BTO Research Report No. 527

The Potential Implications for Birds of Reform of the Sugar Beet Industry in England

Authors

Simon Gillings, Phil W. Atkinson, Mike J. May, Robert J. Fuller

Report of work carried out by The British Trust for Ornithology

March 2009

British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU
Registered Charity No. 216652

British Trust for Ornithology

The Potential Implications for Birds of Reform of the Sugar Beet Industry in England

BTO Research Report No. 527

Simon Gillings, Phil W. Atkinson, Mike J. May, Robert J. Fuller

Published in May 2009 by the British Trust for Ornithology
The Nunnery, Thetford, Norfolk, IP24 2PU, UK

ISBN 978-1-906204-56-3

CONTENTS

Page No.

LIST OF TABLES

Page No.

LIST OF FIGURES

Page No.

Executive Summary

Sugar beet is a key crop in arable rotations in eastern and central England, and up until the early 2000s could account for up to 16% of farmland in its stronghold counties. The European Union sugar industry has been heavily criticised for its price support systems that maintained unfavourable market distortions. In 2006 the European Union began a major reform of the sugar industry. The broad aim of this review is to assess the extent to which farmland bird populations might be impacted by changes following industry reform.

We first review the current and future trends of sugar beet growing in England. Whilst the initial closure of two processing factories will lead to a significant decline in sugar beet growing in York and the West Midlands, remaining areas are likely to be largely unaffected. However, the longer term future is less certain since British planting of sugar beet will depend on its EU quota and the value of sugar beet to the grower. For the purposes of this review we assess the likely impacts of drives in efficiency and a reduction in sugar beet planting.

The distribution of sugar beet cropping within England could change as the least economically viable farms convert to alternative crops and the remaining quota is taken up by cooperatives who share the high harvesting overheads. Sugar beet will not disappear as a crop, but management changes such as non-inversion tillage and improved weed control are likely as farmers intensify to increase efficiency. Local losses of sugar beet are likely to be replaced with winter sown barley and oilseed rape, which will involve marked changes to rotations, herbicide application and reduced organic inputs (“tops” and manure).

A review of the farmland bird habitat associations literature found few studies in which sugar beet was considered explicitly. Some ground-nesting species (e.g. Stone Curlew, Lapwing, Skylark) are associated with sugar beet fields, but in general, few species show a positive association with beet in the breeding season. During the non-breeding season a wide variety of invertebrate-feeding birds are positively associated with sugar beet stubble fields. Internationally-important numbers of wintering geese are reliant on stubble fields post harvest. In the absence of strong direct effects, many species may be associated with beet through its effects in the rotational system, for example organic inputs and the likelihood of cereal stubble retention prior to the spring sowing of beet. Lack of evidence for this may simply reflect the fact that there have been few studies assessing such “carry-over” effects.

We reanalysed data from the BTO/JNCC Winter Farmland Bird Survey, the MAFF funded “Stubbles project” and data collected as part of a PhD to evaluate the significance of sugar beet in the landscape and typical patterns of habitat selection in comparison with winter barley and oilseed rape, the two most likely replacement crops. In all cases a wide range of species showed positive response to sugar beet stubbles, especially in late winter. In particular, invertebrate feeders were most strongly associated with beet and reached higher densities in beet than in likely replacement crops. These include migratory species for which Britain may provide critical wintering habitat.

We conclude that whilst the future trajectory of beet growing is unclear, it is unlikely to be upwards. We find a large number of species are positively associated with sugar beet, especially invertebrate feeders and geese during the non-breeding season, and that loss of beet or intensification and redistributing beet have the potential to negatively influence these species. Agri-environment schemes promoting bare patches in fields could mitigate the loss of beet as a breeding habitat. Any losses of beet in goose wintering areas will need to be carefully managed to prevent future farmer-goose conflicts. More broadly, maintaining viable populations of soil macro fauna in arable fields is critical and alternative means of turning organic matter into the soil may be needed if beet fields are lost.

1. INTRODUCTION

The steep declines in farmland bird populations between the 1970s and 1990s throughout north-west Europe are strong evidence that biodiversity can be strongly affected by changes within the agriculture industry (Pain & Pienkowski 1997; Krebs *et al*. 1999; Donald *et al*. 2001a). With the benefit of hindsight some of these impacts could perhaps have been predicted, but at the time they were unforeseen and it has taken intensive research to identify the causes of declines and to design industry-friendly mitigation measures (Grice *et al*. 2004). If we are to prevent repeats of this scenario we need to be better prepared and better able to assess trends within the agriculture industry before they impact upon biodiversity (Butler *et al*. 2007).

One area where biodiversity may be impacted by industry reform is in the sugar beet (*Beta vulgaris* L.) industry (Carter 2006). Rather than the advancements in crop breeds or management techniques that drove major agricultural change from the 1970s onwards, the expected changes in the sugar beet industry are due to economics. Since 1968 the Common Agricultural Policy has governed the EU sugar regime but whilst some sectors of the CAP were reformed in 1992, 2002 and 2003, the sugar regime has remained unchanged (Renwick & Revoredo Giha 2005). Up until the mid 2000s the European Union market was criticised for being highly distorted with a complex system of price support and national quotas. These maintained an industry which would be uneconomical in a free market, and was thought to cost EU consumers and taxpayers €5 for every €1 received by growers (Defra 2006). The EU proposed a variety of measures, the first of which was a cut in the EU quota in the 2006/07 season, with further cuts planned and changes to the price support mechanism. Already these quota cuts have seen reductions and even abandonment of sugar beet growing in some EU countries resulting in an overall 19% cut in EU plantings. It is estimated that by 2012/13 the EU will have moved from being one of the world's largest exporters of sugar beet to a net importer (Carter 2006).

In the UK most industrial sugar beet is grown in England where it accounts for 3% of farmed land (Defra June 2006 census). At this scale it is a relatively minor crop. However, at the regional and local scale it can make up a high proportion of land holdings (up to 17%) and its presence significantly changes the dynamics of the farming system. In such areas, reduction, complete loss or modification of growing practices have the potential to have significant impacts upon farmland bird populations. The aims of this review are four-fold:

- Assess the current and expected trends for sugar beet planting in England
- Assess the available evidence of any direct and indirect benefits of sugar beet for birds
- Assess evidence for linkage between sugar beet planting and population trends of breeding birds
- Identify necessary flanking measures such as AES options

With respect to the latter, Defra (2006) found "The environmental impacts of radical reform are likely to be mixed and localized. They do not constitute a conclusive argument for or against radical reform. Targeted and flanking policies may be required to minimize the problems and maximise the opportunities of reform, for instance in relation to biodiversity benefits of beet growing."

2. BEET PRODUCTION IN THE UK: HISTORICAL AND FUTURE TRENDS

2.1 Historical Context

Though beet has been grown in the UK since ancient times for animal fodder (a practise still underway in Scotland and parts of England), the UK has only had a major sugar beet industry since the 1920s. The first factory was built in Norfolk in 1912 with another 17 constructed in the UK in the 1920s. By the 1930s approximately 112,000 ha of sugar beet was grown annually in the UK (cited in Shrubb 2003). In world terms the UK was the ninth largest producer of sugar beet in 2005, accounting for 8.7 million metric tonnes (3.5%) of the total world production of 249 million metric tonnes (FAOSTAT 2007). This level of production lags behind that of the market leaders France (12.5% of world production), Germany (10.2%) and the USA (10.1%). In the UK the planted area peaked at *c*.200,000 ha in the early 1980s (Chamberlain *et al*. 2000, Defra statistics). The majority of sugar beet production is concentrated in England, and especially in East Anglia, the Midlands and Yorkshire/Humberside (Figure 2.1.1). Five counties regularly hold over 10,000 ha of sugar beet. Norfolk has both the highest area of sugar beet cropping and the highest percentage of its farmed land under beet (Table 2.1.1). According to Table 2.1.1, Telford & Wrekin and York both have a high percentage of beet cropping but this is because both are actually small unitary authorities and the actual areas of sugar beet are low.

2.2 Recent Developments and Future Trends

Since the peak in the 1980s the area of sugar beet grown in the UK has decreased by 40% to the 2006 level of 122,000 ha (Figure 2.2.1A). This downward trend in planting has been represented in all regions, but was slightly less pronounced in the Yorkshire and Humber region (Figure 2.2.1B), though this region only accounts for 10% of the national total. The substantial decline has been accompanied by 12 of the 18 factories closing in the 1980-90s and a further two (York and West Midlands) closing in 2006. Despite this there has been little recent change in the contribution the UK makes to world beet production: from 1990 to 2005 UK production accounted for between 3.3% and 4.3% of world production.

On 1st July 2006 a new EU sugar beet regime came into force and will last for nine years until 30th September 2015 (Carter 2006). In the UK it involves a price cut of 36% and a voluntary restructuring scheme aimed at reducing EU production by five million tonnes (>30%), both over a transition period of 4 years. The reductions are promoted by decoupling of price support and a reduction in the price. Farmers can get compensation at fixed but decreasing levels. In the first year of implementation (2006) these measures led to eight EU countries abandoning sugar beet production and there were cuts of 64% and 52% respectively in plantings in Italy and Greece compared to the 2005 season (Carter 2006). However, since then there has been reluctance to make further voluntary cuts leading the EU Commission to revise compensation in order to achieve a 13.5% reduction in 2007/08. If these measures are not successful the Commission will level mandatory cuts across the member states to reduce production surpluses.

The UK industry is said to be one of the most efficient and hopes to minimise planting losses by taking up the capacity created by other countries leaving the sector. Once the EU regime has been reformed the planting of beet in the UK should be governed by its EU quota and the market value to growers of beet for sugar Other factors could come to play. If carbon offsetting changes farmer behaviour, factors such as the number of tractor passes for spraying and distances driven to factory versus carbon fixation during growth may increasingly influence crop rotations. Initiatives to produce crop-based environmentally-friendly fuels driven by the need to reduce dependence on oil and mitigate climate change initially looked promising for the development of a biofuel industry based on sugar beet. However, recent worldwide food shortages, increases in commodity prices and drives for food security make that now seem less likely. Even Defra admit (2006), that taken together, these factors and others make it extremely difficult to predict by exactly how much the UK sugar beet industry will decline. However, some biofuel is produced at the main Wissington sugar beet factory and is integrated with the sugar processing. Currently 700,000 tonnes of sugar beet are used for ethanol production and this could increase (by two to three fold) if the economic benefits of joint sugar and ethanol production were such that biofuel plants were established within the other three factories.

2.3 How Will a Reduction in Sugar Beet Production be Manifested?

The following section considers how the agricultural landscape will change under a scenario of reduced sugar beet planting in the UK and is based on available literature and extensive discussion with an industry expert (M. May).

2.3.1 Changes in the distribution of sugar beet

At the large scale the closure of the West Midlands and York processing plants in 2006 is likely to lead to a significant reduction in sugar beet planting in surrounding farmland since it now falls outside of the 50 mile economic catchment areas of remaining factories (Figure 2.3.1.1). This is significant because farms further than 50 miles from a factory will not qualify for transport subsidies for distances greater than 50 miles, meaning they are less likely to be economically viable.

Though these closures represented a 33% reduction in the number of factories it only constitutes a 13.5% reduction in total production (M. May pers. comm.). Therefore, the remaining factories require a longer "campaign" (the period of factory operation and beet lifting) in order to process more beet per factory, perhaps up to 140-150 days, which could have knock-on consequences for beet management. For instance, to supply beet to the factories at the end of the longer campaign, farmers may store it in clamps until needed. Since beet stored in clamps looses sugar content, farmers may instead opt to leave the crop in the ground and only harvest it when needed. This practise of "just-in-time" harvesting is already on the increase. However, late harvesting can be problematic on heavy soils due to water logging. As a result there may be a shift towards lighter soils where late harvesting problems are reduced. On the other hand, heavy soils retain water better in spring giving a boost to growing beet, permitting an earlier harvest and a quicker turn around for the next crop. Typically, the next crop would be wheat which also fairs better on heavy soils. Wetter autumns due to climate change would also drive a shift to lighter soils.

At the local scale the distribution of sugar beet may shift because the narrower profit margins associated with some outcomes of the new regime could see quotas shift from the least efficient to the most efficient farmers (Defra 2006). Also, beet farmers may aggregate into cooperatives because beet has one of the highest production costs and few farmers have the necessary equipment. This could see beet become spatially aggregated.

2.3.2 Changes in beet management

It is extremely unlikely that beet will completely disappear from English farmland, but what remains may be managed in a different way:

- to accommodate late harvesting and counter problems on heavy soils and wetter winters, farmers may increasingly adopt non-inversion tillage methods because they promote water movement in the soil.
- currently, weed control is highly variable between farms. A move towards cooperatives is likely to result in a homogenisation of weed control. This does not necessarily mean weed-free fields, but the extremes of weediness may be lost.
- though they are more distant from factories, coastal areas suffer fewer frost days meaning beet can be left in the ground later. If the campaign were to lengthen, factories might be in favour of retaining growers who can keep the crop in the ground towards the end of the lengthened campaign.

