but little evidence is available.

Six species scored highly for a reduction in food availability being an issue in their decline. It is not clear how invertebrate food resources are changed over time, although some evidence suggests that there has been a reduction. Mis-matched timings of food resources and migrants is an issue. For species relying on seed resources, changes with habitat change may be impacting their availability.

Whilst here we have concentrated on the highest scoring drivers, the others should not be ignored. In some cases, such as lack of livestock grazing in upland oak woods or changes in soil moisture, the problem is specific to a single species or restricted group. Likewise, factors such as climate change, competition and disturbance have received relatively little research. For some species specific drivers have not been fully investigated and as such, the overall scores are likely to be lower, which should not be taken as lack of importance necessarily.

It is clear that there is currently no single common driver of decline of species in the woodland indicator for England, and each species appears to be suffering from a combination of drivers. Further work is required on a species by species basis to tease drivers apart and priorities need to be set to do this. Furthermore, there is general research that can assess the contribution of a single driver across several species. For example, habitat management trials should be seen as a major priority given the high scores achieved by this driver and the number of species this affects.

Table 6.6a Summary of key drivers of population declines in declining woodland bird species. 0 = not a driver, 1 = unknown, 2 = contributory driver, 3 = important driver, 4 = primary driver

Driver	Blackbird	Bullfinch	Dunnock	Garden warbler	Goldcrest	Hawfinch	Jay	Lesser redpoll	LS woodpecker	Marsh tit	Nightingale	Song thrush	S flycatcher	Tree pipit	Treecreeper	Willow tit	Willow warbler	Wood warbler
Climate change	1	2	2	1	2	1	1	1	2	1	2	1	2	1	2	2	1	2
Breeding failure - Predation	2	2	1	1	1	2	1	1	2	1	1	1	3	2	2	2	2	2
Direct predation/hunting	1	1	1	2	1	1	1	1	1	1	1	2	1	2	1	1	1	1
Competition	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	2	2	1
Fragmentation and reduced connectivity - loss of woodlands and hedgerows	2	2	1	1	2	3	2	1	3	2	1	2	1	1	2	1	2	1
Changes in woodland structure - increased deer grazing	3	3	3	3	1	1	1	1	1	3	3	2	1	1	1	1	2	1
Changes in woodland structure - lack of livestock grazing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3
Changes in woodland structure - maturation and cessation of active management	3	3	3	3	1	1	1	2	1	3	3	2	2	2	1	3	2	1
Reduction in food availability	1	2	1	1	2	1	2	2	2	1	1	2	2	1	1	2	1	2
Factors operating on wintering grounds (migrants only)				2							2		2	2			2	2
Drying of woodlands - direct/indirect land drainage/water extraction	1	1	1	1	1	1	1	1	2	1	1	2	1	1	2	3	1	1
Agriculture outside of the wood	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Increased disturbance	1	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1	2	1
Invasive species	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2

Table 6.6b Quality of evidence to support the identification of key drivers of population declines in declining woodland bird species. 0.5 =no evidence/not researched, 1 = anecdotal evidence, 2 = expert opinion, 3 = grey literature, 4 =study in 'popular journal' or peer reviewed journal but carried out outside of UK, 5 = study occurs in peer reviewed journal and was carried out in the UK

Driver	Blackbird	Bullfinch	Dunnock	Garden warbler	Goldcrest	Hawfinch	Jay	Lesser redpoll	LS woodpecker	Marsh tit	Nightingale	Song thrush	S flycatcher	Tree pipit	Treecreeper	Willow tit	Willow warbler	Wood warbler
Climate change	0.5	2	1	0.5	3	0.5	0.5	0.5	5	0.5	3	0.5	3	0.5	5	5	0.5	5
Breeding failure - Predation	5	5	0.5	0.5	0.5	3	0.5	0.5	3	0.5	0.5	0.5	5	2	1	2	2	4
Direct predation/hunting	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5	0.5	1	0.5	0.5	0.5	0.5
Competition	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	1	0.5	0.5	0.5	0.5	0.5	1	2	0.5
Fragmentation and reduced connectivity - loss of woodlands and hedgerows	2	3	0.5	0.5	4	0.5	3	0.5	2	5	0.5	5	0.5	0.5	5	0.5	3	0.5
Changes in woodland structure - increased deer grazing	3	3	2	2	0.5	3	0.5	0.5	0.5	3	5	0.5	0.5	0.5	0.5	0.5	3	0.5
Changes in woodland structure - lack of livestock grazing	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5
Changes in woodland structure - maturation and cessation of active management	3	3	2	2	0.5	0.5	0.5	4	0.5	3	5	0.5	3	3	0.5	3	3	0.5
Reduction in food availability	0.5	3	0.5	2	4	0.5	4	2	4	0.5	0.5	5	4	0.5	0.5	4	0.5	3
Factors operating on wintering grounds				2							2		4	2			2	2
Drying of woodlands - direct/indirect land drainage/water extraction	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2	0.5	0.5	5	0.5	0.5	3	5	0.5	0.5
Agriculture outside of the wood	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5	0.5	0.5	0.5	0.5	0.5	0.5
Increased disturbance	0.5	0.5	0.5	0.5	0.5	3	0.5	0.5	0.5	0.5	4	0.5	0.5	4	0.5	0.5	4	0.5
Invasive species	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2

Table 6.6c Combined scores. The quality of evidence score is multiplied by the importance score to give a weighting to the most significant driver and identifies gaps in knowledge. Scores greater than 8 have been highlighted as drivers of importance. Drivers attaining a final score of 4 or 5 are in bold.

Driver	Blackbird	Bullfinch	Dunnock	Garden warbler	Goldcrest	Hawfinch	Jay	Lesser redpoll	LS woodpecker	Marsh tit	Nightingale	Song thrush	S flycatcher	Tree pipit	Treecreeper	Willow tit	Willow warbler	Wood warbler	Total score	Total score divided by species
Climate change	0.5	4	2	0.5	6	0.5	0.5	0.5	10	0.5	6	0.5	6	0.5	10	10	0.5	10	69	4
Breeding failure - Predation	10	10	0.5	0.5	0.5	6	0.5	0.5	6	0.5	0.5	0.5	15	4	2	4	4	8	73	4
Direct predation/hunting	0.5	0.5	0.5	2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	10	0.5	2	0.5	0.5	0.5	0.5	22	1
Competition	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2	2	0.5	0.5	0.5	0.5	0.5	2	4	0.5	17	1
Fragmentation and reduced connectivity - loss of woodlands and hedgerows	4	6	0.5	0.5	8	1.5	6	0.5	6	10	0.5	10	0.5	0.5	10	0.5	6	0.5	72	4
Changes in woodland structure - increased deer grazing	9	9	6	6	0.5	3	0.5	0.5	0.5	9	15	1	0.5	0.5	0.5	0.5	6	0.5	69	4
Changes in woodland structure - lack of livestock grazing	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	15	24	1
Changes in woodland structure - maturation and cessation of active management	9	9	6	6	0.5	0.5	0.5	8	0.5	9	15	1	6	6	0.5	9	6	0.5	93	5
Reduction in food availability	0.5	6	0.5	2	8	0.5	8	4	8	0.5	0.5	10	8	0.5	0.5	8	0.5	6	72	4
Factors operating on wintering grounds				4							4		8	4			4	4	28	5
Drying of woodlands - direct/indirect land drainage/water extraction	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	4	0.5	0.5	10	0.5	0.5	6	15	0.5	0.5	42	2
Agriculture outside of the wood	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5	0.5	0.5	0.5	0.5	0.5	0.5	14	1
Increased disturbance	0.5	0.5	0.5	0.5	0.5	6	0.5	0.5	0.5	0.5	4	0.5	0.5	8	0.5	0.5	8	0.5	33	2
Invasive species	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	4	13	1

6.6.1 Gaps in knowledge of drivers for woodland species

There are extensive gaps in knowledge of drivers of declines in woodland bird populations in England, particularly in relation to some potentially important factors such as the effects of changes on agricultural land outside woodlands, the lack of grazing by livestock, invasive plant species, and the drying out of woodlands. There are also significant gaps in our knowledge of the effects of disturbance, direct predation, hunting, and inter-specific competition. Other drivers have been better studied and our assessment suggests that factors such as changes in woodland structure due to cessation of management or deer browsing, breeding failure due to predation, climate change on breeding and wintering grounds, and reductions in food availability, are at least contributory factors for in the declines of about half of the woodland species assessed.

6.7 Priority Conservation Actions and Policies for Woodland Birds

6.7.1 Actions to aid recovery

Table 6.7.1.1 highlights areas of general woodland policy and their potential to impact upon population declines in woodland species. In cases where there appears to be a link between population decline and habitat change or loss, measures available through ELS, HLS and EWGS may offer potential delivery mechanisms for woodland birds. This work has identified important drivers of decline. Four of the six important driver are linked to habitat: fragmentation and reduced connectivity, increased deer grazing, maturation and cessation of active management, and in some cases a reduction in food availability.

Table 6.7.1.1 Summary of general policy measures and their potential to impact upon populations declines in woodland bird species. 0 = no/minimal potential, 1 = moderate potential, 2 = major potential.