- interest in organic beet production was short lived and effectively ceased in 2004 (M. May pers. comm.). However, restructuring of the beet industry could again see interest in organic methods.
- as with organic techniques, restructuring and the likely shift towards even greater efficiency might well see a resurgence of interest in genetically-modified sugar beet, including herbicide tolerant (GMHT) varieties.
- whist the EU-lead restructuring programme relates to sugar production, it does leave farmers the option to grow sugar beet for the biofuel industry. Currently, there is only one factory capable of producing biofuel and interest is very much market dependent. In terms of management, however, beet used for biofuel is currently identical to beet used for sugar production. Projects to develop biofuel beet varieties are in their infancy so it is uncertain whether any changes in production methods might be on the horizon.

2.3.3 Changes in cropping

Loss of sugar beet and its stubbles aside, other changes in the landscape may be expected as other crops replace beet either directly or at different points in the rotation. Renwick and Revoredo Giha (2005) performed a multi-product cost model of the likely implications of three scenarios of varying quota and price support in eastern England. Whilst the conclusions differed slightly depending on soil conditions, and on whether change was accomplished by a reduction in quota or price support, the general pattern was for some sugar beet to be replaced by a combination of winter wheat, oilseed rape and potatoes. Whilst this study is informative in that it goes on to discuss the balance of changes in soil conditions and chemical and water inputs, the basis of its predictions is limited to financial costs. It seems to ignore other agricultural decision making processes, such as the importance of break crops. So whilst Renwick and Revoredo Giha (2005) note that loss of sugar beet will remove the benefit it provided as a break for pest and disease control they do not consider whether farmers will base their planting decisions around alternative break crops. So whilst winter barley may be the most economically viable crop, consideration of the importance of break crops could push farmers more towards oilseed rape crops.

Sugar beet is the second most widespread spring crop (after barley) and can provide a large area (as much as 16% of cropped land) of sparsely vegetated fields in spring. Replacing sugar beet with a winter sown break crop will markedly change the availability of this resource for birds in spring. Moreover, spring cropping facilitates the retention of over-winter stubbles, so a further consequence of the replacement of spring sown sugar beet by autumn sown barley or oilseed rape is a reduction in the area of over winter stubble.

Late harvested sugar beet is often placed on light soils and many growers automatically opt for spring barley as their next crop. Loss of sugar beet would lead to less interest in planting spring barley.

2.3.4 Management implications of crop changes

A shift from sugar beet to other crops is likely to change farm management in a number of ways. One of the main implications will be fertiliser related. After harvest, sugar beet tops decompose gradually in the soil and act as an important source of nutrients to the following cereal crop. Unless alternative break crops provide similar organic inputs an increase in inorganic fertiliser will be required. Moreover, 25-30% of all beet crops have manure applications and beet offers the best point in the rotation to apply organic fertiliser. A reduction in sugar beet planting is likely to result in a reduction in organic fertiliser inputs and a compensatory increase in inorganic fertiliser applications.

To exacerbate this, compared to beet, all the likely alternative arable crops have higher inorganic nitrogen requirements (CSL 2004, cited in Renwick & Revoredo Giha 2005). Therefore, it seems likely that the application of inorganic fertilisers will be much increased with possible implications for flora and water quality. In contrast, beet has the highest herbicide load (measured as area treated) so a switch from beet to winter barley or oilseed rape will see a reduction in herbicide applications. Since beet is a broad-leaved crop it too can be damaged by herbicide applications after the crop has emerged. For this reason, many beet fields are sprayed with broad spectrum herbicides early in the season before the beet crop has emerged. Switches between crop types will therefore see a switch in the type, effectiveness and timing of herbicide applications. Changes in crop rotation and applications of nitrogen and phosphorus have also been shown to affect both boundary and crop vegetation (Kleijn & Verbeek 2000, Marshall et al. 2003) and the number of herbicide applications in the preceding crop strongly influences the subsequent use of stubbles by granivorous passerines (Robinson 2003). Ultimately, a switch from spring-sown sugar beet to winter sown cereal will probably see a reduction in the number of applications of herbicides, but these applications are more efficient at controlling broad-leaved weeds. The effects on oilseed rape are harder to predict because whilst rape out competes most weeds the main herbicide used on oilseed rape, Atrazine, has recently been banned and alternatives may require a greater number of applications that may be less effective.

3. REVIEW OF ASSOCIATIONS BETWEEN BEET AND BIRDS

There are two main mechanism by which birds may be associated with sugar beet. Firstly, bird species may be directly associated with sugar beet because its presence directly offers nesting sites, foraging resource, opportunities for roosting or predator avoidance. Secondly, there may be *indirect* associations where the presence of the crop in the rotation affects the availability of other resources. It is worth noting at this point that very few studies have specifically considered associations and responses of birds to sugar beet. It is unclear whether this is because it is, or is perceived to be, of little ecological value to birds, or whether its low national availability limits its potential for analysis.

3.1 Direct Associations During the Breeding Season

During the breeding season birds may use sugar beet fields mainly as foraging or nesting habitat. Relatively few species considered as 'farmland birds' commonly nest in fields; most nest in rough vegetation and scrub which, in the farmed environment, correspond to margins and hedgerows. However, for those species that prefer open short vegetation for nesting, such as Stone Curlew *Burhinus oedicnemus*, Lapwing *Vanellus vanellus* and Skylark *Alauda arvensis*, spring sown crops such as sugar beet offer potential nesting habitat in areas that are otherwise dominated by tall dense autumn-sown cereals. On farmland (i.e. excluding those on semi-natural grass and heathland) sugar beet was the most important crop in terms of number of Stone Curlew breeding attempts and spring crops together accounted for 48% (Green *et al*. 2000). In the East Anglian Stone Curlew population, where sugar beet is currently grown, any loss of sugar beet, unless replaced by a spring sown crop, could be detrimental due to loss of nesting habitat. Similarly, Lapwings require areas of short vegetation for nesting and a strong association is shown for nesting in spring tillage adjacent to grassland (Wilson *et al*. 2001). Loss of sugar beet would see a further shift from spring to autumn sowing which could be detrimental to Lapwings breeding on arable land by further reducing the availability of nesting habitat. Additionally, the likely trend towards grouping of sugar beet growers would suggest the future potential for sugar beet fields adjacent to pasture to be limited. The area where this was most likely to take place would have been the mixed agricultural landscapes of the Midlands. The loss of sugar beet from the Midlands is likely to mean that few farms will have the juxtaposition of spring-cropping and pasture that Lapwings prefer.

The national BTO Breeding Skylark Survey (Browne *et al*. 2000) found densities on root crops (a category that included sugar beet, potatoes, carrots, onions and other root crops) intermediate between autumn-sown cereal crops and spring-sown cereal crops. The small area of root crops and spring-sown cereals meant they only accounted for 5% and 4% respectively of the national population which is small in comparison to the 34% accounted for by autumn-sown cereals. Chamberlain and Gregory (1999) also found some positive associations with unspecified root crops though they concluded that this was due to a general association with arable farmland than with the crop per se. Toepfer and Stubbe (2001) found relatively high densities of Skylarks in sugar beet in late spring/summer, perhaps because they had moved from dense cereal crops. They discuss this in relation to a similar preference shown by Jenny and avoidance by Busche (1990 and 1989 respectively, both referenced in Toepfer & Stubbe 2001).

Most multi-species studies of breeding farmland birds consider sugar beet within the broader category of spring sown crops making it difficult to assess the crop-specific value of sugar beet alone to the farmland bird community. An example of this is the study by Mason and Macdonald (2000) in which habitat associations were examined for eight farmland birds (Turtle Dove *Streptopelia turtur*, Skylark, Yellow Wagtail *Motacilla flava*, Whitethroat *Sylvia communis*, Lesser Whitethroat *S. curruca*, Linnet *Carduelis cannabina*, Yellowhammer *Emberiza citrinella*, Reed Bunting *E. schoeniclus*). Skylarks, for example, reached highest densities on set-aside, followed by spring-sown crops, then autumn-sown crops. However, when crops were considered individually, densities on sugar beet were lower than on any of the autumn-sown crops. For none of the eight species was there strong selection for sugar beet crop in territories.

Kragten and de Snoo (2008) present mean densities for five species across a range of crops, including sugar beet. Lapwing, Skylark, Quail *Coturnix coturnix*, Yellow Wagtail and Meadow Pipit *Anthus pratensis* all occurred at intermediate density on sugar beet fields. Green *et al*. (1994) considered how the crop type abutting hedgerows affected their occupancy by a suite of 18 bird species. On average, sugar beet was ranked sixth lowest, though for Blackbird, the only species considered individually, occupancy was ranked third above cereals.

In summary, few species show a strong association, or achieve high densities, in sugar beet crops in the breeding season, though the ability to assess this is limited by the tendency for authors to subsume sugar beet within broader categories such as "spring crops" or "root crops".

3.2 Direct Associations During the Non-breeding Season

After harvest, beet "stubbles" (also called "aftermath") have the potential to provide an important winter feeding resource for farmland birds: remains of leaves and tops may be attractive to herbivores in their own right; the invertebrates that feed on them may be attractive to invertebrate feeders; and beet stubble fields may have high densities of the broad-leaved weed seeds that are common in the diet of many granivorous passerines (Wilson *et al*. 1996). Many of these weeds, notable Fat-hen (*Chenopodium album*) are closely related to beet and therefore difficult to control with herbicide applications. However, licensing and uptake by farmers of genetically modified herbicide-tolerant (GMHT) sugar beet could change this situation markedly. Watkinson *et al*. (2000) modelled possible changes in *C. album* seed densities and subsequent impacts on Skylark trends with a switch to GMHT sugar beet. Under certain management scenarios the loss of weed seed could be significant with severe population consequences for Skylarks, and presumably other granivorous passerines. Use of GMHT beet could be seen as one way to improve efficiency within the beet industry, and depending upon the outcome of management decisions, could result in a decrease in weed seed for farmland birds. The precise management options are important, however, since the timing of herbicide applications can be optimised for both yield and biodiversity with significant financial savings (May 2003).

The main limitation to the potential that beet stubbles offer to wintering birds is the short period during which they are available. In many areas beet stubbles are ploughed in soon after harvest so offering a very narrow window for their use. However, the fact that beet is often lifted gradually due to bottlenecks at factories means that beet stubbles are present somewhere in the landscape over a protracted period throughout the mid to late winter period (see section 4.2, 4.3). This period, the so-called "hungry gap", is when seed resources may be especially limited elsewhere (Siriwardena *et al*. 2008) .

As with sugar beet crop, very few studies explicitly consider sugar beet stubbles. Most instead opt to subsume them within broad categories such as "other stubbles" or "broad-leaved crops", or consider agricultural systems lacking sugar beet crops (e.g. Wilson *et al*. 1996). An exception is that of Vickery and Atkinson (2003) that took place in the Breckland area of eastern England and found higher densities of finches and sparrows on sugar beet stubbles than on cereal or linseed stubbles. Only oilseed rape stubbles were comparable in density. The highest densities of thrushes and Starling *Sturnus vulgaris* were also found on oilseed rape and sugar beet stubbles. The use of a stubble field by granivorous farmland birds was highly dependent upon the quantity of seed in the field, which varied more between fields than between crop types (Robinson 2003; Vickery & Atkinson 2003). Nonetheless, compared to cereals, linseed and rape, beet fields tended to have the highest density of weed seeds, many being those of broad-leaved weeds (Vickery & Atkinson 2003).

In terms of individual species, Donald *et al*. (2001) found particularly high densities of Skylarks in sugar beet stubbles and Gillings and Fuller (2001) found they used sugar beet stubbles more than expected by random settlement during early and mid winter. After Skylark, Dunnock *Prunella modularis* was one of the most frequently encountered species in beet stubbles in East Anglia during the 1980s (R. Green pers. comm.). In a study in the heart of the sugar beet growing region, Golden

Plovers *Pluvialis apricaria* and Lapwings both preferentially selected sugar beet stubbles over other arable habitats for diurnal foraging during November to January (Gillings *et al*. 2007) and for nocturnal foraging throughout the winter (Gillings *et al*. 2005). These fields were also frequented by large numbers of Meadow Pipits *Anthus pratensis*, Pied Wagtails *Motacilla alba,* Starlings and winter thrushes (S. Gillings pers. obs.). See section 4.3 for further analysis of these data.