Action/Policy	Justification	Blackbird	Bullfinch	Dunnock	Garden warbler	Goldcrest	Hawfinch	Jay	Lesser redpoll	LS woodpecker	Marsh tit	Nightingale	Song thrush	S flyctatcher	Tree pipit	Treecreeper	Willow tit	Willow warbler	Wood warbler
BAP - Species	Work to achieve BAP species targets	0	2	0	0	0	2	0	2	2	2	0	2	2	2	0	2	0	2
Birds Directive	Legal framwork to meet BAP targets. Protection of habitat through SPA network	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Climate Change Act 2008	Aims to reduce the impacts of climate change	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Public service Agreements - farmland birds index	Aims ro reverse the declines in woodland birds	1	1	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
English Forestry Strategy	Framework to meet BAP and indicator targets	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
UK Woodland Assurance Standard	Aims to achieve standards in forestry	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Woodfuel Statretgy for England	Management of woodlands for bioenergy	2	2	2	2	0	0	0	2	0	2	2	2	2	0	0	2	2	0
PAWS	Restoration of ancient woodlands	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
HAP - Lowland mixed deciduous woodland	Maintain, restore and create habitat	2	2	2	2	1	1	1	2	1	2	2	2	2	1	1	2	2	1
HAP - Upland oakwood	Maintain, restore and create habitat	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2
HAP - Lowland beech & yew woodland	Maintain, restore and create habitat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
HAP - Wet woodland	Maintain, restore and create habitat	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1
HAP - Upland birchwoods	Maintain, restore and create habitat	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	2	2
HAP - Upland mixed ashwoods	Maintain, restore and create habitat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The first table in this section identifies the potential for each general policy instrument or initiative to provide benefits to each of the declining woodland bird species included in this study. This is a diverse array of policies or actions operating at different spatial and temporal scales, but most have the capacity to provide benefits for at least some of the species. The polices or actions that scored highest overall across this group of species due to their major potential for benefits were: (i) the Birds Directive, in particular the legal framework to meet BAP targets and provide habitat protection through the SPA network, and (ii) the England Forestry Strategy, which aims to meet BAP and indicator targets. Ten species are on the UK BAP list and there are species-specific actions identified in BAP plans to reverse their declines by addressing the causal factors. The Woodfuel Staretgy for England has the potential for major benefits for 11 species on the list, and the Habitat Action Plan (HAP) for Lowland Mixed Deciduous Woodland has the potential for major benefits for another 11 species. HAPs for Upland Oakwood, Wet Woodland and Upland Birchwoods each have the potential for major benefits for a small number of species, whereas the restoration of ancient woodland through PAWS, the UK Woodland Assurance Standard and the Climate Change Act 2008 have moderate potential to benefit a very wide range of the declining species in this list. Overall, there are few differences in the conservation policies relevant to species although specific-specific actions through BAP or HAPs provide more opportunities to address problems for BAP species and those associated with these habitats. The next two tables in this section (Tables 6.7.2.1 and 6.7.3.1) explore in more detail the benefits provided by specific options within HLS and ELS. The main findings are summarised below.

6.7.2 Benefits of ELS

Options for boundary features will benefit species which use habitat outside of woodlands (Blackbird, Bullfinch, Dunnock, Garden Warbler, Song Thrush and Willow Warbler) or require a connected landscape of woodlands and trees (Lesser Spotted woodpecker and Hawfinch in particular). In-field trees may benefit Hawfinch, Jay and Lesser Spotted Woodpecker but only in conjunction with other management. Fencing and establishing the ability to include or exclude grazing (depending on species needs) will benefit a number of species reliant on cover at low levels, or in the case of Wood Warbler, lack of cover. Management of woodland edges so that there is less of a sharply defined edge against other habitats should also benefit a number of species that depend on young vegetation. Furthermore, maintenance of buffer strips in arable habitats against woodlands may provide foraging for many species and will protect against agricultural operations impacting woodland habitats, especially if a scrubby fringe is maintained.

Although some woodland birds could benefit from options in ELS, it is doubtful that these options alone will deliver woodland bird recovery. ELS is aimed primarily at agricultural options and is of most benefit to farmland birds. Generalist species will benefit from many of the options, but woodland specialists such as Hawfinch and Lesser Spotted Woodpecker are unlikely to. Furthermore, ELS can deliver nothing to enhance within woodland habitat quality.

Table 6.7.2.1 Potential delivery mechanisms for woodland birds through ELS

		Blackbird	Bullfinch	Dunnock	Garden warbler	Goldcrest	Hawfinch	Jay	Lesser redpoll	LS woodpecker	Marsh tit	Nightingale	Song thrush	S flycatcher	Tree pipit	Treecreeper	Willow tit	Willow warbler	Wood warbler
Options for boundary features	Hedgerow management (on both sides of hedge)	■	■	■	■					■			■					■	
	Hedgerow management (on one side of hedge)	■	■	■	■					■			■					■	
	Enhanced hedgerow management	■	■	■	■					■			■					■	
	Combined hedge and ditch management	■	■	■	■					■			■					■	
Options for trees and woodland	Protection of in-field trees on arable land						■	■						■					
	Protection of in-field trees on grassland						■	■						■					
	Maintenance of woodland fences	■	■	■	■				■		■	■	■	■	■		■	■	■
	Management of woodland edges	■	■	■	■				■	■		■	■	■	■		■	■	
Options for buffer strips and field margins	2 m buffer strips on cultivated land	■						■					■	■					
	4 m buffer strips on cultivated land	■						■					■	■					
	6 m buffer strips on cultivated land	■						■					■	■					
	2 m buffer strips on intensive grassland	■						■					■	■					
	4 m buffer strips on intensive grassland	■						■					■	■					
	6 m buffer strips on intensive grassland	■						■					■	■					

6.7.3 Benefits of HLS and EWGS

HLS offers the potential for more targeted woodland management to suit declining species. As well as management of boundary features and retention of ancient tress, the scheme offers options to maintain and restore woodland, which will provide benefit to all woodland birds. Specific options to maintain, restore and create parkland and wood pasture and successional areas and scrub is also likely to benefit the majority of declining species. Options associated with orchards are also likely to be a great benefit for species such as Lesser Spotted Woodpecker, Hawfinch and Spotted Flycatcher. Finally Tree Pipit will benefit from habitat created through lowland heathland options.

EWGS offers grants for general woodland management targeted at a species or suite of species and has the potential to deliver recovery for many woodland birds where habitat is thought to be an issue. EWGS and HLS are specific and targeted to a greater extent than ELS. However, their success depends on the targeting of grants to key areas for specific species. Broad scale options such as woodland maintenance and restoration are likely to be of most benefit but, again, require careful targeting and monitoring of success. Fundable options under HLS and EWGS are discussed below.

Establishing the ability to control grazing, restoring neglected coppice stands, enhancing wide rides with scrubby edges, developing a scrubby woodland edge, creating new woodland and allowing thicket stages to develop should all be of benefit to Blackbird, Bullfinch, Dunnock, Garden Warbler, Jay, Marsh Tit, Nightingale, Song Thrush, Spotted Flycatcher, Tree Pipit, Willow Tit, Willow Warbler. Wood Warbler has a requirement for establishing the ability to control grazing, ensuring enough grazing pressure to maintain an open structure without removing the field layer.

Blackbird, Song Thrush and Spotted Flycatcher will also benefit through providing buffers between woodland and arable habitats. Goldcrest and Treecreeper will benefit in the longer term from new woodland creation to allow connectivity of woodlands. Furthermore, there should be consideration given to areas of conifer plantation to retain for Goldcrest (and Firecrest). The most appropriate method of PAWS restoration will need consideration for this species also.

Hawfinch requires specific management such as restoration of parkland and restructuring of mature woodland to maintain required habitat. New woodland planting will improve connectivity, although mature trees are preferred. Jay, Lesser Spotted Woodpecker and Song Thrush will also benefit from restored parkland, retention of mature trees and increased connectivity in the landscape.

Restructuring of closed canopy woodland to open up areas for successional species, in particular birch, will provide habitat for Lesser Redpoll. This species will also benefit from management targeted at other early successional habitat species listed above.

Species requiring wet woods and damp features within woods, such as Song Thrush, Willow Tit, Marsh Tit and Hawfinch may benefit from actions to reverse drainage inside and outside of the woodland. However, the issue of woodlands becoming drier is likely to be a result of a general reduction in water tables and reduced summer rainfall.

Deadwood retention is of importance to hole nesters – Lesser Spotted Woodpecker, Marsh Tit and Willow Tit.

For long distance migrants where there is evidence of effects on wintering grounds, work in Africa which sets out to establish specific wintering areas, habitat needs and threats will undoubtedly increase our knowledge of the species and in some cases may provide solutions to population change. However, contributory factors operating on breeding grounds should not be ignored. For all the declining long distance migrants in the woodland indicator there is suggestion of other drivers apart from wintering ground issues. In particular those species favouring young, early successional woodland will benefit from habitat management to create more of this sort of habitat, and a continuous turnover as areas mature.

Table 6.7.3.1 Potential delivery mechanisms for woodland birds through HLS

		Blackbird	Bullfinch	Dunnock	Garden warbler	Goldcrest	Hawfinch	Jay	Lesser redpoll	LS woodpecker	Marsh tit	Nightingale	Song thrush	S flycatcher	Tree pipit	Treecreeper	Willow tit	Willow warbler	Wood warbler
Hedgerow options	Management of hedgerows of very high environmental value (both sides)	■	■	■	■					■			■					■	
	Management of hedgerows of very high environmental value (one side)	■	■	■	■					■			■					■	
Woodland, trees and scrub options	Ancient trees in arable fields						■	■		■									
	Ancient trees in intensively managed grass fields						■	■		■									
	Maintenance of wood pasture and parkland						■	■		■			■	■					
	Restoration of wood pasture and parkland						■	■		■			■	■					
	Creation of wood pasture						■	■		■			■	■					
	Maintenance of woodland	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Restoration of woodland	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Creation of woodland in the SDA of the LFA	■	■						■									■	
	Creation of woodland outside the LFA SDA and the Moorland Line	■	■						■									■	
	Maintenance of successional areas and scrub	■	■						■		■	■	■				■	■	

		Blackbird	Bullfinch	Dunnock	Garden warbler	Goldcrest	Hawfinch	Jay	Lesser redpoll	LS woodpecker	Marsh tit	Nightingale	Song thrush	S flyctatcher	Tree pipit	Treecreeper	Willow tit	Willow warbler	Wood warbler
Woodland, trees and scrub options	Restoration of successional areas and scrub																		
	Creation of successional areas and scrub																		
	Woodland livestock exclusion supplement																		
Orchard options	Maintenance of high-value traditional orchards																		
	Restoration of traditional orchards																		
	Maintenance of traditional orchards in production																		
	Creation of traditional orchards																		
Lowland heathland options	Restoration of forestry areas to lowland heathland																		

Table 6.7.3.1 Continued**.**

6.7.4 Gaps in conservation actions and policies to address declines in woodland species

Overall, these tables suggest that declines in many of these woodland species are best addressed by species-specific actions through BAP, as well as more broadly through policies such as Environmental Stewardship options to enhance boundary features (hedgerow management, woodland fences, woodland edge management, buffer strips) and the creation, restoration and maintenance of woodland, scrub and successional areas. These options provide most benefits to woodland edge species such as Blackbird, Bullfinch, Dunnock, Song Thrush and Spotted Flycatcher. Orchard options will benefit species such as Hawfinch, Lesser Spotted Woodpecker, Jay and Spotted Flycatcher and successional / scrub areas would benefit Nightingale, Marsh and Willow Tit and Willow Warbler. Overall, there is a gap in ES options or other conservation policies for species such as Lesser Redpoll, Goldcrest, Treecreeper, Tree Pipit and Wood Warbler although the latter two are BAP species and should have conservation actions identified through that process.

6.8 Specific Conservation Actions and Policies for Woodland Birds

Details of the conservation action requirements for each of the declining wetland species are described in the following section.

Blackbird

- Establish ability to manage grazing – exclusion of deer and livestock in key areas.
- Restore neglected coppice – coppice on a cycle of 7-10 years
- Ride enhancement – wide rides with scrub cover at edges
- Develop scrubby woodland edge – provide buffers to woodland with a structured edge.
- New woodland creation – ensure opportunities for thicket stages to develop and be retained/replaced.
- Provide buffer between woodland and arable crops for foraging.

Bullfinch

- Establish ability to manage grazing – exclusion of deer and livestock in key areas.
- Restore neglected coppice – coppice on a cycle of 4-15 years
- Ride enhancement – wide rides with scrub cover at edges
- Develop scrubby woodland edge – provide buffers to woodland with a structure edge.
- New woodland creation – ensure opportunities for thicket stages to develop and be retained/replaced.

Dunnock

- Establish ability to manage grazing – exclusion of deer and livestock in key areas.
- Restore neglected coppice – coppice on a cycle of 2-10 years
- Ride enhancement – wide rides with scrub cover at edges
- Develop scrubby woodland edge – provide buffers to woodland with a structured edge.
- New woodland creation – ensure opportunities for thicket stages to develop.

Garden Warbler

- Establish ability to manage grazing – exclusion of deer and livestock in key areas.
- Restore neglected coppice – coppice on a cycle of 2-10 years
- Ride enhancement – wide rides with scrub cover at edges
- Develop scrubby woodland edge – provide buffers to woodland with a structured edge.
- New woodland creation – ensure opportunities for thicket stages to develop.

Goldcrest

- Identification of areas of conifer plantation to retain
- New woodland creation – to allow connectivity of woodlands.

Hawfinch

- Restructure neglected mature woodland – thin to reduce competition on mature trees with keys, seeds and fruits.
- Restore parkland – reduce competition from immature in-fill, retain some as replacements.
- Establish ability to manage grazing
- Maintain and enhance wet features – the species has a dependence for drinking.
- New woodland creation – to allow connectivity of woodlands.

Jay

- Restore neglected coppice – retain mature standards
- Ride enhancement – wide rides for foraging and hording.
- New woodland creation
- Provide buffer between woodland and arable crops for foraging and hording.
- Restore parkland – reduce competition from immature in-fill, retain some as replacements.

Lesser Redpoll

- Restructure closed canopy woodland – favour birch in conifer stands
- Ride enhancement – provide diverse edge structure, favour birch.
- Glade creation/improvement – provide diverse edge structure, favour birch.
- Develop scrubby woodland edge – provide buffers to woodland with a structured edge including young birch.
- New woodland creation – early successional habitats with birch.

Lesser Spotted Woodpecker

- Restructure immature closed canopy woodland– encourage crown development. Retain any deadwood. Restore coppice where crowding standards.
- Thin mature but under managed wood.
- Ride enhancement
- Increase deadwood.
- Maintain/restore soil moisture conditions.
- Restore parkland – reduce competition from immature in-fill, retain some as replacements.
- New woodland creation.

Marsh Tit

- Establish ability to control grazing/browsing – to aide healthy coppice/shrub layer regeneration and growth.
- Restore crowded immature woodland – Thin to encourage shrub layer regeneration
- Restored neglected coppice – restore long rotation coppice cycle (10-15 years) with standards.
- Retain deadwood – including low in shrub layer
- New woodland creation – for connectivity. Ensure opportunities for thicket stages to develop.

Nightingale

- Establish ability to manage grazing – exclusion of deer and livestock in key areas.
- Restore neglected coppice – coppice on a cycle of 2-10 years
- Ride enhancement – wide rides with scrub cover at edges
- New woodland creation – ensure opportunities for thicket stages to develop.

Song Thrush

- Establish ability to manage grazing – exclusion of deer and livestock in key areas.
- Restore neglected coppice – 15 year cycles with standards.
- Ride enhancement – wide rides with scrub cover at edges
- Develop scrubby woodland edge – provide buffers to woodland with a structure edge including young birch etc.
- New woodland creation – ensure opportunities for thicket stages to develop.
- Restore parkland – reduce competition from immature in-fill, retain some as replacements.
- Reverse drainage inside and influencing wood – block/slow internal drains and buffer woodland from agricultural land drainage.
- Provide buffer between woodland and arable crops for foraging.

Spotted Flycatcher

- Restructure immature closed canopy woodland and thinning – to develop in-stand structure and shrub layer, encourage crown development, and enhance micro-climate (sheltered sunny patches).
- Ride enhancement, glade creation and improvement – develop/restore wide rides and glades with shelter, in feature standards, non-regimented edge.
- Retain/enhance deadwood – in-tree features as nest sites and general volume for invertebrates.
- Retain ivy and other climbers – potential nest sites.
- Buffer strips to woodland edge – especially to intensive agriculture, to provide invertebrates.
- Thin regular woodland edge (where wind fastness permits) – to create diverse structure at particularly sheltered edges.
- Retain standards in restored coppice.

Treecreeper

- New woodland creation

Tree Pipit

- Manage grazing/browsing – to maintain open structure.
- Restructure closed canopy woodland – develop open canopy. Gradually thin to ensure supply of early stage regeneration.
- Ride enhancement – creation of wide rides
- Glade creation/improvement – including temporary glades via small group felling.
- Coppice – will use early to medium stage coppice, ideally with standards.
- Create scrubby woodland edges – especially in open upland habitats
- Conifer clearfell and restocks – retain scatter when clearfelling.

Willow Tit

- Restructure immature closed canopy woodland – to generate abundant shrub layer. Produce tall stumps and leave existing deadwood.
- Coppice maturing woodland – especially abandoned coppice in damp woodland and along wet features. Long cycles – 8-15 years.
- Reverse drainage inside and influencing wood – block/slow internal drains. Buffer woodland from agricultural land drainage.
- Retain deadwood – especially standing.
- Establish ability to control grazing – to prevent loss or degradation of the shrub layer.
- Create/encourage new areas of scrub woodland to develop on wet ground.

Willow Warbler

- Restore neglected coppice – ideally coppice cycle 2-10 years.
- Ride enhancement – wide rides with scrub cover at edges.
- Develop scrubby woodland edge – provide buffers to woodland with a structure edge including young birch.
- New woodland creation – ensure opportunities for thicket stages

Wood Warbler

- Establish ability to control grazing – preference for stands with little or no shrub layer or under-storey. Enough grazing/browsing pressure needed to maintain this without removing field layer.
- Small coupe felling for regeneration or coppice – restructure even aged woods.

6.9 References for Drivers and Conservation of Wetland and Woodland Bird in this Chapter

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7. PRIORITIES FOR FUTURE RESEARCH

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Using the information in the literature review, the results of the analytical work carried out under Objective 2, and drawing on the broader literature related to drivers of decline in woodland and wetland birds, this chapter provides a provisional set of priorities for future research. These reflect gaps in knowledge revealed by the literature review as well as the need for further exploration of additional data sets, both of birds and potentially relevant environmental factors beyond the scope of this project. The overall aim of Objective 4 is to provide research recommendations that will identify the drivers of declines more conclusively, as well as relate directly to pragmatic and policy- relevant management actions that offer good value for money through benefiting a wide range of species. A general area of research that might help shed more light as to why individual species are declining is the study of other species sharing the same habitat which are not themselves declining. For example, Oystercatcher is a species that breeds on wet grasslands which is currently increasing whilst many other wet grassland species are declining. Furthermore, there is clearly a need for continued targeted single species research.