Aside from the invertebrate and seed-eating farmland bird species, one group of well studied species is the geese and swans. Many of the north-west European countries that have large areas of sugar beet are also recognised as internationally important for the populations of migratory geese and swans that they support. Formerly these species were associated with coastal marshes and grasslands but at least from the latter half of the 20^{th} century they began to switch to use intensive agricultural crops including winter sown cereals and the post-harvest remains of sugar beet (Ellis & Frye 1965; Lippens 1982; Mayes 1991; Gill 1994, 1996; Nilsson 1997; Nilsson & Persson 1998, 2000; Nolet *et al*. 2002, 2006). At least 50% of the Great Britain wintering population of Pink-footed Geese *Anser brachyrhynchus* relies on the sugar beet stubble fields in Norfolk (Banks *et al*. 2006) and it is thought that the spread of this species in Britain can be attributed to cultural learning of sugar beet as a food resource (Gill *et al*. 2008). For Greenland White-fronted Geese *Anser albifrons flavirostris* sugar beet stubble represented the most profitable food on offer in an Irish study site (Mayes 1991), though use of beet by geese in Ireland does not appear to be widespread and is mainly confined to mid winter with birds generally preferring intensively managed grass pastures (Fox *et al*. 2005, 2006). Beet for sugar is no longer grown in the Republic of Ireland, though some is still grown for animal fodder.

Significant loss of sugar beet from East Anglia could have serious implications for Pink-footed Geese, not least because it would result in c150,000 geese looking for alternative feeding areas. If factories use coastal sugar beet farmers as a late winter supply these geese could be presented with a shortage of harvested fields in early winter. Geese will, on occasion (Gill pers. comm.), consume the tops of unharvested beet but would more likely overflow onto autumn-sown cereals. These changes would bring a significant number of geese into conflict with farmers. To some extent, conflict can be managed using the modelling results of Gill (1994). If sugar beet fields are to be lost, losing those more distant from roosts and nearer to roads (i.e. more disturbed) would probably minimise the impact on geese and thus on cereal farmers (Gill pers. comm.). Also, the timing of harvest of different fields could be coordinated to provide a food resource throughout the winter.

3.3 Indirect Associations with Sugar Beet Systems

Fitting sugar beet into the arable rotation has certain consequences that are beneficial to birds. Foremost is the potential for cereal stubbles to be left over-winter until the field is needed for sowing with sugar beet in March. Potentially, sugar beet regions could have a greater availability of cereal stubbles which could be of great benefit to granivorous passerines. This potential may not always be realised, especially in heavy soil areas where farmers might opt to plough the stubble before winter to allow frost action to help break up the soil to create a better seed bed. Any change from spring-sown sugar beet to autumn-sown alternatives such as oilseed rape can only further reduce the availability of over-winter stubbles. This will have knock-on negative consequences for population trends in granivorous passerines (Gillings *et al*. 2005) that are likely to be exacerbated by the loss of set-aside stubbles from 2008 onwards.

Upon harvesting, a large volume of organic matter (leaves, tops) is ploughed into the soil, increasing the organic matter content of the soil and providing a more favourable environment for invertebrates such as earthworms. Furthermore, the addition of farmyard manure as part of the sugar beet rotation will also benefit soil invertebrates (e.g. Edwards & Bohlen 1996) with potential benefits for invertebrate-feeding birds such as plovers and thrushes. Several studies show benefits of manure application for invertebrate feeding birds (Tucker 1992; Gillings *et al*. 2007) but very few studies have investigated the effects of previous cropping. Contrary to expectation, Gillings (2003) found a positive correlation between field occupancy by Lapwings and Golden Plovers and the number of years of consecutive cereal cultivation (i.e. no break crops). Tucker (1992) showed that the presence of an oilseed rape break-crop in the previous year influenced field use by Black-headed Gulls *Larus ridibundus*. Slug damage to cereal crops is greater following oilseed rape (Glen *et al*. 1993, cited in Frank 1997) hinting at greater abundance of slugs. Similar effects may occur following sugar beet but the fact that oilseed rape also shows a carry-over effect suggests that, in this respect at least, replacement of sugar beet by oilseed rape will have limited impact on soil macrofauna and their predators.

4. ANALYSES

The preceding review of associations produced mixed results, partly because there has been a tendency for authors to subsume sugar beet crops and stubbles in broader categories thus masking any positive or negative associations. Three BTO archive datasets offer the possibility to re-evaluate the importance of sugar beet for farmland birds. Each of these datasets are dealt with in turn in the following sections. For some of these analyses it was necessary to subset the data into those sample squares falling within the region where beet is produced. This "beet growing region" was defined using the Defra agricultural census data to identify the contiguous block of counties and administrative areas with sugar beet cropping (Figure 2.1.1). The counties encompassed by this region span a range of sugar beet growing, from those such as Norfolk with 16% of cropped area under beet to Bedfordshire with just 1%. Furthermore, there were areas of these counties with no sugar beet and others with high densities of beet. Both these features facilitated analyses of the associations between beet farming and bird populations.

4.1 Winter Farmland Bird Survey Analysis

4.1.1 Data source and methods

During the winters 1999/2000, 2000/01 and 2002/03, a stratified random sample of 1093 1-km squares in lowland Britain were surveyed for a suite of farmland birds and their habitats to assess associations (Gillings *et al*. 2008). Of these squares 338 fall within the beet growing region. Even within the beet region, the prevalence of sugar beet stubble within these squares was low: only 65 (19%) squares had sugar beet stubbles on at least one visit. Of the original 30 species surveyed under WFBS, six were too scarce in this subset of squares to be used (Brambling, Curlew, Lesser Redpoll, Snow Bunting, Stonechat, Twite and Woodlark occurred on less than 10% of squares).

The influence of sugar beet stubble on farmland birds in winter was tested with a series of models aimed at understanding associations at different scales. Since WFBS squares were visited multiple times, both within and among winters, an autoregressive repeated measures generalised linear modelling approach was taken to account for temporal autocorrelation of counts. An initial analysis tested for spatial autocorrelation. Here we modelled the mean count for a species across visits in relation to easting and northing (linear and quadratic predictors) to first remove any surface trend. Residuals from these relationships were tested for significant spatial autocorrelation using Moran's I (SAS Proc Variogram, SAS Institute). Significant spatial autocorrelation was detected for only three species, Grey Partridge (Moran's I = 0.011, $P = 0.011$), Redwing (Moran's I = 0.021, $P < 0.0001$) and Mistle Thrush (Moran's I = 0.013, $P = 0.007$). For these three species model results should be interpreted with caution.

In the first analysis the simple presence of beet stubble in a square was related to the presence, and subsequently the abundance, of bird species in the square. The former analysis used an event-trials syntax, the latter used either a Poisson or a negative binomial error structure to accommodate the highly skewed bird counts. The choice of which error structure to use was determined by running an initial exploratory model without repeated measures and assessing the model fit on the basis of deviance/degrees of freedom. The model structure with deviance/degrees of freedom closest to 1 was re-run with repeated measures.

Having identified any effects of sugar beet on square occupancy by a given species, field scale-models were run on a subset of squares that had been occupied by the species at least once over the three years. In this way we aimed to broadly restrict the sample of squares to those within the species' range thus removing large numbers of squares where no fields were ever occupied by the species (e.g. they were outside the range). We then modelled the density of each bird species in each field according to whether or not the field contained sugar beet stubble. As earlier, models were first formulated without repeated measures to determine the appropriate error structure before then using a more robust structure to account for repeated visits within and among winters.

The WFBS dataset offers the potential to assess the likely implications of swapping beet stubbles for the likely replacements winter barley or winter oilseed rape. This is only limited by the difficulty of separating young barley and wheat crops in the field. A further set of field scale analyses was performed in which fields were classified as beet stubble, cereal crop, cereal stubble, rape crop or rape stubble. All parameter estimates were produced relative to beet stubble, so habitat parameters that were significantly different from zero indicated densities that were significantly higher or lower on a given habitat type compared to beet stubble.

4.1.2 Results

A simple test of whether bird occupancy and abundance in 1-km squares was influenced by the presence of sugar beet stubbles revealed significant positive effects for seven species (Skylark, Pied Wagtail, Mistle Thrush, three finches and two buntings). For these species the likelihood of occupancy of squares was 7-15 percentage points greater if sugar beet stubbles were present than if not (Table 4.1.2.1). Four of these species (Pied Wagtail, Chaffinch, Greenfinch and Yellowhammer) also occurred at significantly higher density in squares with sugar beet than those without (Table 4.1.2.1).

At the field scale only three species had densities in stubble fields that were significantly different from all other field types, though this low number is not surprising given the breadth of habitat types this comparison involves. Nevertheless, Pied Wagtails reached densities up to seven times higher in beet stubble fields than elsewhere (Table 4.1.2.2). Bullfinch densities in beet stubble fields were only 20% of those on other field types.

A more useful comparison is that of densities in beet stubbles relative to the two crops (and their stubbles) that are most likely to replace sugar beet, namely cereal and oilseed rape. Table 4.1.2.3 shows the results of GLMs testing differences in bird densities and shows that for 17 of the 21 species for which models could be produced there was a significant difference in density among these five field types. In all 12 species in which densities on beet differed from densities on cereal crop, beet came out higher. Of five species for which significant differences were found for cereal stubble, only one (Skylark) achieved higher densities on cereal stubble, the remainder being higher on beet stubbles. Fourteen species had significant differences for rape crops and all but one (Bullfinch) had higher densities on beet. Finally, results for rape stubble were mixed; two species achieved higher densities on rape stubble, three on beet stubble (Table 4.1.2.3).

4.1.3 Discussion

The incidence of sugar beet on WFBS squares was very low but still allowed for some assessment of bird associations in subsets of squares. The species showing the clearest evidence of preference for sugar beet at multiple scales was Pied Wagtail. This small invertebrate feeder presumably makes use of the flies and beetles associated with decaying beet tops, and may consume small earthworms in wetter fields. It is surprising, however, that Meadow Pipit did not show a similar response since they are often seen in mixed feeding flocks.

Whilst there is little evidence for outright preference for sugar beet, a large number of species reached higher densities on sugar beet stubbles than either of the crops most likely to replace it in rotations. No species reached higher density in cereal crops, one in cereal stubbles, one in rape crops and two in rape stubbles. These results suggest that replacement of beet with cereals or rape, which would most likely result in increased area of their crops in winter, would be detrimental to a diverse range of species. If management maintains a proportion of cereal or rape stubbles over winter the impact is lessoned because whilst few species reached higher densities in these stubbles, densities were at least rarely significantly lower than on beet stubbles.

4.2 MAFF Stubbles Project

4.2.1 Data source and methods

During the harvest season of 2000/2001 a MAFF funded project investigated the birds, weeds and management of stubble fields in East Anglia. From harvest until ploughing, 169 fields of five main crop types (barley, wheat, linseed, oilseed rape and sugar beet) were monitored (Vickery *et al*. 2002). This study did not record habitat or birds across all habitat types (e.g. cereal crops or bare till) so it is not possible to investigate absolute use of beet stubbles relative to all agricultural habitat types. However, cereal stubbles are widely cited as being highly selected by a range of farmland bird species (Wilson *et al*. 1996; Moorcroft *et al*. 2002) so considering use of beet stubbles relative to cereal stubbles is informative. The dataset also offers the possibility to investigate the availability and longevity of sugar beet stubble fields.

Fields were surveyed once every c.2 weeks from harvest until ploughing. On each visit all stubble fields in the study area were surveyed for birds using the whole area search method (Robinson 2003), providing complete counts of birds in fields (but excluding field boundaries). The original study aimed to consider all stubble types and therefore began in July when the first fields were harvested and ran through until late February when the last stubble field was ploughed. To evaluate the contribution that beet makes to the seasonally changing farmland landscape we first show stubble availability throughout the summer, autumn and winter, before concentrating the analysis on the winter period when beet stubble is available.

Sixty two bird species were recorded but we concentrate on three functional groups – granivorous passerines (Skylark, Woodlark, House Sparrow, Tree Sparrow, Chaffinch, Greenfinch, Goldfinch, Linnet, Reed Bunting and Yellowhammer); large invertebrate-feeding passerines (thrushes and Starling) and small invertebrate-feeding passerines (Meadow Pipit and Pied Wagtail).

A broad assessment of beet stubble use relative to other stubble types was performed using compositional analysis (Aebischer *et al*. 1993) to derive rankings of habitat use, taking into account habitat availability. For this analysis the total number of birds in each species grouping was calculated for fields of each stubble type during each visit period. These were then expressed as a proportion of the total for that visit period. Similarly, proportional stubble area was calculated for each stubble type in each period. Zero values were replaced with a value one order of magnitude smaller than the smallest proportional habitat area (in this case 0.001). Tests of the degree to which observed rankings differed from random choice were computed by randomisation.

Next, generalised linear models were used to test for differences in a) probability of occupancy, b) species richness and c) density between different stubble types. The models were run separately for each visit period so as to evaluate seasonal patterns of habitat association. For a), each field was coded according to whether it was occupied on a visit by at least one individual of any species from the given functional group. For b), each field was scored according to how many species of the functional group were present on each visit. These data were analysed using an events-trials syntax with trials = 1 for a) and trials = the maximum number of species in the functional group for b). Thus b) tested whether sugar beet was more likely to hold a greater proportion of the species of a particular functional group than other stubbles. For analysis c) counts summed within a functional group were analysed using Poisson regression with log of field area as an offset so as to model bird densities. For all three analyses separate models were created for each 2-week period since stubble use may change through the season owing to depletion and changes in the alternative resources available.