7.1 Declining Wetland Birds: Research Recommendations

HIGH priority research:

1. Identify the processes and quantify the impact of agricultural intensification and identify management solutions.
2. Determine the role of semi-natural habitats / patches on the viability of key wetland bird populations
3. Quantify factors related to the impact of predation on wetland birds and identify potential solutions
4. Develop improved modelling approaches to identify critical factors and stages in life cycle

HIGH priority species:

1. Yellow Wagtail
2. Curlew
3. Common Sandpiper
4. Lapwing
5. Redshank

HIGH Priority

1. Research to quantify the impact of agricultural intensification on breeding birds in wet grasslands and to identify management options to mitigate against these effects

The intensification of agriculture comprises a suite of potential impacts on wetland breeding birds that are difficult to separate, including effects operating through changes in vegetation density and structure, insect abundance and availability, as well as predation risk and the availability of cover for predators. In the context of the declining species in the wetland bird index, this relates mainly to the intensification of management on lowland wet grasslands and in the uplands. Research should focus on identifying habitat management techniques that counter the effects of grassland intensification, provide suitable nesting habitat, cover and food resources, and that could potentially be incorporated into agri-environment measures in revisions to ELS, HLS and in proposed upland ELS options. Priority areas that need addressing include:

- Studies at a range of scales on the relationships between agricultural intensification (especially the role of livestock, rates of fertilizer and pesticide input), habitat structure and food availability in wet grasslands, and use of these habitats by breeding wetland birds. HIGH
- Increased eutrophication of water bodies as a result of agricultural intensification may be an issue, requiring an initial scoping study / review to assess its importance LOW

2. Studies relating population trends and viability to the distribution of semi-natural habitats

This area of research is aimed at investigating the importance of relatively scarce, special, habitats within the broader landscape and needs to be carried out at several spatial scales, for instance, reserves within the broader agricultural landscape, or features such as wet areas within farms. This will provide information on patch sizes or networks needed to support viable populations of the breeding waders in the wetland bird indicator. Specific research recommendations include:

- Further explore the role of protected areas and semi-natural habitats in the population dynamics of species such as Redshank, Curlew, Lapwing and Snipe, including interaction with the effects of predation in and outside such areas. Do reserves/protected areas act as source populations of some species for the wider countryside? Does experience gained in managing wetland reserves, in particular by RSPB, have relevance to the wider development of agri-environment schemes? This should incorporate landscape-scale effects, the effects of habitat and regional heterogeneity and the interaction between these factors. HIGH
- The influence of reserve size also needs to be examined in relation to predation pressure and the ability to manage habitat, in particular water levels. Studies such as these could help inform whether agri-environment money should target areas around existing populations to increase patch and population size or if small patchy populations can contribute to meta-population productivity. MEDIUM
- Explore the use of meta-population models to address the issues above. LOW

3. Research on methods to mitigate against the impact of predation – particularly to ground-nesting wetland birds

Predation was identified as a key factor influencing productivity in local studies and there is a need better to quantify the impact of predation on the overall population dynamics (overall productivity and recruitment to breeding population) of declining wetland species, particularly the ground-nesters (Curlew, Snipe, Redshank, Lapwing, Yellow Wagtail). The ultimate cause of population declines is not an increase in predation or an increase in predators but what has caused those increases. We need to understand the mechanisms by which predators respond to the environment and thus affect their prey, so that appropriate habitat management measures can be designed. Specific work areas include:

- Identify and quantify the relative importance of different predators of chicks and working towards landscape-scale solutions to reduce chick predation. HIGH
- Investigate interactions between predator species. Particularly in relation to reduced abundance of one predator species through predator control allowing another predator species, that is harder to control, to flourish e.g. foxes and stoats or crows and magpies. HIGH
- Investigate the interaction between effects of predators and habitat change, especially as a result of agricultural intensification. HIGH
- Quantify the role of predation, and nest predation, in national / local level declines. LOW
- Investigate the ecology (including interactions with prey), behaviour and population dynamics of predators. HIGH
- Further studies on the effectiveness of predator control in patchy, small populations could help inform whether agri-environment money should target areas around existing populations or if small patchy populations can contribute to meta-population productivity. LOW

4. Development of modelling approaches to identify vulnerable stages of the life cycle and/or critical environmental factors

Predictive and demographic models can help to identify key habitat or management requirements and critical stages in the life cycle (productivity, winter survival) influencing population trends. Although not suited for all species (due to lack of sufficient data), there is scope for adapting these approaches for a broader suite of birds including some key declining wetland (and woodland) birds. The use of Bayesian approaches will make the most out of sparse data. Dedicated field research could fill gaps in knowledge regarding demography and habitat-specific survival/productivity.

- Develop demographic modelling to identify key life cycle stage at risk for those species for which sufficient data are available (e.g. Sedge Warbler, Reed Bunting, Curlew). These type of models are a prerequisite for the development of other models HIGH
- Develop predictive models including the effects of several key factors, such as climate change and land-use change, on population change. MEDIUM

5. Study on the effects of changes in hydrology / water table dynamics

Water tables and flow rates have changed dramatically as rivers have been altered and abstraction has increased. Urbanisation within the catchment will also affect hydrology.

- Research is required to determine how these changes in water flow have influenced the habitat and conditions of rivers and their floodplains, and to assess the potential impact of such changes on the wetland species that use these habitats – particularly the declining species. This should include research to determine when and how flow rates might be controlled to protect biodiversity (not just wetland birds), and inform decisions related to the timing of abstraction to have minimum impact on wildlife. HIGH

- Study on the effects of urbanisation through run-off (pollutants, nutrients, etc) as well as disturbance, the effects of introduced / invasive species and changes to the surrounding habitats. LOW

LOWER Priority

5. Investigate the effects of changes in land use, habitat and environmental conditions on wintering areas of wetland birds that are long distance migrants

Further research into processes affecting wintering and migration periods for declining sub-Saharan migrants (Common Sandpiper, Sedge Warbler and Yellow Wagtail, as well as many of the woodland migrants) is much needed. Although droughts in the Sahel region were identified as a probable driver of previous population crashes for Sedge Warbler, continuing habitat loss and land-use changes in

Africa due to human encroachment and habitat degradation through agricultural intensification, as well as a range of changes in climatic variables (rainfall, storm frequency) may be important. Research is needed to determine how these changes impact on survival; and whether they affect survival on the wintering grounds or during migration, for example on stop-overs. MEDIUM

6. Research into the impact of hunting on population levels

This work would need to have an international perspective, as losses (hunting and incidental losses) of these species occur outside as well as within the UK (for quarry species such as Curlew and Snipe). MEDIUM

7. Studies on the effects of change in climate and sea level rise on breeding grounds

Despite the lack of much evidence for the effects of climate change in the UK for most of the declining species in the wetland bird indicator, the development of improved predictive models incorporating changes in land use as well as climatic factors, is essential to gain an insight into how to maintain populations in the future. This is particularly relevant to upland-breeding waders such as Curlew and Snipe. Species such as Redshank, and other coastal species that may not be declining at present, are likely to become increasingly threatened by sea-level rise. The new UKCIP2009 climate change predictions forecast extensive loss of coastal habitats and Britain has signed up to compensating for loss of SPA / *Natura 2000* habitat. There is a need for developments in spatial modelling to assess these impacts. LOW

8. Studies on the effects of disturbance and how this impacts upon productivity

There is evidence for some bird species that disturbance can have negative effects and may cause birds to redistribute themselves; further research on the impact of disturbance, particularly with respect to increased open access to the countryside and recreational use of waterways, on the productivity of ground-nesting species such as Curlew, Redshank and Lapwing,is desirable. Such studies should consider season-long productivity as the main effect of disturbance may be to reduce the frequency of re-nesting. Disturbance of feeding waders on narrow estuaries over the winter, with subsequent effects on survival, may also be an issue, warranting further research. LOW

9. Investigation into the effects of afforestation on breeding birds of grasslands in the uplands

Afforestation and the resulting loss of open habitats in the uplands has been shown to have a negative impact on moorland birds such as Curlew, mainly through direct habitat loss. There is currently relatively little new afforestation, but further work to investigate more subtle effects of afforestation such as edge-effects and the interaction between afforestation and rates predation could be useful. LOW

PRIORITIES BY SPECIES

The evidence for the declines in the wetland species covered by this review comes from broad-scale long-term monitoring schemes, and clearly continued monitoring is required in order to continue to assess population status. For some of the less widespread species, monitoring could be improved through periodic special surveys (e.g. Breeding Waders in Lowland Meadows), by continuing to promote and expand existing schemes where possible (e.g. BBS, WBBS) and by additional monitoring targeted at particular habitats (e.g. England Upland Breeding Bird Survey). To permit easier assessment of research priorities at the species level, we provide a list of research requirements on a species by species basis in Table 8.1.1 (below).

Table 7.1.1 Species-specific research requirements for wetland birds, listed in order of the magnitude of long-term trends as measured by BoCC, BAP and BBS*.

Species	BoCC	BAP	BBS trend	Actions
Yellow Wagtail	Red	No	-48%	- There is no good evidence that this species had been affected by periodic droughts in the Sahel. Research into processes acting during the wintering and migration periods is needed to confirm this. - Quantify the impact of predation in affecting population declines. - Examination of different processes affecting grassland and arable breeding birds and how these are impacting on the population as a whole.
Curlew	Amber	Yes	-21%	- Quantify the impact of predation in affecting population declines. - Explore the role of reserves, other protected areas and semi-natural habitats in the population dynamics - Examine the role of climate change on the breeding grounds, particularly in the uplands - Investigation of the impact of hunting - Quantify the impacts of disturbance on population dynamics
Redshank	Amber	No	-19%	- Explore the role of reserves, other protected areas and semi-natural habitats in the population dynamics. - Quantify the impact of predation in affecting population declines. - Examine the role of sea level rise on coastal populations to determine what the likely effects of this will be on the population in the future. - Quantify the impacts of disturbance on population dynamics
Common Sandpiper	Amber	No	-18%	- Research into processes acting during the wintering and migration periods - Quantify the impacts of disturbance on population dynamics
Snipe	Amber	No	-12%	- Explore the role of reserves, other protected areas and semi-natural habitats in the population dynamics of Snipe - Quantify the impact of predation in affecting population declines. - Examine the role of climate change on the breeding grounds, particularly in the uplands - Further investigation of the impact of hunting

Species	BoCC	BAP	BBS trend	Actions
Lapwing	Red	Yes	+6%	- Explore the role of reserves, other protected areas and semi-natural habitats in the population dynamics. - Examine different processes affecting grassland and arable breeding birds and how these are impacting on the population as a whole. - Quantify the impact of predation in affecting population declines. - Research into what exactly is causing low chick survival i.e. increased predation, trampling, starvation etc.? - Quantify the impacts of disturbance on population dynamics - Quantify the impacts of hunting on population numbers
Dipper	Green	No	-12% (UK)	- Quantify which population processes are driving the decline; broods are now on average larger, and there has been substantial reduction in failure rates of nests at the egg stage but the most recent trends still show that Dipper populations are declining.
Reed Bunting	Amber	Yes	+25%	- Further research to identify the causes of differences in levels breeding performance (i.e. breeding performance has fallen on arable and mixed farms but has risen on grazing farmland. - Research into whether the loss of small wet features caused the relatively sudden population decline between 1976 and 1983. - Research into whether the large-scale loss of winter stubbles since the 1970s has been a major driver in population declines. - Research into the relative importance of predation across habitats and regions -Further work to establish which population processes are driving the population decline.
Sedge Warbler	Green	No	-12%	- Research into processes acting during the wintering and migration periods - Quantify the relative role of habitat degradation on breeding grounds in preventing population recovery. - One study was identified (Berthold 1973) in the literature review which stated that increased pesticide use in Africa was important in driving population declines. Work to establish more insight into this is needed.