4.2.2 Results

Analysis of habitat availability showed that sugar beet stubbles were not available in any significant quantity until early November and peaked at 200 ha. This is approximately half of the peak availability of barley, wheat and rape stubbles (Figure 4.2.2.1A). There was a clear difference in the seasonal pattern of availability and turnover of stubble types. Whereas most stubble types showed a very rapid increase in availability and declined moderately quickly thereafter, sugar beet stubbles increased more slowly to a peak that was then sustained for 1-2 months. This is more apparent when looking at cumulative area available over the whole season (Figure 4.2.2.1B). Except sugar beet, all other stubble types achieved 90-100% of their total availability within 1-2 months of the first field being harvested. In contrast, it took approximately four months for most of sugar beet fields to be harvested. This gradual harvest of sugar beet leads to a continual presence of at least some fresh sugar beet stubble fields in the landscape. (Figure 4.2.2.1). In this way, continual production of freshly disturbed fields may be particularly attractive to invertebrate feeders if harvesting increases the availability of prey.

Compositional analysis run across the whole winter revealed significantly non-random habitat use by Pied Wagtail/Meadow Pipit, Starling/thrushes and granivores (Table 4.2.2.1). The two small invertebrate feeders were most strongly associated with sugar beet stubble (Table 4.2.2.2). Starling/thrushes showed non significant selection for sugar beet stubble. In fact, they were more strongly associated with oilseed rape stubble (Table 4.2.2.2). Granivorous passerines were most strongly associated with barley stubble, though they did use sugar beet stubbles more than wheat stubble (Table 4.2.2.2).

These general patterns of habitat selection hide marked seasonal variability in habitat availability and use (Figure 4.2.2.1). Figure 4.2.2.2. shows the percentage of birds (combined and split by species group) found on each stubble type along with the percentage availability of each type. A simple comparison of percentage use and availability showed that in all but one period a greater proportion of the “all birds” category was found on beet fields than expected given the proportion availability of beet fields. Sugar beet stubbles accounted for 19-42% of all birds encountered within a period. This included 40-89% of Meadow Pipits and Pied Wagtails, 45% to 90% of late winter Starling/thrushes and 15-42% of granivorous passerines. Formal tests via generalised linear models showed that of all the groups, granivorous passerines were least strongly associated with beet stubbles: each month only 21-40% of fields were occupied whereas consistently 76-88% of barley stubble fields were occupied (Table 4.2.2.3). In three of the six periods sugar beet stubbles were significantly less likely to be occupied by granivores than other stubble types and in two periods they held fewer granivorous species, although in two periods they contained a higher density of granivores than other stubbles (Table 4.2.2.13. Both small and large invertebrate feeders occurred in more sugar beet stubble, at higher species richness and at higher densities than in other stubble types. This was especially the case in late winter (Table 4.2.2.3).

4.2.3 Discussion

The difference between peak area and cumulative area for different stubbles indicates a difference in the longevity of individual fields of different stubbles. Life table analysis conducted by Vickery *et al*. (2002) confirmed that beet stubble fields remained on average for 88 days compared with 59 days for rape, 120 days for barley and 140 days for wheat. These figures can vary widely between different farms and different soil types and it would be useful to have a wider picture of stubble longevity and a better understanding of the agricultural, environmental and social pressures leading to early versus late winter ploughing. In the context of these Breckland fields, the light soil may have allowed farmers to plough late into the winter, thus reducing the need to plough early. It is also important to note that whilst cereal stubbles were present for, on average, four months, they became available in August and therefore disappeared from the landscape in November, meaning the mid-late winter period was characterised by a lack of cereal stubble habitat.

In summary, a clear distinction is apparent between granivores that do not use sugar beet stubbles and invertebrate feeders that do. Earlier we discussed how there was potential for sugar beet stubbles to have higher weed seed loads. The paucity of granivores from sugar beet stubbles suggests that in this study area, this is not the case. The high prevalence of invertebrate feeders points to an abundance of invertebrate prey. Gillings (2003) found large numbers of diptera larvae and pupae in sugar beet stubbles. In his study area the heavy soils and wet winters often meant that sugar beet stubble fields were waterlogged producing a flush of earthworms that may also have attracted invertebrate-feeding species.

4.3 Invertebrate Feeders on Arable Farmland Study

4.3.1 Data sources and methods

During the six winters 1996/97 to 2001/02 a study area of approximately 2000 ha of arable farmland in eastern England was surveyed at least twice per month for Golden Plovers and Lapwings (Gillings *et al*. 2007) and habitats were mapped on each visit. In winter 1999/2000 field use by other invertebrate feeders was also recorded. These data allow an evaluation of the seasonal availability of sugar beet and to consider its use by invertebrate feeding birds. In this case study, since all habitats were mapped, absolute areas of sugar beet and use relative to all agricultural habitats can be investigated.

Use and availability of eight habitat types (cereal crop, other crop, cereal stubble, beet stubble, other stubble, bare till, grass pasture and other) was determined for a suite of invertebrate feeding birds. The main focus of the study was Lapwings and Golden Plovers but gulls, especially Black-headed Gulls (Larus ridibundus) were often present, as were Starlings and winter thrushes (Redwing and Fieldfare). Finally, large numbers of black crows (mostly Rook *Corvus frugilegus*, but also Carrion Crow *C. corone* and Jackdaw *C. monedula*) also used this area. Between November and February of winter 1999/2000 all individuals of these species were counted and mapped on all field types. For analytical purposes some species were grouped into the following species groups: gulls, thrushes and black crows. As in section 4.2, habitat rankings were calculated by compositional analysis, taking each visit as an independent observation.

4.3.2 Results

The peak availability of sugar beet stubble amounted to between 21% and 54% of the total cropped area of sugar beet (Figure 4.3.2.1), indicating that generally less than half of the available sugar beet stubble was available at any given time.

For all species or species groups considered, habitat use was significantly non-random (Table 4.3.2.1). Only one species, Lapwing, selected sugar beet stubbles more often than any other habitat type (Table 4.3.2.1 & 4.3.2.2). However, even for this species, use of sugar beet stubbles was not significantly greater than use of cereal crops, bare till or grass pasture. (Table 4.3.2.2). Sugar beet was the third most highly selected habitat by Golden Plovers after cereal crops and bare till. Again, its use was not significantly greater than use of grass pasture, other habitat and other stubble. Other habitat was a catch-all category for a number of habitats that were too rare or transient to analyse using compositional analysis. For the remaining species (groups) beet was the fourth most positively selected habitat and always ranked above other crops, other stubbles and other habitats but below grass pasture, bare tillage and cereal crops (Table 4.3.2.2).

4.3.3 Discussion

These results show that as one of the key habitats in the winter landscape in terms of areas, sugar beet stubbles were used by a range of invertebrate feeding birds but that for only one species, Lapwing, was sugar beet the preferred habitat. These data concerning a range of invertebrate feeders were collected in just one winter. Data on Golden Plover and Lapwing use of fields were also collected in five additional winters and analysed by Gillings *et al*. (2007). These analyses showed that the use of grass pasture by plovers was atypical as it was confined only to 1999/2000. More broadly, across all six winters these two species positively selected sugar beet stubbles in mid winter for daytime feeding. It is unknown to what degree the habitat selection presented here for gulls, crows, Starlings and thrushes is also atypical.

5. CONCLUSIONS

Within the region where sugar beet is currently grown there is great potential for substantial modification to the farming landscape if there is a significant reduction in the planting of sugar beet. This review suggests that many of the changes that could stem from a reduction in sugar beet have direct or indirect consequences for birds using farmed environments. However, the extent of these changes is highly dependent upon market forces and the behaviour of farmers making predictions of the magnitude of landscape change very difficult.

The best documented group for which beet is important is over-wintering geese, but paradoxically it is for this group that loss of sugar beet can be most easily managed, in part due to previous research but also for practical agronomic reasons. Reviewing the implications of sugar beet loss for other farmland birds is seriously hampered by the reporting of habitat associations that have tended to aggregate sugar beet into one of several possible miscellaneous crop or stubble categories. The reanalyses reported here show that within the region in which sugar beet is grown a range of species are positively associated with sugar beet stubble fields in winter. This is especially true for invertebrate feeding species. As shown here, at any one time, sugar beet fields comprise a relatively small part of the landscape even within the beet growing region. However, the tendency for fields to be harvested gradually to maintain a steady supply of beet to factories means there is constant field turnover and the availability of freshly disturbed fields that are highly attractive to invertebrate-feeding birds. Sugar beet stubble fields can contain high weed seed densities (Robinson 2003) and there is some evidence that sugar beet stubble fields are attractive to granivores (Donald *et al*. 2001) but in comparison with other stubble types (including cereals) we found no evidence to support this in our reanalysis of WFBS and stubbles data. It may still be true that granivore use of sugar beet stubble fields is greater than bare till or cereal crops. During the breeding season, relatively few species are associated strongly with sugar beet crops, but this includes the red listed Stone Curlew and amber listed Lapwing.

Under a scenario of beet loss we expect to see sugar beet replaced by winter sown barley and/or oilseed rape. Under current management regimes we expect these to generate little over winter stubble, so the switch from sugar beet to these alternatives will see loss of sugar beet stubbles and replacement with barley and oilseed rape crops. In our comparisons both of these alternative habitats had significantly lower densities of a range of farmland birds compared to beet stubbles, suggesting an overall negative effect of the direct loss of sugar beet. Moreover, we review how the loss of sugar beet will see simplification of rotations and possibly a reduction in organic inputs into fields which could further reduce food resources for invertebrate-feeding birds. It is noteworthy that many of these invertebrate-feeding birds are migratory and Britain plays host to significant numbers of thrushes, Starlings, Golden Plovers and Lapwings from northern and eastern Europe. Effects of granivorous birds are mixed and will depend strongly on any uptake and subsequent management of GMHT sugar beet.

Of the species considered in the WFBS analysis the population trends of 12 contribute to the farmland component of the UK's Wild Bird Indicator. Five of these were positively associated with sugar beet stubble at the square scale and for seven there was evidence for higher densities in sugar beet stubbles than in likely replacement habitats. This suggests that the farmland bird indicator will be negatively affected by the loss of stubbles. The situation could indeed be worse than the indicator may suggest since many of the species showing strong association with sugar beet stubbles are wintering invertebrate-feeding birds whose population trends are not included in the farmland bird indicator.

Mitigating the loss of sugar beet stubble will depend on the actual pattern of sugar beet loss. In the case of breeding species, agri-environment scheme options that promote bare patches in fields may offset the loss of the open structure that birds such as Stone Curlew find attractive in spring sown sugar beet. For geese, maintaining those sugar beet fields that are nearest roosts and furthest from roads will minimise the impact on foraging opportunities and may agree with agronomic requirements to have beet crops near the coast that are harvested in late winter. For the broader group of invertebrate-feeding farmland birds maintaining populations of soil macrofauna in the absence of significant soil organic inputs is an area for future research.

Acknowledgements

This work was funded under a partnership between BTO and the Joint Nature Conservation Committee (on behalf of Natural England, Scottish Natural Heritage, the Countryside Council for Wales and the Council for Nature Conservation and the Countryside). We would like to thank the volunteers who supplied data for the Winter Farmland Bird Survey.

References

Aebischer, N.J., Robertson, P.A. & Kenward, K.E. (1993). Compositional analysis of habitat use from radio-tracking data. *Ecology*, **74**, 1313-1325.

Banks, A.N., Collier, M.P., Austin, G.E., Hearn, R.D. & Musgrove, A.J. (2006). *Waterbirds in the UK 2004/05: The Wetland Bird Survey*. BTO/WWT/RSPB/JNCC, Thetford.

Browne, S.J., Vickery, J.A. & Chamberlain, D.E. (2000). Densities and population estimates of breeding Skylarks *Alauda arvensis* in Britain in 1997. *Bird Study*, **47**, 52-65.

Butler, S.J., Vickery, J.A. & Norris, K. (2007). Farmland biodiversity and the footprint of agriculture. *Science*, **315**, 381-384.

Carter, C. (2006). Sugar reform outcome – implementing the changes. *British Sugar Beet Review*, **74**, 24-25.

Chamberlain, D.E. & Gregory, R.D. (1999). Coarse and fine scale habitat associations of breeding Skylarks *Alauda arvensis* in the UK. *Bird Study*, **46**, 34-47.

Chamberlain, D.E., Fuller, R.J., Bunce, R.G.H., Duckworth, J.C. & Shrubb, M. (2000). Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. *Journal of Applied Ecology*, **37**, 771-788.

Defra (2006). *Regulatory impact assessment of options for reform of the EU sugar regime*. Defra.

Donald, P.F., Green, R.E. & Heath, M.F. (2001a) Agricultural intensification and the collapse of Europe's farmland bird populations. *Proc. R. Soc. B*, **268**, 25–29.

Donald, P.F., Buckingham, D.L., Moorcroft, D., Muirhead, L.B., Evans, A.D. & Kirby, W.B. (2001b). Habitat use and diet of skylarks *Alauda arvensis* wintering on lowland farmland in southern Britain. *Journal of Applied Ecology*, **38**, 536-547.