Table 7.1.1 Continued.

* BoCC are the red and amber assessments in 'Birds of Conservation Concern 3: 2009' (Eaton *et al*. 2009)'. BAP indicates whether the species is listed on the UK Biodiversity Action Plan. BBS trend gives the 1995-2007 change in the smoothed population trend for England (or UK) using data from 1994 to 2008 (Risely *et al* 2009).

7.2 Declining Woodland Birds: Research Recommendations

HIGH priority research:	HIGH priority species for research:
1. Investigate changes in woodland management. **2. Investigate change in woodland structure brought about through deer browsing.** **3. For migrants, investigate processes occurring on wintering grounds or during migration.** **4. Investigate the impacts of climate change on woodland bird species.**	**Specialist residents** **a. Lesser spotted woodpecker** **b. Willow tit** **c. Hawfinch** **d. Lesser redpoll** **e. Marsh tit** **Long distance migrants** **f. Wood warbler** (and upland oak suite) **g. Tree pipit** **h. Spotted flycatcher** **i. Nightingale** **j. Willow Warbler**

1. Investigate changes in woodland management

A major driver of woodland bird declines is change in woodland management resulting in structures that may not be suitable for some priority woodland birds. In this research area, there is a need for a combined approach that measures bird responses to existing variation in management, to dedicated management trials and to emerging and potential changes to woodland management.

(a) Investigate change in woodland structure brought about through the cessation of active management – trial habitat management solutions

Cessation of active habitat management in woodlands has been identified as a driver of population declines for many woodland species and we consider research in this area to be of primary importance to deliver woodland bird recovery.

Habitat requirements of woodland species have been established using RWBS data and species prescriptions developed to guide management. Prescriptions now require testing in long-term, large scale, well monitored experiments that trial management techniques to benefit woodland species. Together with examination of existing variation in types and stages of management we need to use trials to understand:

- mechanisms for habitat quality effects e.g. prevention of nesting or foraging, displacement, competition, food declines, facilitation of predation?
- what stand structures can be produced through management, how they develop and the species composition that is likely to follow

Trial woodland management should appraise a range of possible woodland management systems and rotations to generate appropriate vegetation structures, habitats and timings to benefit a suite of species. The habitat value of past, current and potential woodland management approaches and systems (such as planned non-intervention, traditional coppice, coppice with standards, scrub, high forest, new woodland) should be evaluated and assessed in terms of how they provide high quality habitats.

We need an understanding of the scale of suitable habitat required, woodland layout and the phasing of management of compartments, rides and glades, related to the timing, location and size of habitat patches required. There is also a need to understand the interaction between woodland management and deer browsing in modifying woodland understorey structures and the consequences for habitat quality in woodland birds (see priority 2 below). Specific recommendations are outlined below:

- Establishing long-term, large scale and well monitored habitat management trial plots to monitor bird response to changes in woodland structure and to investigate the development of stand structures HIGH.
- In combination with the above, use existing variation in habitat management to measure bird response to woodland structural changes HIGH.
- In Western Atlantic oakwoods trial management to find suitable grazing regimes for Wood Warbler and other priority species HIGH.
- Investigation of sympathetic methods of PAWS restoration which could have effects on several species MEDIUM.
- If considered a primary driver for the decline, trial habitat management for the wetting up of formerly occupied woods to benefit Willow Tit. MEDIUM.

(b) Test delivery and effectiveness of grant schemes specifically targeted at woodland birds

Alongside assessing existing management and dedicated management trials, the effectiveness and delivery of grant schemes specifically targeted at woodland birds should be monitored in terms of the changes in habitat structure they produce and long-term changes in woodland bird composition HIGH.

(c) Studies on the impact of emerging forest management practices, including woodfuel.

Research into the impact of potential widespread changes in woodland structure due to management for wood fuel, or other economic pressures on woods, is also needed.

- Assessing the response of woodland birds to future woodfuel management implemented under the Forestry Commission's 'Woodfuel Strategy for England' HIGH.
- Demonstration of techniques of woodland management which deliver woodland birds and provide an economic return for woodland owners HIGH.
- Investigation of the opportunities of short-rotation willow coppice in woodland bird delivery MEDIUM.
- The impact of woodland development and structural change in the uplands MEDIUM.
- Studies on changes in bird communities in conifer plantations LOW.

2. Investigate change in woodland structure brought about through deer browsing

The consequences of deer browsing are similar to those of reduced woodland management resulting in increased shading because of canopy closure. As with management trials key questions are: what are the mechanisms for habitat quality effects; prevention of nesting or foraging, displacement, increased competition, food declines, facilitation of predation? We recommend that where possible, deer research should operate alongside woodland management trial research.

- Comparative and experimental studies to further investigate of the role of deer, in affecting breeding habitat quality for early successional species HIGH.
- Investigate the interaction between woodland management and deer browsing in modifying woodland understorey structures and the consequences for habitat quality in woodland birds HIGH.
- Research into how appropriate stand structures can be attained in the *presence* of deer would be particularly valuable e.g. through fencing or control methods HIGH.

3. For migrants, investigate processes occurring on wintering grounds or during migration

Investigation of the role of processes occurring on the wintering grounds in the population decline of Wood Warbler, Tree Pipit, Willow Warbler, Garden Warbler, Nightingale and Spotted Flycatcher are needed. Key recommendations are:

– Establish locations of core wintering areas HIGH.
– Investigation of habitat use and population processes in Africa and how these have changed would provide information on how wintering habitat may have impacted upon populations HIGH.
– Investigation of the role of continental-scale population processes in the British decline, and in some cases range contraction, of some migrants MEDIUM.

4. Investigate the impacts of climate change on woodland bird species

The impacts of climate change on most of the species considered in this review are as yet largely unknown. Further research into how changes in climatic variables influence populations, and how they might be predicted to do so in the future, is needed.

– Determine the direct effects of changes in temperature and rainfall on survival and productivity MEDIUM.
– Determine the Influence of climatic change on phenology, in the timing of migration and onset of egg-laying. MEDIUM
– Investigate changes in food resources operating through climatic change. This includes consideration of changes in winter food availability for resident species, alteration of the food resource in wintering grounds for long-distance migrants, and food availability for breeding birds – including mis-matches in timing for migrants MEDIUM.
– Investigate potential of climate change to increase incidence of disease MEDIUM.
– Investigation of changes in species distribution as a result of climatic changes MEDIUM.

LOWER priority research areas for declining woodland birds

5. Woodland fragmentation and landscape processes

The fragmented nature of woodland in the UK may continue to have a negative effect on the population status of declining woodland species, largely through interactions with other drivers of decline such as changes in micro-habitats and rates of predation. Research is needed to establish the role of fragmentation (i.e. woodland stand size, structure and distribution). There are two possible approaches to this. In the first, the current situation with woodland fragmentation in the UK could be used in comparative studies to determine the relationship between woodland block size and distribution (e.g. large blocks versus networks of smaller blocks) and the population viability of key woodland species. A second approach is to test the effectiveness of different methods and scales of woodland habitat creation, in maintaining populations of target woodland species. MEDIUM.

Related to the issue of fragmentation is the role of surrounding habitats (including agricultural and urban landscapes) to species in the woodland bird index – some of which are known to occupy a range of habitats, not only woodland *per se*. This area of research would need to address the role of different woodland types, including scrub, in maintaining bird populations in the wider landscape and the relationship with other habitat types.

– How woodland species use other habitat, such as hedgerows and other aspects of the agricultural landscape and the importance of these habitats in over-winter survival and breeding productivity. MEDIUM.
– Investigation into the role of landscape structure and landscape-level habitat availability for species associated with successional habitats such as Willow Warbler and Garden

Warbler and their role in metapopulation persistence and as a source of immigrants MEDIUM.

- Investigation of Lesser Spotted Woodpecker and Hawfinch use of the wider landscape at different stages of the year MEDIUM.

6. Drainage/drying out of woodlands

There is a need to establish the influence of soil moisture in the population decline of Lesser Spotted Woodpecker and Willow Tit (and potentially other species). Determine the mechanism for observed relationships between soil moisture and species presence e.g. relationships with food availability and/or nest site conditions. MEDIUM.

7. Predation

The role of predation as a mechanism for population change needs continuing consideration in order to help identify potential landscape management options for mitigation. Remaining research areas include:

- Identification of nest predators in woodland and continued research into the contribution of grey squirrel and jay is needed MEDIUM.
- Investigation of habitat-predation interactions e.g. predation risk in a range of woodland stand structures – to be addressed where possible in the management trials and deer research themes MEDIUM.
- Autecological studies should monitor predation, especially of Hawfinch and Lesser Spotted Woodpecker MEDIUM.

8. Food availability

Changes in food availability is likely to be the mechanism for negative effects of primary drivers such as climate change and changes in woodland management, and investigation of the this process in an integral aspect of much of the research priorities already listed. Following are recommendations for research specifically addressing food availability.

- Studies of invertebrate food resources in woodlands and how this changes with varying stand structure MEDIUM.
- Assessment of how food resources have changed over time or become mis-matched with species needs, for example through climate change. MEDIUM.
- Food availability for Willow Tit and Lesser Spotted Woodpecker may be linked to soil moisture content of woodland soils and this merits further study as part of a fuller investigation of soil moisture processes, as noted above MEDIUM.
- Investigations into the abundance of winter and summer food resources for Lesser Spotted Woodpecker are also required MEDIUM.