Edwards, C.A. & Bohlen, P.J. (1996) *Biology and ecology of earthworms*, 3rd edition. Chapman & Hall, London.

Ellis, J.W. & Frye, J.R. (1965). Utilization of sugar beets by Canada Geese. *Journal of Wildlife Management*, **29**, 396-397.

FAOSTAT (2007). Food and Agriculture Organization of the United Nations. *Core production data 2005*. http://faostat.fao.org/site/340/default.aspx

Fox, A.D., Madsen, J., Boyd, H., Kuijkens, E., Norriss, D.W., Tombre, I.M. & Stroud, D.A. (2005). Effects of agricultural change on abundance, fitness components and distribution of two arctic-nesting goose populations. *Global Change Biology*, **11**, 881-893.

Fox, A.D., Stroud, D., Walsh, A., Wilson, J., Norris, D. & Francis, I. (2006). The rise and fall of the Greenland White-fronted Goose: a case study in international conservation. *British Birds*, **99**, 242-261.

Frank, T. (1997). Slug damage and numbers of the slug pests, *Arion lusitanicus* and *Deroceras reticulatum*, in oilseed rape grown beside sown wildflower strips. *Agriculture, Ecosystems and Environment*, **67**, 67-78.

Gill, J.A. (1994). *Habitat choice and distribution of wintering pink-footed geese,* Anser brachyrhynchus. Unpublished PhD thesis, University of East Anglia, Norwich.

Gill, J.A. (1996). Habitat choice in Pink-Footed Geese: quantifying the constraints determining winter site use. *Journal of Applied Ecology*, **33**, 884-892.
Gill, J.A., Watkinson, A.R. & Sutherland, W.J. (2008). Causes of the redistribution of Pink-footed Geese *Anser brachyrhynchus* in Britain. *Ibis*, **139**, 497-503.

Gillings, S. (2003) *Diurnal and nocturnal ecology of Golden Plovers* Pluvialis apricaria *and Lapwings* Vanellus vanellus *wintering on arable farmland*. Unpublished PhD thesis, University of East Anglia, Norwich.

Gillings, S. & Fuller, R.J. (2001). Habitat selection by Skylarks *Alauda arvensis* wintering in Britain in 1997/98. *Bird Study*, **48**, 293-307.

Gillings, S., Fuller, R.J. & Sutherland, W.J. (2005). Diurnal studies do not predict nocturnal habitat choice and site selection of European Golden-Plovers (*Pluvialis apricaria*) and Northern Lapwings (*Vanellus vanellus*). *Auk*, **122**, 1249-1260.

Gillings, S., Fuller, R.J. & Sutherland, W.J. (2007). Winter field use and habitat selection by Eurasian Golden Plovers *Pluvialis apricaria* and Northern Lapwings *Vanellus vanellus* on arable farmland. *Ibis*, **149**, 509-520.

Gillings, S., Newson, S.E., Noble, D.G. & Vickery, J.A. (2005). Winter availability of cereal stubbles attracts declining farmland birds and positively influences breeding population trends. *Proc. Roy. Soc. B.*, **272** (1564), 733-739.

Gillings, S., Wilson, A.M., Conway, G.C., Vickery, J.A. & Fuller, R.J. (2008). Distribution and abundance of birds and their habitats within the lowland farmland of Britain in winter. *Bird Study*, **55**, 8-22.

Glen, D.M., Spaull, A.M., Mowat, D.J., Green. D.B., Jackson, A.W. (1993). Crop monitoring to assess the risk of slug damage to winter wheat in the United Kingdom. *Annuls of Applied Biology*, **122**, 161-172.

Green, R.E., Osborne, P.E. & Sears, E.J. (1994). The distribution of passerine birds in hedgerows during the breeding season in relation to characteristics of the hedgerow and adjacent farmland. *Journal of Applied Ecology*, **31**, 677-692.

Green, R.E., Tyler, G.A. & Bowden, C.G.R. (2000). Habitat selection, ranging behaviour and diet of the stone curlew (*Burhinus oedicnemus*) in southern England. *Journal of Zoology*, **250**, 161-183.

Grice, P., Evans, A., Osmond, J., Brand-Hardy, R. (2004). Science into policy: the role of research in the development of a recovery plan for farmland birds in England. *Ibis*, **146** (suppl 2), 239-249.

Kleijn, D. & Verbeek, M. (2000). Factors affecting the species composition of arable field boundary vegetation. *Journal of Applied Ecology*, **37**, 256-266.

Kragten, S. & de Snoo, G.R. (2008). Field-breeding birds on organic and conventional arable farms in the Netherlands. *Agriculture, Ecosystems and Environment*, **126**, 270-274.

Krebs, J.R., Wilson, J.D., Bradbury, R.B., & Siriwardena, G.M. (1999). The second Silent Spring? *Nature*, **400**, 611-612.

Lippens, L. (1982) [A new source of winter food for Bewick's Swans, *Cygnus bewickii*, in Flanders]. *Gerfaut*, **72**, 101-106.

Marshall, E.J.P., Brown, V.K., Boatman, N.D., Lutmans, P.J.W., Squire, G.R. & Ward, L.K. (2003). The role of weeds in supporting biological diversity within crop fields. Weed Research 43: 77-89.

Mason, C.F. & Macdonald, S.M. (2000). Influence of landscape and land-use on the distribution of breeding birds in farmland in eastern England. *Journal of Zoology*, **250**, 339-348.

May, M.J. (2003). Economic consequences for UK farmers of growing GM herbicide tolerant sugar beet. *Annals of Applied Biology*, **142**, 41-48. Publisher: Association of Applied Biologists.

Mayes, E. (1991) The winter ecology of Greenland White-fronted Geese *Anser albifrons flavirostris* on semi-natural grassland and intensive farmland. *Ardea*, **79**, 295-304.

Moorcroft, D., Whittingham, M.J., Bradbury, R.B. & Wilson, J.D. (2002). The selection of stubble fields by wintering granivorous birds reflects vegetation cover and food abundance. *Journal of Applied Ecology*, **39**, 535–547.

Nilsson, L. (1997). Changes in numbers and habitat utilization of wintering whooper swans *Cygnus Cygnus* in Sweden 1964-1997. *Ornis Svecica*, **7**, 133-142.

Nilsson, L. & Persson, H. (1998). Field choice of staging Greylag Geese *Anser anser* in relation to changes in agriculture in South Sweden. *Ornis Svecica*, **8**, 27-39.

Nilsson, L. & Persson, H. (2000). Changes in field choice among staging and wintering geese in southwestern Scania, south Sweden. *Ornis Svecica*, **10**, 161-169.

Nolet, B.A., Bevan, R.M., Klaassen, M., Langevoord, O., van der Heijden, Y.G.J.T. (2002). Habitat switching by Bewick's swans: maximization of average long-term energy gain? *Journal of Animal Ecology*, **71**, 979-993.

Nolet, B.A., Gyimesi, A., Klaassen, R.H.G. (2006). Prediction of bird-day carrying capacity on a staging site: a test of depletion models. *Journal of Animal Ecology*, **75**, 1285-1292.

Pain, D.J. & Pienkowski, M.W. (1997). *Farming and birds in Europe. The common agricultural policy and its implications for bird conservation*. Academic Press, London.

Renwick, A.W. & Revoredo Giha, C.L. (2005). Crop substitution on UK sugar beet farms and its effects on the environment: a multi-product cost function approach. *Environmental Economy and Policy Research Discussion Paper Series Number 10*. University of Cambridge, Cambridge.

Robinson, L.J. (2003). *Spatial scale and depletion models of farmland birds in a fragmented landscape*. Unpublished PhD thesis, University of Reading.

Shrubb, M. (2003). *Birds, scythes and combines: a history of birds and agricultural change*. Cambridge University Press, Cambridge.

Siriwardena, G.M., Calbrade, N.A. & Vickery, J.A. (2008). Farmland birds and late winter food: does seed supply fail to meet demand? *Ibis*, **150**, 585-595.

Toepfer, S. & Stubbe, M. (2001). Territory density of the Skylark (*Alauda arvensis*) in relation to field vegetation in central Germany. *Journal für Ornithologie*, **142**, 184-194.

Tucker, G.M. (1992). Effects of agricultural practices on field use by invertebrate-feeding birds in winter. *Journal of Applied Ecology*, **29**, 779-790.

Vickery, J. & Atkinson, P. (2003). The value of post harvest sugar beet land for birds. *Sugar Beet Review*, **71** (4), 27-29.

Vickery, J.A., Atkinson, P.W., Robinson, L.J., Marshall, J.M., West, T., Gillings, S., Wilson, A., Kirby, W. & Norris, K. (2002). *The effects of different crop stubbles and straw disposal methods on wintering birds and arable plants*. Final report to Defra. (BD1610). BTO, Thetford.

Watkinson, A.R., Freckleton, R.P., Robinson, R.A. & Sutherland, W.J. (2000). Predictions of biodiversity response to genetically modified herbicide-tolerant crops. *Science*, **289**, 1554-1557.

Wilson, A.M., Vickery, J.A. & Browne, S.J. (2001). Numbers and distribution of Northern Lapwings *Vanellus vanellus* breeding in England and Wales in 1998. *Bird Study*, **48**, 2-17.

Wilson, J.D., Arroyo, B.E. & Clark, S.C. (1996) *The diet of bird species of lowland farmland: a literature review*. Royal Society for the Protection of Birds, Sandy.

County/Unitary Authority	2000	2001	2002	2003	2004	2005	2006	%CL
Norfolk	50,596	52,039	51,224	48,566	47,026	45,230	39,052	16%
Lincolnshire	30,463	31,147	28,473	27,165	25,478	23,628	20,709	7%
Suffolk	18,875	18,941	18,070	17,792	16,383	16,094	13,976	8%
Cambridgeshire CC	18,391	19,077	17,881	17,376	16,246	16,066	14,714	9%
North Yorkshire CC	10,517	10,878	10,802	10,556	10,313	10,309	8,909	5%
Shropshire CC	7,080	7,378	7,346	7,110	6,315	6,250	5,550	7%
North Nottinghamshire	6,140	6,000	5,513	5,318	5,006	4,932	4,336	7%
N & NE Lincolnshire	4,542	4,716	4,557	4,141	4,242	3,727	2,902	7%
East Riding of Yorkshire	4,043	4,212	4,168	4,171	4,197	3,876	3,521	3%
Essex CC	3,783	3,927	3,516	3,593	3,085	3,064	2,876	2%
Staffordshire CC	2,246	2,359	2,122	1,789	1,850	1,836	1,419	4%
Worcestershire	2,238	2,300	2,063	1,806	1,753	1,692	1,516	4%
Peterborough	1,893	1,888	1,855	1,695	1,695	1,734	1,569	9%
Telford & Wrekin	1,901	1,854	1,844	1,890	1,783	1,605	1,429	15%
Herefordshire, county of	1,672	1,736	1,618	1,663	1,775	1,744	1,501	2%
Barnsley, Doncaster & Rotherham	1,592	1,507	1,498	1,444	1,323	1,267	1,248	4%
York	1,128	1,282	1,228	1,241	1,123	1,246	1,083	11%
South Nottinghamshire	1,274	1,347	1,213	1,003	1,018	1,047	998	4%
Leicestershire CC & Rutland	858	1,003	853	787	794	747	615	1%
Bedfordshire CC	466	477	433	430	454	329	286	1%
Northamptonshire	364	399		287	277	210		0%
Leeds	234		293	294	247		266	2%
Lancashire CC	249	273	219	200	160			1%
Somerset	359	331	234	167	146	69	57	0%
Gloucestershire	164	181	196	202	136	226	151	0%
Hertfordshire					168			0%
East Derbyshire		222			67			1%
Warwickshire			157		111			0%
Calderdale, Kirklees & Wakefield	100		136	120	74			1%
East Merseyside	172	153	106	81	66	50		2%
Cheshire CC	113	102			41			0%

Table 2.1.1 The major sugar beet producing counties and unitary authorities in England during 2000 to 2006. Figures are the area (ha) in June Census returns. Counties are placed in descending order of mean area across years. %CL is the percentage of cropped land devoted to sugar beet (mean across years). Cells with missing values are because there were no data supplied and may or may not relate to true zeroes.