9. Demographic modelling to identify critical stages in the life cycle of declining woodland birds

Following the successful application of this approach to farmland birds, integrated analyses of productivity and survival data for declining woodland birds for which sufficient data exist could provide insight into whether effects on the breeding grounds (e.g. habitat change) or during the winter (e.g. in Africa for long-distance migrants) are most important. Although this has been done for some of the priority species such as Spotted Flycatcher, and Marsh Tit, there is a suite of moderately-declining species such as Garden Warbler, Pied Flycatcher and Dunnock for which this could be undertaken. This has been assessed as a medium/low priority because data for some of the more steeply declining species are very sparse but should be addressed when and if new data become available. MEDIUM

10. Competition

- Research into potential competition between Great Spotted Woodpecker and Lesser Spotted Woodpecker and between Willow Tit and Marsh Tit and other tits as part of autecological studies MEDIUM.
- Investigation of the impact of potential competition for high quality nesting territories between resident species and returning migrants LOW.
- The influence of nest box schemes in woodlands on community structure and competition LOW.
- Autecological studies comparing Willow Warbler and Chiffchaff to help establish any evidence for the role of competition in driving Willow Warbler declines LOW.

11. Impact of invasive plant species

Invasion by Rhododendron has resulted in sub-optimal habitat for species such as Wood Warbler in upland oakwoods. Investigate methods of removal and habitat restoration to create suitable habitat. LOW

PRIORITIES BY SPECIES

The evidence for the declines in the woodland species covered by this review comes from broad-scale long-term monitoring schemes, and clearly continued monitoring is required in order to continue to assess population status. For some of the less widespread species, monitoring could be improved through periodic special surveys (e.g. Nightingale, Hawfinch), by continuing to promote and expand existing schemes where possible (e.g. BBS) and by additional monitoring targeted at particular habitats.

Alongside continued monitoring and research on the potential drivers of decline, there is a need for specific autecological studies on habitat use, diet, productivity etc. To permit easier assessment of research priorities at the species level, we provide a list of research requirements on a species by species basis in Table 8.2.1 (below).

Table 7.1.1 Species-specific research requirements for wetland birds, listed in order of the magnitude of long-term trends as measured by BoCC, BAP and BBS*.

Species	BoCC	BAP	England BBS trend 1995-2007	Actions
Wood warbler	**Red**	**Yes**	**- 60 (UK trend)**	Investigation of factors operating on breeding grounds which may be associated with the decline, including the role of habitat change and invertebrate availability, timing and abundance. Trial management of grazing regimes in Western Atlantic Oakwoods. Investigation of habitat use and factors operating on wintering grounds.
Lesser spotted woodpecker	**Red**	**Yes**	**Not available**	Investigation of the species' use of the wider landscape and the role of landscape in local population persistence. Further investigation of correlates of breeding success. Investigations of the abundance of winter and summer food resources. Role of competition with and predation by Great Spotted Woodpecker in population declines. Establish influence of soil moisture in habitat occupancy.
Hawfinch	**Red**	**Yes**	**Not available**	Review the population status of Hawfinch and establish baseline population monitoring. Autecological study of Hawfinch ecology and breeding success including the role of nest predation
Willow tit	**Red**	**Yes**	**- 68**	Trial habitat management solutions – e.g. wetting up of formerly occupied woods. Further research into the role of soil moisture in population persistence e.g. relationship with food abundance and nesting opportunities.
Spotted flycatcher	**Red**	**Yes**	**- 41**	Trial habitat management solutions – e.g. the creation of edges and woodland glades. Analyses of habitat selection and persistence at the landscape scale Further investigation of the role of nest predators and the relationship between predation risk and adult behaviour. Investigation of factors operating on wintering grounds.

Species	BoCC	BAP	England BBS trend 1995-2007	Actions
Tree pipit	**Red**	**Yes**	**- 38**	Trial habitat management solutions in range of occupied habitat e.g. upland oakwoods, conifers. Further investigation into limiting factors operating on breeding grounds. Investigation of factors operating on wintering grounds.
Lesser redpoll	**Red**	**Yes**	**- 33**	Autecological study of Lesser Redpoll ecology and breeding success. Establish targeted population monitoring across range of habitats. Establish use of other habitats e.g. farmland and scrub and the importance of this in over winter survival and breeding productivity. Trial habitat management solutions – e.g. methods of PAWS restoration, development of stand structures and the continuity of food resources.
Marsh tit	**Red**	**Yes**	**- 23**	Trial habitat management solutions and the impact of deer– e.g. investigate methods of restoring understory. Investigate dispersal and role in very fragmented/isolated areas? Further monitoring of breeding success particularly with respect to climate change
Song thrush	Red	Yes	+ 24	Ecological study of the song thrush in woodland habitats Trial habitat management solutions – methods of creating and maintain shrub layers. Effect of deer and woodland management.
Bullfinch	Amber	Yes	- 13	The ecology of woodland Bullfinch populations The species use of internal and external woodland edges Investigate the role of predation in woodland populations of Bullfinch. Trial habitat management solutions – methods of creating and maintain shrub layers. Food availability for Bullfinch in different age stand structures.
Nightingale	Amber	No	- 37	Investigation of habitat requirements away from coppice Investigation of factors operating on wintering grounds. Habitat use on wintering grounds

Table 7.2.1 Continued.

Species	BoCC	BAP	England BBS trend 1995-2007	Actions
Willow warbler	Amber	No	- 32	Analysis of breeding data from different areas on the UK Autecological studies of Willow Warbler compared to Chiffchaff – establish any evidence for competition driving Willow Warbler declines. Effect of deer and woodland management. Trial habitat management solutions – e.g. methods of creating early successional habitats. Investigation of factors operating on wintering grounds.
Dunnock	Amber	No	+ 15	Research into Dunnock productivity in woodlands. Trial habitat management solutions – e.g. methods of creating early successional habitats.
Garden warbler		No	- 17	Analyses of changes in phenology in relation to Garden Warbler breeding success Analyses of changes in breeding success and survival Role of wintering grounds in population decline Effect of deer and woodland management Trial habitat management solutions – e.g. methods of creating early successional habitats Effect of deer and woodland management
Treecreeper		No	- 8	Further work on the ecology of Treecreeper in UK woodlands. Analysis of Nest Record Cards.
Jay		No	+ 4	Investigation into the link between beech mast years and population declines. Study into the ecology of Jays and the role of the species as a nest predator of other woodland birds to address questions such as how and where do they forage, how important are nests in their diet, and can management influence foraging behaviour and success?
Blackbird		No	+ 23	An investigation into the availability of earthworms in woodlands and the species use of woodland edges for foraging. Investigation into the role of predation in nest loss in woodland habitats.

Table 7.2.1 Continued.

Species	BoCC	BAP	England BBS trend 1995-2007	Actions
Goldcrest		No	+ 35	Targeted population monitoring to establish the true extent of decline (coniferous woodland bird survey). Analysis of nest record data Investigation into where key areas are across the country, in terms of habitats and regions.

Table 7.2.1 Continued.

*Areas of recommended research by species. Species are ordered in terms of their BoCC and UKBAP statuses and their short term BBS trends in England (Risely et al. 2009). Species in bold are priority species based on this criteria

7.3 References

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8. MAIN DRIVERS OF DECLINES - OVERALL CONCLUSIONS

8.1 Changes in Agricultural Land Use

Changes in agricultural land use is the primary driver for declines in farmland birds (see reviews by Aebischer et al. 2003, Newton et al., 2004) and this review of declines in wetland birds and the matrix analysis of the importance of these drivers also identified changes in agriculture – in particular issues related to drainage, use of pesticides and fertilizers, and changes in livestock stocking rates – as the key driver associated with population declines for species in the wetland bird indicator. Agricultural intensification encompasses a broad spectrum of concurrent practices including changes in crop types and cropping patterns, more intensive grassland management, increased use of pesticides and fertilizers, increased stocking rates, drainage and management of adjacent water bodies, changes in boundaries and margins, and specialisation leading to the loss of mixed farming systems. Birds using farmland for foraging or breeding will be impacted by all of these changes, and individual processes can be difficult to elucidate.

The exploratory analyses of wetland bird trends in chapter three confirmed the importance of agricultural land use on the populations of many wetland bird species. Declines were steeper in arable regions for Curlew and Snipe, and steeper for Sedge Warbler in areas with a higher proportion of arable land, than in pastoral areas. However, fine-scale analysis of the relationship between habitat and abundance for declining species showed that almost species were significantly less common in areas surrounded by farmland, especially where this was grassland, suggesting that pastoral systems may have lost populations of these species earlier. We also found a negative impact of local urban development and woodland area on breeding wetland birds with four and five species (of nine) being significantly scarcer in areas of increasing urban and woodland area, respectively.

Of the declining woodland birds, changes in agricultural land use were identified as a potential driver of declines only in the Song Thrush. However, given the large gaps in the evidence base for woodland birds, we cannot rule out the possibility of impacts on species such as Dunnock and Bullfinch, where a large proportion of the population occupies wooded areas of farmland such as hedgerows, scrub areas and small woods.

Drainage was the key driver implicated in the population declines of most wet grassland species, including all four waders, especially during the earlier parts of the time period, due to the resulting loss of breeding habitat in terms of quantity and quality. However, these effects are confounded with other processes such as increased use of fertilizers, pesticides, machinery and higher stocking rates on land that has been made drier, and the effects may be synergistic. Lowering of water levels allows stock and machinery to be brought onto the land earlier, which may increase breeding failure due to nest destruction and trampling. Drainage permits stock and machinery to be deployed earlier, increasing rates of nest and brood destruction, allows grasslands to be reseeded with more vigorous growing plant species which changes sward structure and reduces the availability of invertebrate prey, and can also result in direct loss of wet grassland through conversion to arable land. Drainage of farmland continues and the lack of sufficient wet areas through general lowering of the water table remains a significant problem for most of the declining wetland species included in this review.