		Probability of occupancy							Abundance			
Species	**df**	**Dev/df**	χ^2_1	**P**	**Stubble**	**+ Stubble**	**- Stubble**	**Stubble**	**Dev/df**	χ^2_1	**P**	**Stubble**
Grey Partridge	1976	0.83	0.05	0.8294	0.0512			0.0512	0.34 ^{n}	1.57	0.2101	0.3244
Golden Plover	1977	0.47	0.64	0.4247	0.2724			0.2724	0.14 ^{n}	0.31	0.5765	-0.3329
Lapwing	1977	0.84	3.82	0.0506	0.5592			0.5592	0.32 ^{n}	0.61	0.4364	0.2409
Snipe	1977	0.70	2.53	0.1117	0.5778			0.5778	2.66 ^{p}	1.89	0.1689	0.9209
Stock Dove	1977	0.99	1.94	0.1636	0.3616			0.3616	0.44 ^{n}	0.59	0.4425	0.3258
Skylark	**1977**	**1.38**	**3.93**	**0.0475**	**0.3994**	**59 (50-68)**	**50 (46-54)**	0.3994	0.91 ^{n}	2.41	0.1209	0.4362
Meadow Pipit	1977	1.22	3.37	0.0663	0.4294			0.4294	0.62 ^{n}	0.80	0.3703	0.2654
Pied Wagtail	**1977**	**1.27**	**6.91**	**0.0086**	**0.4975**	**44 (37-52)**	**33 (29-36)**	**0.4975**	**0.70** ^{n}	**5.27**	**0.0217**	**1.2317**
Fieldfare	1975	1.38	0.28	0.5972	0.0927			0.0927	0.94 ^{n}	1.06	0.3037	-0.1548
Song Thrush	1975	1.38	0.40	0.5249	-0.1143			-0.1143	0.90 ^{n}	0.01	0.9248	-0.0206
Redwing	1975	1.34	0.51	0.4762	-0.1386			-0.1386	0.75 ^{n}	0.02	0.8783	-0.0498
Mistle Thrush	**1977**	**1.35**	**5.55**	**0.0185**	**0.4333**	**50 (42-58)**	**39 (36-43)**	0.4333	0.84 ^{n}	2.31	0.1283	0.2483
Starling	1975	1.37	1.12	0.2897	0.1799			0.1799	0.83 ^{n}	0.94	0.3331	0.9332
House Sparrow	1977	1.34	0.25	0.6157	-0.0753			-0.0753	0.78 ^{n}	0.08	0.7779	-0.0328
Tree Sparrow	1977	0.66	1.22	0.2687	0.3199			0.3199	0.24 ^{n}	0.22	0.6362	0.0950
Chaffinch	**1976**	**1.01**	**4.61**	**0.0318**	**0.5182**	**86 (79-92)**	**79 (76-82)**	**0.5182**	**1.16** ^{n}	**4.46**	**0.0346**	**0.8787**
Greenfinch	**1977**	**1.37**	**2.97**	**0.0849**	**0.3151**	**51 (43-59)**	**43 (39-47)**	**0.3151**	**0.82** ^{n}	**5.55**	**0.0184**	**0.6952**
Goldfinch	**1977**	**1.15**	**10.15**	**0.0014**	**0.6931**	**40 (32-49)**	**25 (22-28)**	0.6931	0.56 ^{n}	3.75	0.0527	0.8764
Linnet	1977	0.88	2.37	0.1240	0.3877			0.3877	0.35 ^{n}	1.74	0.1868	0.7437
Bullfinch	1976	0.88	0.08	0.7759	-0.0710			-0.0710	1.69 ^{p}	1.92	0.1663	-0.3138
Yellowhammer	**1976**	**1.37**	**7.43**	**0.0064**	**0.5414**	**58 (49-66)**	**44 (41-48)**	**0.5414**	**0.85** ^{n}	**5.46**	**0.0195**	**0.4014**
Reed Bunting	**1976**	**0.89**	**4.51**	**0.0338**	**0.4750**	**23 (17-31)**	**16 (14-19)**	0.4750	model failed to converge			
Corn Bunting	1977	0.30	2.08	0.1489	-0.6767			-0.6767	3.43 ^{p}	3.01	0.0826	-0.9485

Table 4.1.2.1 Results of generalised linear models testing whether the presence of sugar beet stubble in WFBS squares significantly affected the probability of the square being occupied by, and the abundance of, each bird species. df = degrees of freedom; Dev/df = model deviance divided by df (for abundance models superscript p or n indicate models formulated with Poisson errors or negative binomial errors respectively); χ^2_1 = chi-squared likelihood ratio test of the influence of sugar beet stubble; stubble = parameter estimate for stubble presence. Positive parameter estimates indicate higher probability of occupancy or abundance in squares where beet stubble was present. Species with a significant effect of stubble are highlighted in bold and back-transformed probabilities of occupancy with (+) and without (-) beet stubble are shown (with 95% confidence limits). The abundance model for Reed Bunting did not converge due to insufficient data.

Species	df	Dev/df	χ^2_1	P	Stubble
Grey Partridge	12091	1.04 ^{p}	0.3	0.5855	0.4057
Golden Plover	5534	0.07 ^{n}	0.1	0.7573	0.2903
Lapwing	14069	0.07 ^{n}	1.71	0.1915	1.549
Snipe	10600	0.72 ^{p}	0.59	0.4419	0.6233
Stock Dove	15463	1.59 ^{p}	1.53	0.2166	1.403
Skylark	22399	4.10 ^{p}	1.01	0.3151	0.3316
Meadow Pipit	18751	2.61 ^{p}	1.02	0.3115	0.388
Pied Wagtail	**21366**	**1.03 ^{p}**	**11.04**	**0.0009**	**1.9825**
Fieldfare	24930	0.19 ^{n}	0.03	0.8581	-0.0692
Song Thrush	24281	0.61 ^{p}	2.02	0.1556	-0.3697
Redwing	22589	0.15 ^{n}	0.54	0.4612	-0.3541
Mistle Thrush	23378	0.61 ^{p}	0.86	0.3524	-0.2538
Starling	23975	0.15 ^{n}	0.02	0.8990	0.0602
House Sparrow	19614	3.85 ^{p}	1.42	0.2337	-0.2226
Tree Sparrow	8996	1.98 ^{p}	0.46	0.4976	0.4705
Chaffinch	26987	0.40 ^{n}	1.66	0.1982	0.4197
Greenfinch	24331	3.39 ^{p}	2.04	0.1535	0.9941
Goldfinch	19558	2.59 ^{p}	1.89	0.1694	1.0684
Linnet	14911	6.27 ^{p}	0.43	0.5142	0.4034
Bullfinch	**14809**	**0.40 ^{p}**	**13.24**	**0.0003**	**-1.5723**
Yellowhammer	22921	3.03 ^{p}	0.94	0.3322	0.5038
Reed Bunting	12892	1.68 ^{p}	0.45	0.5013	0.8837

Table 4.1.2.2 Results of a generalised linear model testing for differences in bird densities between sugar beet stubble fields and all other field types. df = degrees of freedom, Dev/df = model deviance divided by df (superscript p or n indicate models formulated with Poisson errors or negative binomial errors respectively), χ^2_1 = chi-squared likelihood ratio test of the difference in bird densities between sugar beet stubble fields and all other field types, stubble = parameter estimate for sugar beet stubble presence: positive parameter estimates indicate high bird density where the field was sugar beet stubble. Species with a significant effect of stubble are highlighted in bold. The model for Corn Bunting did not converge due to insufficient data.

Species	**df**	**dev/df**	χ^2_4	**P**	**Cereal crop**	**Cereal stubble**	**Rape crop**	**Rape stubble**
Grey Partridge	4946	1.26^{p}	6.55	0.1619	-0.55	-0.03	-0.12	-0.74
Lapwing	5445	0.09^{n}	15.76	0.0034	-1.42*	-2.78**	-3.60***	-1.12
Snipe	3824	0.51^{p}	7.29	0.1213	-1.65*	-0.49	-1.65*	-0.45
Stock Dove	5958	1.57^{p}	11.43	0.0221	-1.82**	-1.13	-2.49***	-0.72
Skylark	9042	0.33^{n}	16.62	0.0023	-0.57	1.08**	0.37	0.93*
Meadow Pipit	6882	3.35^{p}	39.04	<0.0001	-1.89***	0.03	0.92	-0.64
Pied Wagtail	7544	0.81^{p}	35.8	<0.0001	-2.88***	-2.08***	-4.10***	-3.29***
Fieldfare	9099	0.18^{n}	7.87	0.0964	-0.17	-0.28	-0.89	0.68
Song Thrush	8872	0.55^{p}	21.78	0.0002	-0.21	0.47	0.22	0.60
Redwing	7894	5.04^{p}	9.96	0.0410	-1.49*	-1.01	-2.05**	-1.89*
Mistle Thrush	8292	0.61^{p}	18.58	0.0009	-0.17	0.46	-0.78*	-0.44
Starling	8272	0.10^{n}	14.22	0.0066	-1.13	-0.62	-2.39***	0.05
House Sparrow	6657	1.96^{p}	13.08	0.0109	-0.52	-0.19	-1.34*	-1.95*
Tree Sparrow	3404	1.97^{p}	7.59	0.1078	-1.30	-0.26	-1.92*	1.61
Chaffinch	9953	0.38^{n}	33.87	<0.0001	-1.81***	-0.63*	-2.18***	0.52
Greenfinch	8910	2.94^{p}	10.95	0.0271	-1.84***	-0.94	-1.54**	0.08
Goldfinch	6884	1.84^{p}	12.19	0.0160	-2.55***	-1.34*	-2.36***	-1.65
Linnet	5779	7.15^{p}	17.21	0.0018	-2.09***	0.32	-0.30	1.05
Bullfinch	5143	0.48^{p}	9.50	0.0498	1.28	1.43	1.80*	2.18*
Yellowhammer	8930	4.15^{p}	55.02	<0.0001	-1.28**	0.61	-1.15*	1.14
Reed Bunting	5092	1.55^{p}	17.81	0.0013	-2.11*	0.04	-1.80	0.36

Table 4.1.2.3 Results of a generalised linear model testing for differences in bird densities between sugar beet stubble fields and the likely replacement habitats (stubbles and crops of cereal and oilseed rape). df = degrees of freedom, dev/df = model deviance divided by df (superscript p or n indicate models formulated with Poisson errors or negative binomial errors respectively), χ^2_4 = chi-squared likelihood ratio test of the influence of field type on density; next four columns = parameter estimate for field types relative to sugar beet stubble: negative (/positive) parameter estimates indicate the crop supports lower (/higher) densities than beet stubbles. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. Models for Golden Plover and Corn Bunting did not converge due to insufficient data.

Species	Wilks' Λ	F	Ba	Li	Or	Wh	Beet
All species	0.11	16.7	2	4	1	5	3
Meadow Pipit/Pied Wagtail	0.048	24.3*	2	5	3	4	1
Starling/thrushes	0.0014	46.7*	5	3	1	4	2
Granivores	0.064	24.3*	1	4	2	5	3

Table 4.2.2.1 Summary results of compositional analysis of stubble use by birds, showing ranked habitat preferences (1 = greatest number of positive log ratios, 8 = fewest positive log ratios). The F statistic (d.f. = 4) indicates deviation from random habitat use. Ba = barley, Li = linseed, Or = oilseed rape, and Wh = wheat. * $P < 0.05$.

a) All species

	Ba	Li	Or	Wh	Beet
Barley	.	+++	-	+++	+
Linseed	---	.	---	+++	---
Oilseed rape	+	+++	.	+++	+
Sugar beet	-	+++	-	+++	.
Wheat	---	---	---	.	---

b) Meadow Pipit and Pied Wagtail

	Ba	Li	Or	Wh	Beet
Barley	.	+	+	+	-
Linseed	-	.	-	-	---
Oilseed rape	-	+	.	+	---
Sugar beet	+	+++	+++	+++	.
Wheat	-	+	-	.	---

c) Starling and thrushes

	Ba	Li	Or	Wh	Beet
Barley	.	-	-	-	-
Linseed	+	.	---	+++	-
Oilseed rape	+	+++	.	+++	+
Sugar beet	+	+	-	+	.
Wheat	+	---	---	.	-

d) Granivores

	Ba	Li	Or	Wh	Beet
Barley	.	+++	+	+++	+
Linseed	---	.	---	+	-
Oilseed rape	-	+++	.	+++	+
Sugar beet	-	+	-	+++	.
Wheat	---	-	---	.	---

Table 4.2.2.2 Simplified pair-wise ranks of habitats based on log ratios. Positive values indicate the row habitat is more highly selected than the column habitat. Single symbols indicate non-significant differences, multiple symbols indicate significant differences (at $P < 0.05$). Ba = barley, Li = linseed, Or = oilseed rape, and Wh = wheat.

a) Granivorous passerines

Period	Beet	Other stubble				P-a		Rich		Density	
		Ba	Li	Ra	Wh	d	P	d	P	d	P
9	21%	76%	50%	67%	44%	-	0.016		0.830	+	0.001
10	38%	81%	50%	67%	42%		0.086	-	0.004		0.294
11	46%	86%	58%	67%	42%		0.241		0.663	+	0.008
12	32%	84%	75%	50%	31%		0.050		0.140		0.105
13	33%	88%	63%	a	46%	-	0.021		0.056		0.521
14	40%	88%	88%	a	58%	-	0.009	-	0.033		0.557

b) Large invertebrate-feeding passerines

Period	Beet	Other stubble				P-a		Rich		Density	
		Ba	Li	Ra	Wh	d	P	d	P	d	P
9	14%	0%	50%	33%	19%		0.662		0.273		0.146
10	46%	14%	50%	100%	27%		0.190		0.138		0.974
11	42%	19%	58%	100%	35%		0.708		0.063		0.145
12	48%	21%	50%	100%	28%		0.144	+	0.025	+	<0.001
13	62%	35%	25%	a	21%	+	0.005	+	0.041		0.104
14	65%	6%	50%	a	26%	+	0.001	+	<0.001	+	<0.001

c) Small invertebrate-feeding passerines

Period	Beet	Other stubble				P-a		Rich		Density	
		Ba	Li	Ra	Wh	d	P	d	P	d	P
9	43%	33%	0%	33%	13%		0.051	+	0.012	+	<0.001
10	42%	52%	0%	33%	0%	+	0.039	+	0.013		0.085
11	63%	57%	8%	0%	23%	+	0.005	+	0.001	+	<0.001
12	48%	21%	0%	0%	24%	+	0.008	+	0.008	+	0.001
13	38%	41%	0%	a	21%		0.255		0.071	+	0.021
14	45%	19%	25%	a	11%	+	0.017	+	0.002	+	<0.001

Table 4.2.2.3 Percentage occupancy of different stubble types (% of fields occupied in each period) by bird functional groups and results of generalised linear models testing for differences in occupancy rate (P-a), species richness (Rich) and bird density (Density) between sugar beet stubble and other stubble types. Stubble types are: Ba = Barley, Li = Linseed, Ra = Rape, Wh = Wheat. Period is the 2-week period from mid November to mid February in which each analysis was performed. For each test *d* gives the direction of any significant effect (+ = more in beet fields) and *P* is the significance of a χ^2_1 L-R test. *a* indicates periods when a stubble type was absent from the landscape.