Changes in grazing patterns was scored as the second most important driver in declines in the wetland species, and changes in stocking levels could have either positive (over-grazed) or negative effects (under-grazed). This is related to the impact of livestock on sward height and structure, and nutrient enrichment.

The increased use of fertilizers and pesticides was identified as another key driver in declines of wetland bird species. Fertilizers influence sward height and structure, and increased pesticide use has been shown to decrease the invertebrate food supplies available directly (by insecticides) or indirectly (by herbicides and reductions in insect food plants).

Other changes in agriculture, including destruction of nests of ground-nesting birds by farm machinery, changes in the timing of crop sowing, and destruction of nests due to trampling by livestock were identified as factors in wetland bird declines but with intermediate scores for importance. However, the impact of nest loss to predation, trampling and destruction by machinery may be higher than identified here, and information on chick loss (likely to have the most impact on populations) is scarce: hence a remaining gap in knowledge.

High priority research areas addressing this driver include: (i) Determine the role of semi-natural habitats / patches on the viability of key wetland bird populations, and (ii) Develop improved modelling approaches to identify critical factors and stages in life cycle

8.1.1 Priority conservation actions and gaps in delivery mechanisms

Polices or actions with major potential to address drivers associated with changes in agriculture include: (i) Biodiversity Action Plans (BAP) to maintain, restore and create key habitat such as grazing marshes, fens, lowland bog, (ii) protection of habitat through the SPA network, (iii) to maintain, restore and create habitat in Environmentally Sensitive Areas (ESAs), (iv) actions related to water management and abstraction, and (v) habitat improvements through the Higher Level Stewardship (HLS) scheme. The Entry Level Stewardship (ELS) and Upland Entry Level Stewardship (UELS) schemes, the BAP for coastal saltmarshes, and the Climate Change Act 2008 showed moderate potential to benefit a large proportion of the species assessed.

The Higher Level Scheme of Environmental Stewardship offers the best opportunity to address the negative effects of agricultural changes, as the scheme involves plans specifically tailored to individual sites and includes actions to ensure appropriate levels of grazing and water level management to improve and create habitat for breeding waders and other declining wet grassland species, as well as a suite of options aimed at providing foraging, breeding and wintering resources for a suite of declining farmland birds. The Entry Level Scheme, although broader-scale, offers less potential for wetland species as it includes less habitat creation and the options are mainly those relating to arable land (albeit valuable for enhancing conditions for many farmland species). Success using ES will depend on the details such as the appropriate spatial deployment of options, and their management throughout the season. Actions identified here focus on Environmental Stewardship, partly because this suite of options are already available thanks in part to research on farmland birds but overall, habitat restoration and creation, and better management of existing habitat, are key to reversing the declines in the wetland species. Collectively, the results highlight the importance of land use management on farmland for wetland birds overall, as well as for all declining farmland birds. Conservation measures that target wet meadow habitats will likely have the widest and most profound benefits for wetland species. Given the marked declines on arable land as well as the fact that five of the nine declining species are already less abundant in pastoral dominated landscapes, suggests that arable habitat should be treated as a priority for conservation action. The fact that the declines for most species are particularly pronounced in the Midlands suggests that this region warrants particular attention.

8.2 Changes in Woodland Habitat

Based on the breadth of its influence, maturation of woodland and the cessation of active management is the key driver of declines in woodland species, and has changed woodland structure to such an extent that 13 woodland species show evidence of this being a contributory or important driver of decline. Blackbird, Bullfinch, Dunnock, Garden Warbler, Marsh Tit, Nightingale, Song Thrush, Lesser Redpoll, Tree Pipit, Spotted Flycatcher, Willow Tit, Wood Warbler and Willow Warbler are all associated with early succession habitat, open areas within woodlands or to areas with low dense vegetation such as those created through coppicing and felling.

Fragmentation of woodlands and reduced connectivity may be an important contributory driver of decline for at least nine species, with Hawfinch and Lesser Spotted Woodpecker populations potentially most at threat through this process due to their requirement for large areas with suitable foraging areas. A number of woodland species (Goldcrest, Marsh Tit) show preferences for larger-sized woodlands and avoid woodlands below a particular size but mechanisms are likely to vary among species, including reductions in available resources and greater vulnerability to predators. The interaction with predation is particularly relevant because it is possible that even if woodlands are not currently becoming more fragmented, increased numbers of predators in fragmented woodlands (and those with a high proportion of edge) may be an important driver.

Deer impacts on woodland structure may be linked to the decline of eight species in the woodland indicator. Deer have increased dramatically in many areas of England and their impact on early succession habitats and reduction of low vegetation cover in woods may have reduced nest site availability and foraging areas for several species requiring this habitat – Blackbird**,** Bullfinch**,** Dunnock**,** Garden Warbler**,** Marsh Tit, Nightingale**,** Song Thrush and Willow Warbler. Deer-induced habitat changes may have also increased vulnerability to nest predation.

As for wetlands, continuing drying out of woodlands could be contributing to declines of Lesser Spotted Woodpecker and Willow Tit**,** which favour wetter woods. The drying of surface soils may also reduce the availability, and/or accessibility, of the key prey of species such as Song Thrush, as well as other ground-foraging species.

In this report we have tended to distinguish between farmland and woodland habitats but many of the declining species occupy both habitats (for example breeding in woodland and foraging on farmland). In fact there is a gradient between scrub and wood elements on farmland, to woodland edges and woodland habitat varying from open areas of recent felling to mature forest. Nevertheless, we detected little evidence of the impact of farmland processes on declining woodland species (Song Thrush being the exception) and woodland processes have not been much implicated in the declines in British farmland birds where the steepest declines have been experienced by species more associated with open farmland (Lapwing, Skylark, Yellow Wagtail, Corn Bunting). However, changes in woodland or scrub may have impacted on populations of Turtle Dove, Tree Sparrow and Yellowhammer.

High priority research topics include: (i) Identify the processes and quantify the impact of agricultural intensification and identify management solutions, and (ii) Investigate changes in woodland management., and (ii) Investigate change in woodland structure brought about through deer browsing.

8.2.1 Priority conservation actions and gaps in delivery mechanisms

Polices or actions with major potential for benefits for species affected by changes in woodlands include: (i) the Birds Directive, in particular the legal framework to meet BAP targets and provide habitat protection through the SPA network, (ii) the England Forestry Strategy, which aims to meet BAP and indicator targets, (iii) the UK BAP process and its species-specific actions, this list including ten of the woodland species and three farmland birds that also depend on woodland or scrub, (iv) the Woodfuel Strategy for England, and (v) the Habitat Action Plans (HAPs) for Lowland Mixed Deciduous Woodland, Upland Oakwood, Wet Woodland and Upland Birchwoods. Other policies such as the restoration of ancient woodland through PAWS, and the UK Woodland Assurance Standard have moderate potential to benefit a range of the declining woodland species.

Overall, we conclude that declines in many woodland species might be best addressed by species-specific actions through BAP, as well as more broadly through policies such as Environmental Stewardship options to enhance boundary features (hedgerow management, woodland fences, woodland edge management) and the creation, restoration and maintenance of woodland, scrub and successional areas. HLS offers the potential for more targeted woodland management including management of boundary features retention of ancient tress, and woodland creation, the latter beneficial to all woodland birds. EWGS offers grants for general woodland management targeted at a species or suite of species and has the potential to deliver recovery for many woodland birds where habitat is thought to be an issue. These provide most benefits to woodland edge species such as Blackbird, Bullfinch, Dunnock, Song Thrush and Spotted Flycatcher, whereas orchard options within ES will benefit species such as Hawfinch, Lesser Spotted Woodpecker, Jay and Spotted Flycatcher. The provision of successional / scrub areas should benefit Nightingale, Marsh Tit, Willow Tit and Willow Warbler, and Tree Pipit will benefit from habitat created through lowland heathland options.

There are gaps in conservation policies or actions for species associated with coniferous woodlands such as Lesser Redpoll, Goldcrest, Treecreeper and Tree Pipit, and relatively few options identified to benefit Wood Warbler and other oakwood specialists (apart from through species-specific BAPs and PAWS). EWGS and HLS are specific and more targeted than ELS. However, their success depends on the targeting of grants to key areas for specific species. Broad scale options such as woodland maintenance and restoration are likely to be of most benefit but, again, require careful targeting and monitoring of success. There are also many fewer options for non-BAP species.

8.3 Effects of Predators

The negative impact of nest predators was a cross-cutting theme, that also applies to farmland birds. In the matrix analysis, predation was identified as an important factor in declines of this suite of wetland birds. However, this partly reflects the attention focused on this issue, as well as the potential for strong local effects of predators evident in the literature. It should be noted that the effects of predation are likely to interact with the effects of other factors – in particular habitat modification – and affecting changes in these factors is likely to be more sustainable than broad-scale predator control. For the larger-bodied wetland bird species that nest on or near the ground, key nest predators are probably corvids and mammals. Patterns of predation may differ from those of many woodland species because of the more patchy distribution of nests (near wetlands and semi-natural areas) and the longer period over which the precocial chicks of waders are vulnerable to predation. There is a long list of avian and mammalian predators of both nest contents and of nesting adult birds, and further research on the ecology and behaviour of predators is a recommendation. The effects of predation are also likely to be influenced by factors such as disturbance.

Predation was identified as an important issue for nine woodland bird species, and potentially an important driver in the declines of Bullfinch and Spotted Flycatcher. Note that due to the arboreal locations of the nests of many species, they are influenced by a different suite of predators including Great Spotted Woodpeckers (on hole-nesting species), Jays and Grey Squirrel, as well as other corvids and a range of mammals. Despite other studies showing regional impacts (for example predation by Jays on Spotted Flycatcher nests) there was no evidence from the RWBS analyses that the presence of Jays was related to declines in any of the woodland species. The link between Great Spotted Woodpecker presence and declines in Willow Warbler is difficult to explain. The effects of predators such as Sparrowhawk, corvids and key predatory mammals are currently being investigated by BTO using site-specific information, but results are not yet available.