Species	Wilks' Λ	F	CC	OC	BT	GP	OH	CS	OS	Beet
Lapwing	0.11	20.2***	3	7	2	4	6	8	5	1
Golden Plover	0.048	47.7***	1	8	2	4	5	7	6	3
Gulls	0.0014	1988.5***	1	6	2	3	5	8	7	4
Crows	0.064	39.6***	3	7	2	1	6	5	8	4
Starling	0.11	21.3***	5	8	3	1	7	2	6	4
Thrushes	0.12	14.9***	2	8	7	1	6	3	5	4

Table 4.3.2.1 Summary results of compositional analysis of habitat use by invertebrate feeding birds in an area of arable farmland in East Anglia in 1999/2000 showing ranked habitat preferences (1 = greatest number of positive log ratios, 8 = fewest positive log ratios). The F statistic (d.f. = 7) indicates deviation from random habitat use. CC = cereal crop, OC = other crop, BT = bare till, GP = grass pasture, OH = other habitat, CS = cereal stubble, OS = other stubble, Beet = beet stubble. *** $P < 0.001$.

a) Lapwing

	CC	OC	BT	GP	OH	CS	OS	Beet
CC	.	+++	-	+	+++	+++	+++	-
OC	---	.	---	---	---	+	---	---
BT	+	+++	.	+	+++	+++	+++	-
GP	-	+++	-	.	+++	+++	+++	-
OH	---	+++	---	---	.	+++	-	---
CS	---	-	---	---	---	.	---	---
OS	---	+++	---	---	+	+++	.	---
BS	+	+++	+	+	+++	+++	+++	.

b) Golden Plover

	CC	OC	BT	GP	OH	CS	OS	Beet
CC	.	+++	+	+++	+++	+++	+++	+++
OC	---	.	---	---	---	-	---	---
BT	-	+++	.	+	+++	+++	+++	+++
GP	---	+++	-	.	+	+++	+	-
OH	---	+++	---	-	.	+++	+	-
CS	---	+	---	---	---	.	---	---
OS	---	+++	---	-	-	+++	.	-
BS	---	+++	---	+	+	+++	+	.

c) Gulls

	CC	OC	BT	GP	OH	CS	OS	Beet
CC	.	+++	+	+++	+++	+++	+++	+++
OC	---	.	---	---	-	+	+	-
BT	-	+++	.	+++	+++	+++	+++	+++
GP	---	+++	---	.	+++	+++	+++	+
OH	---	+	---	---	.	+++	+	-
CS	---	-	---	---	---	.	-	-
OS	---	-	---	---	-	+	.	-
BS	---	+	---	-	+	+	+	.

d) Crows

	CC	OC	BT	GP	OH	CS	OS	Beet
CC	.	+++	---	---	+++	+	+++	+
OC	---	.	---	---	-	---	+	---
BT	+++	+++	.	---	+++	+	+++	+
GP	+++	+++	+++	.	+++	+++	+++	+
OH	---	+	---	---	.	---	+	---
CS	-	+++	-	---	+++	.	+++	-
OS	---	-	---	---	-	---	.	---
BS	-	+++	-	-	+++	+	+++	.

Table 4.3.2.2 Simplified pair-wise ranks of habitats based on log ratios. Positive values indicate the row habitat is more highly selected than the column habitat. Single symbols indicate non-significant differences, multiple symbols indicate significant differences (at $P < 0.05$). CC = cereal crop, OC = other crop, BT = bare till, GP = grass pasture, OH = other habitat, CS = cereal stubble, OS = other stubble, Beet = beet stubble.

e) Starling

	CC	OC	BT	GP	OH	CS	OS	Beet
CC	.	+++	-	-	+++	-	+	-
OC	---	.	---	---	---	---	---	---
BT	+	+++	.	-	+++	-	+++	+
GP	+	+++	+	.	+++	+	+++	+
OH	---	+++	---	---	.	---	-	---
CS	+	+++	+	-	+++	.	+++	+
OS	-	+++	---	---	+	---	.	-
BS	+	+++	-	-	+++	-	+	.

f) Thrushes

	CC	OC	BT	GP	OH	CS	OS	Beet
CC	.	+++	+++	-	+++	+	+	+
OC	---	.	---	---	---	---	---	---
BT	---	+++	.	---	-	---	-	-
GP	+	+++	+++	.	+++	+	+	+
OH	---	+++	+	---	.	---	-	-
CS	-	+++	+++	-	+++	.	+	+
OS	-	+++	+	-	+	-	.	-
BS	-	+++	+	-	+	-	+	.

Table 4.3.2.2 Continued**.**

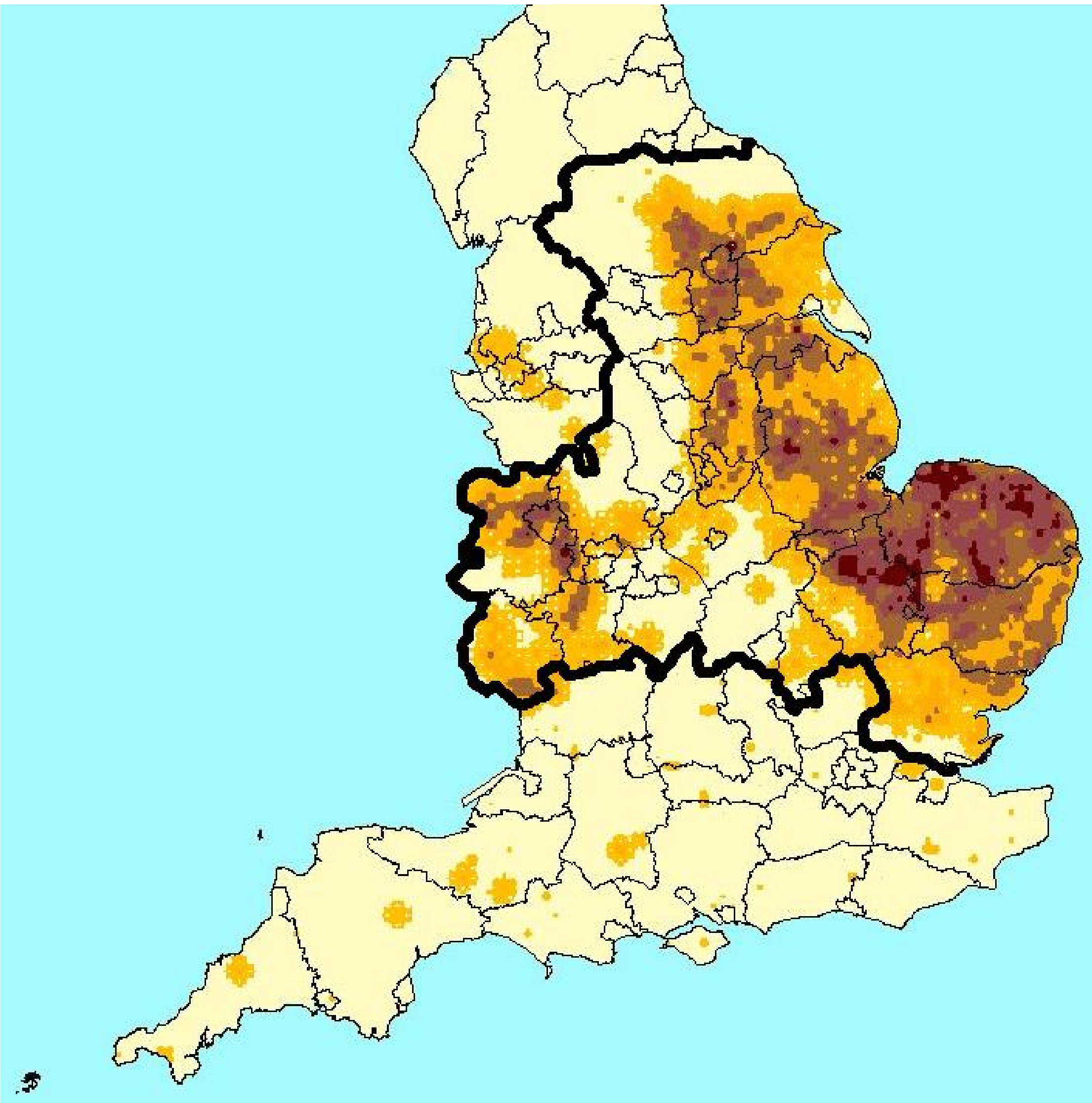
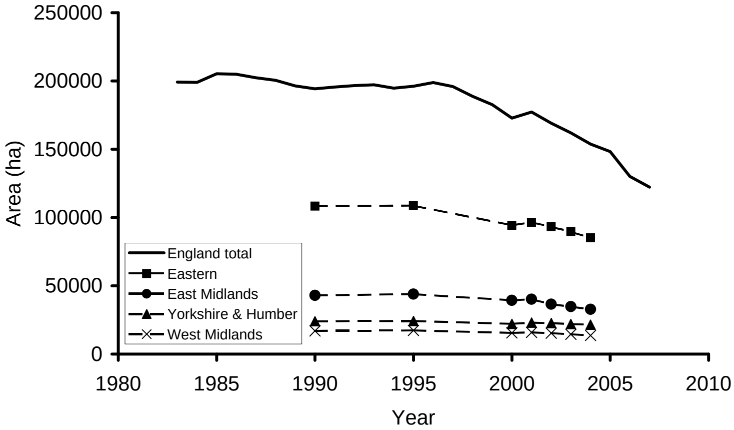


Figure 2.1.1 Distribution of sugar beet in England in June 2006 according to the Defra June Agricultural Survey (http://www.defra.gov.uk/evidence/statistics/index.htm) with the region of main beet growing counties enclosed within the solid black line. This region is used for later analyses and is subsequently referred to as the "beet growing region". Wales and Scotland are omitted because neither grow significant quantities of industrial sugar beet.

A



B

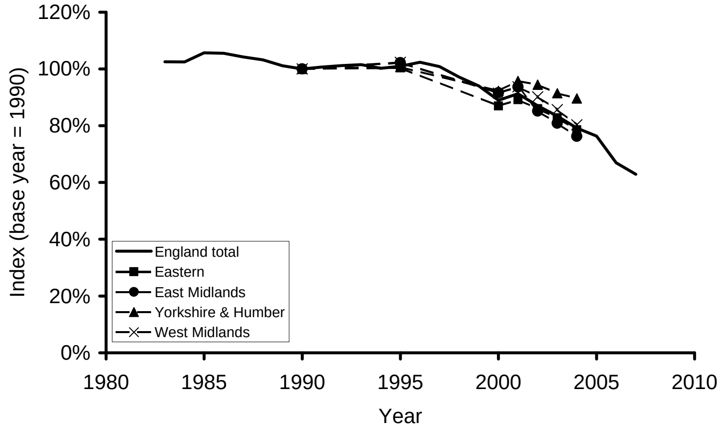


Figure 2.2.1 Trends in a) the area of sugar beet planted and b) an index of planting relative to 1990 levels, in England (1983-2007) and in the four government office regions (1990-2004) that account for 99% of area grown.