High priority research topic related to this driver include: Quantify factors related to the impact of predation on wetland birds and identify potential solutions

8.3.1 Priority conservation actions and gaps in delivery mechanisms

Breeding failure by predation was considered a contributory driver for nine woodland species and a primary concern for Blackbird, Bullfinch, Spotted Flycatcher and Wood Warbler. This is an area which is not well studied and critically studies rarely do any studies look at impacts at the population level. Corvids, mustelids, and grey squirrels and many other mammals are often implicated in nest predation issues but little evidence is available, and this remains a key gap in knowledge. Predation was also highlighted as an important factor in the declines of declining wetland species, but is not addressed specifically by any of the conservation actions (and hence a gap in delivery). Measures to mitigate this, including predator control, need to be considered, but only in the context of maintaining habitat in the best possible condition.

8.4 Climate Change

Climate change was identified as an driver in the declines of woodland birds, considered a contributory factor for nine of the declining species. Analyses of the RWBS data revealed that changes in winter rainfall and/or mean winter temperature were found to have significant effects on changes in numbers of Dunnock, Garden Warbler, Wood Warbler, Willow Warbler, Blackbird and Spotted Flycatcher. It is not yet clear what mechanisms are operating in these relationships, as this list includes migrant species not present in the UK during the winter.

However, climate change was not identified as one of the primary drivers in the declines of wetland birds, for which three different aspects of climate change effects gleaned from the literature were evaluated: droughts in wintering grounds, loss of coastal habitats to sea level rise and unpredictable summer rainfall. Despite not been identified as a key driver for wetland species, some negative impacts of climate change have been recorded. The severe droughts of the late 1960s in the Sahel wintering areas of British Sedge Warblers are known to have affected this species as well as other migrants (e.g. Whitethroats) and conditions on African wintering areas may continue to have a negative impact on a suite of migrant species (woodland, wetland and farmland) wintering in the more humid zones of West Africa, as well as the Sahel (Hewson and Noble, 2009). Clearly, factors operating outside the breeding season – on wintering grounds or stopovers – could be influencing declines in any of the long-distance migrants. Although some research has been initiated, it is yet to be determined whether the demonstrated effects of African wintering area on population trends in migrant species are due to changes in climate, changes in land use, or both. One of the declining wetland species – Redshank – could be negatively impacted by sea-level rise and other species that breed in coastal saltmarshes may be similarly affected. However, impacts as a result of climatic changes (increases in temperature or changes in rainfall) during the breeding season in Britain have yet to be shown for any of these wetland species.

Good evidence for climate change is lacking and this remains one of the key gaps in knowledge. It is also a rapidly changing situation, as the effects of climate change on birds are complex and linked with changes in other important drivers such as land use, invertebrate availability, and vegetation structure.

High priority research topics include: (i) Investigate the impacts of climate change on woodland bird species, and (ii) For migrants, investigate processes occurring on wintering grounds or during migration.

8.4.1 Priority conservation actions and gaps in delivery mechanisms

For mitigating against climate change, national and international policies such as the Climate Change Act 2003 offer the most direct mechanism for improvement through aims to reduce emissions. However, considerable work to mitigate against climate change effects through the creation and maintenance of habitat networks and corridors, protected areas, is under consideration. This is a very important and rapidly-growing subject, the details of which are beyond the scope of this report.

8.5 Effects of Changes in Water Quality

Species dependent on insects are susceptible to the effects of changes in water quality due to pollution, acidification and eutrophication. Although most of the declining species in the wetland bird indicator feed at least partially on aquatic insects in the water, emergent, or in associated wetland habitats, negative impacts of changes in water quality were not identified as a key driver for wetland species (with some specific exceptions). Dipper, one of the declining wetland species, is highly dependent on aquatic invertebrates in streams and there is good evidence of previous declines due to increased acidification as a result of afforestation in uplands. This is also potentially an important factor in Common Sandpiper declines. However, the effects of acidification should be lessening, albeit slowly, and this seems unlikely to be a major influence on current trends in the species. There is no evidence of other pollutant effects on the wetland species, and most of the fish-eating species known to be sensitive to pollution by organochlorine pesticides and mercury are increasing, possibly in recovery from effects half a century ago. Although no studies were found linking eutrophication of water bodies to changes in the abundance of any of the wetland bird species investigated, the effects of eutrophication remains a gap in knowledge. In general, species that feed mainly on vegetative matter are increasing.

The decline in the reed specialists (chapter three) is also a cause for concern; however this group includes only four species and data for only three of them were sufficient for analysis. Subsequent analyses could include habitat-specific patterns of abundance of other species found commonly in reed beds (e.g. Moorhen, Coot, Little Grebe) but which are not defined as reed specialists.

8.5.1 Priority conservation actions and gaps in delivery mechanisms

Based on these analyses, the Water Framework Directive showed little potential for benefit to wetland species overall but could have major potential for improving conditions for riparian species such as Dipper and Common Sandpiper. Species with specialist wetland habitat requirements should also benefit from HAPs for fens, reedbeds and lowland raised bogs.

8.6 Effects Due to Other Potential Drivers in Bird Population Declines

8.6.1 Hunting

Although two of the wetland bird species (Curlew and Snipe) and two farmland species (Grey Partridge and Turtle Dove) are hunted legally in the UK and elsewhere, and several woodland species are taken in large numbers by hunters in the Mediterranean, there is no evidence that hunting pressure has contributed significantly to the population declines of any species included in this study. Moreover, given current international efforts to reduce illegal hunting of migrants, expert opinion is that this impact should be lessening. Understanding of the impact of hunting and direct predation was identified as a gap in knowledge for woodland and farmland birds. More studies of hunting impacts on some of the declining wetland birds have been undertaken but the role that hunting has played in their declines has been poorly quantified.

8.6.2 Disturbance

Similarly, despite local effects of human disturbance of numbers of a range of bird species, there is little evidence that this has contributed to overall declines. Monitoring is currently underway on English uplands to assess potential effects of potentially increased disturbance as a result of open access legislation on numbers of upland species – particularly ground-nesting waders. The effects of disturbance (i.e. human disturbance in breeding areas) on populations of wetland or woodland birds remains largely unknown and this remains a gap in knowledge.

8.6.3 Invasives

It remains a possibility that populations of some of the constituent species in the indicators are influenced by other species, either through competition from other native species occupying the same habitats, or from the spread of introduced species. The latter includes the potential impact of introduced plants in woodlands and in water bodies, as well as the potential threats of introduced species such as Canada Geese and Ring-necked Parakeets. The spread of new species should be monitored, their impact assessed, and controlled where possible. The impacts of increasing numbers of Grey Squirrel and deer, both native and introduced, are particular issues already discussed above, and warrant further investigation. Changes in the proportions of native and non-native species following introductions and invasions are largely attributable to ultimate factors such as land use and climate change and are best addressed by research on the effects of changes in these parameters at the community level, whether in woodlands, wetlands or farmland.

8.6.4 Disease

Although currently hypothesised to be reducing populations of Greenfinch (one of the 19 species in the farmland bird index, albeit one that has increased markedly since the 1960s), we found no evidence that disease is impacting any species in the wetland or woodland indicator. Nevertheless, this remains a gap in knowledge.

8.7 Conclusions (and Caveats)

The aim of the reviews of studies of wetland and woodland birds was to identify potential causes of the declines, observed at the national level over the time period covered by the PSA indicator, of a suite of species in the wetland and woodland sub-indicators. In assessing the evidence, the following caveats should be kept in mind. Firstly, relatively few studies were based on national datasets; with the majority being auto-ecological research carried out at a local scale. Secondly, the reviews and the results of the matrix analyses are necessarily predominantly based on the published literature and hence can be biased by particular issues in prevalence at a certain time or in particular areas. This is particularly relevant to species whose occupation of breeding habitats may have changed over time (Redshank in salt marshes and in uplands; Yellow Wagtails on wet grassland and arable land; Reed Buntings in wetlands and on farmland) but where studies have focused on only one of the main habitats. Thirdly, the potential drivers can be divided into those which are ultimate causes and those which are proximate mechanisms. Hence, reduced food availability and lower productivity may be the mechanism in the decline, but the ultimate causes tend to be changes in the habitat due to human activity (changes in land management) or climatic effects. A fourth and important point is that the best evidence that particular ecological (or demographic) factors are influencing the national species decline is that these factors have changed over the time period covered by the population trends. Spatial variation in effects of a particular factor on bird abundance constitutes a much lower level of evidence, although it suggests a plausible cause. A final point is that the reviews and matrix analyses only cover the declining species in the wetland and woodland indicators, and hence miss potentially relevant results from work on stable or increasing species – such as Oystercatchers in wet grassland areas. On this issue, the wetland bird analyses that identify suites of species with similar population trajectories provide a useful starting point.

As noted above, changes in food availability and subsequent effects on survival and reproductive success are likely to be one of the main mechanisms for population declines, but not an ultimate cause in the same sense as loss or changes in habitat due to agricultural or forest management, or climate change. Hence, a high rate of nest predation cannot be regarded as a driver in population declines, but is instead the process through which an external factor such as increased numbers of predators, or increased rates of disturbance impact on the population. Low survival rates of granivorous farmland birds like Reed Buntings are ultimately caused by reductions in winter food availability on farmland and linked to loss of over-winter stubbles. Another key requirement for breeding birds is suitable nesting habitat, identified as a potential constraint for species that nest in the woodland under-storey, or for species such as Willow Tit that are dependent on decaying wood for nesting. A number of species exhibit natural fluctuations in populations driver due to dependence on key food sources such as beech mast or birch seed, but these are also unlikely to be responsible for the long-term underlying trends, and we do not discuss them further. Quantifying the provision of these resources (summer food, winter food and breeding habitat) is the approach taken in chapter 5 to assess the key limiting factors to populations of each of the species in the farmland bird indicator.

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