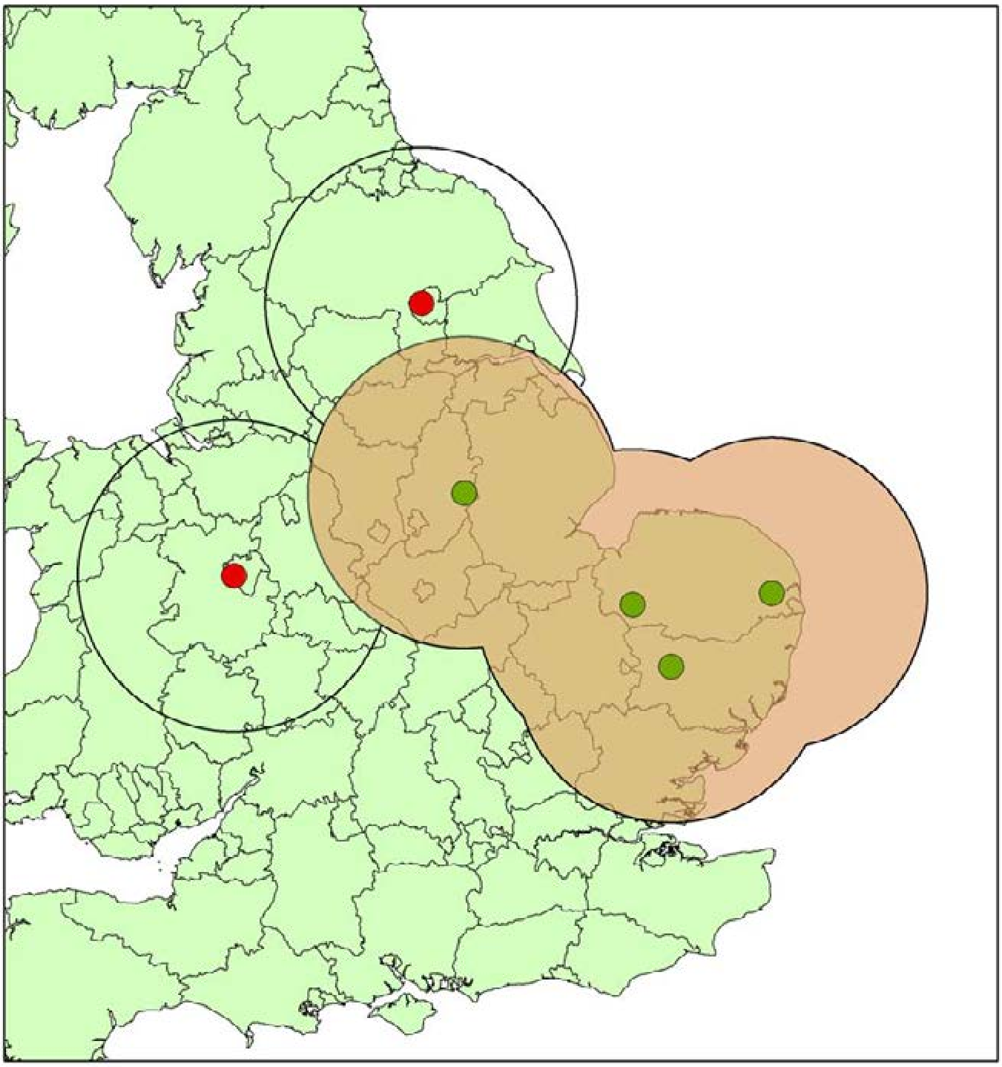
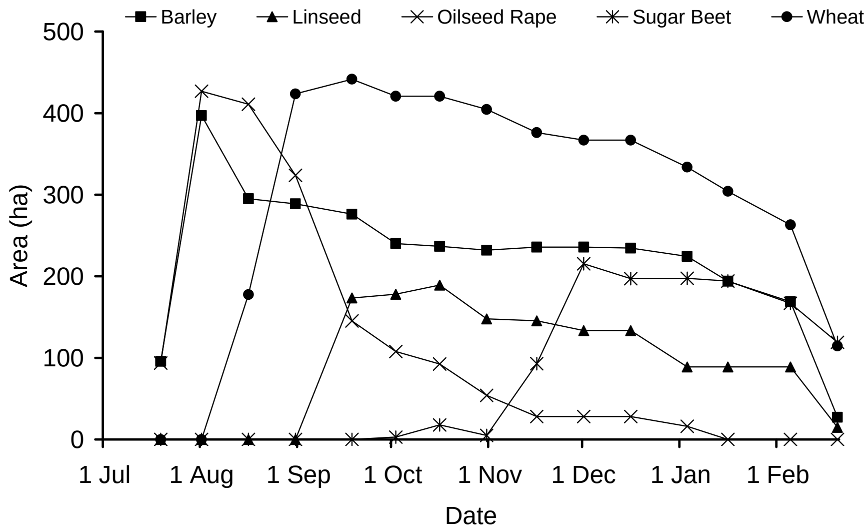


Figure 2.3.1.1 The location of factories processing sugar beet in 2006 and 2007. Red dots are the two factories that closed following the 2006 campaign. Circles show the area enclosed within a 50 mile radius. This is approximately the area within which farmers receive travel costs to bring beet to the factory (the distance is actually 50 miles by road so these circles will slightly overestimate each factory's catchment area).

A



B

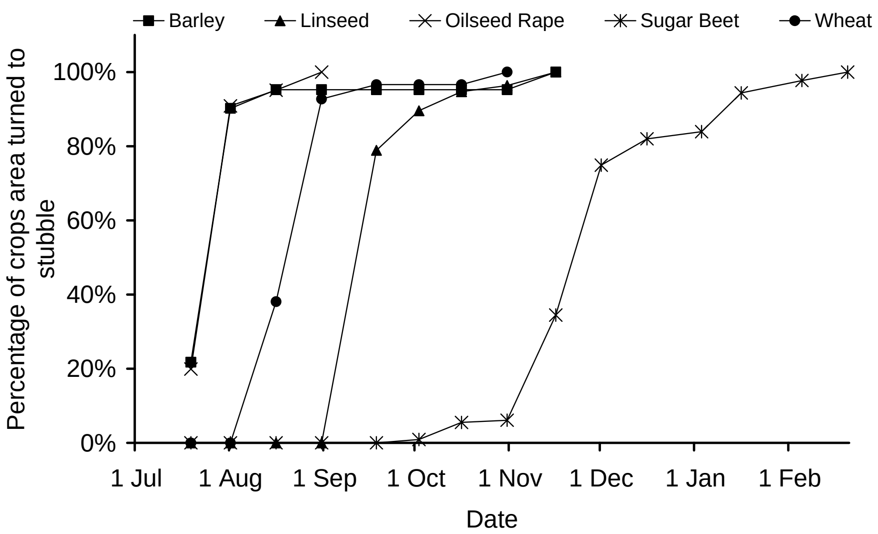


Figure 4.2.2.1 The seasonal availability of various stubble types during winter 2000/01 in a study area in Breckland. a) shows trends in the availability of each stubble type and b) shows the change in the proportion of each crop that had been harvested. Note that the area of other habitats such as crops (unharvested and recently sown) and bare till were not recorded so these figures cannot be converted to percentage of farmed area.

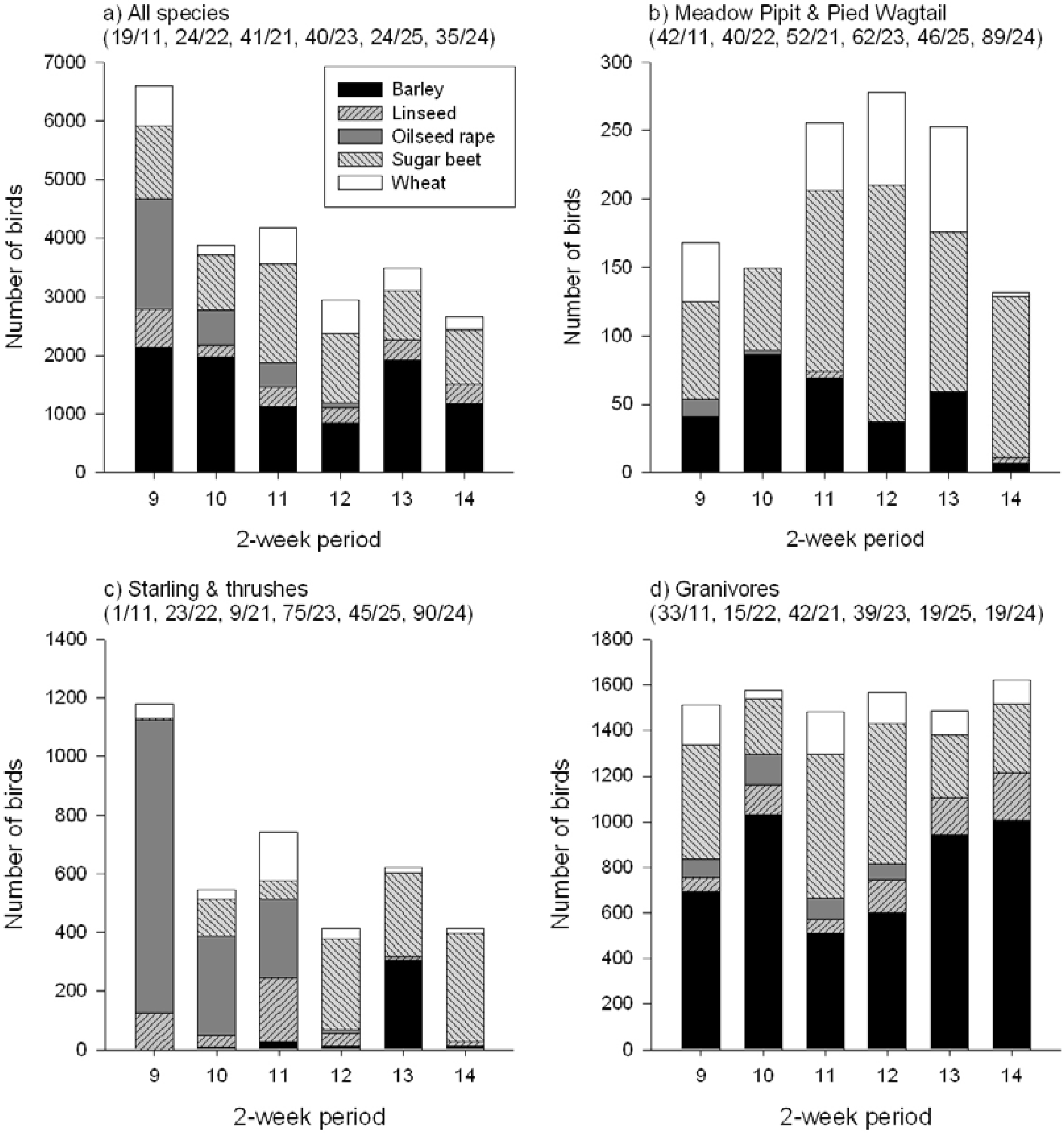


Figure 4.2.2.2 Number of birds on different stubble types in Breckland during 2-week periods from mid November (9 = 16/11 to 31/11/2000) to mid February (14 = 05/02 to 19/02/2001). The figures in parentheses give the percentage of birds on sugar beet stubble relative to the percentage of the area under sugar beet stubble in each period.

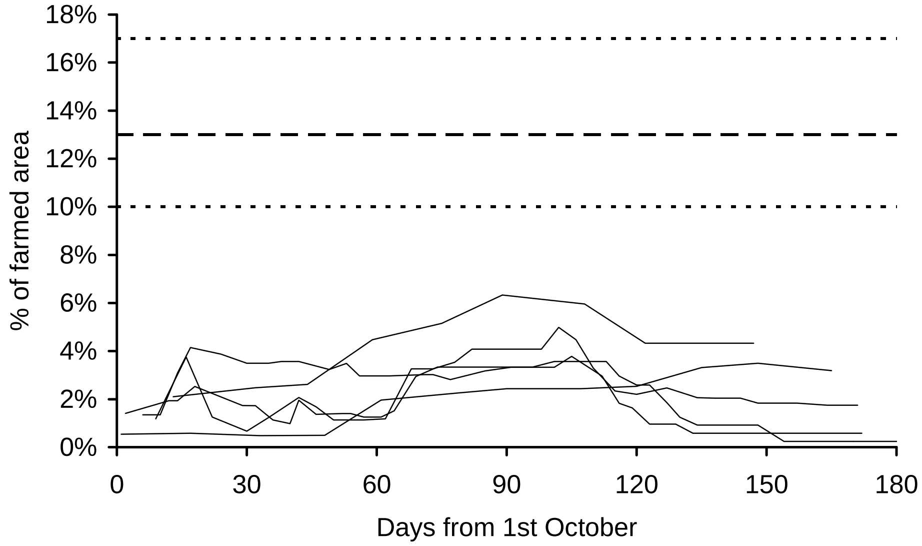


Figure 4.3.2.1 Variation in the seasonal availability of sugar beet stubbles in the Diss study area. Solid lines show availability of sugar beet stubbles in different winters. The upper dashed lines show the mean (long dash) and range (short dash) of annual cropping of sugar beet indicative of the potential total stubble availability.