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THE USE OF CEREAL WINTER FOOD PLOTS BY THE THREATENED YELLOWHAMMER *EMBERIZA CITRINELLA*

Sander Ostyn

Supervisor: LUC DE BRUYN, Research Institute for Nature and Forest (INBO)

Co-supervisor: PROF. DR. LUC LENS, University of Ghent

Tutor: OLIVIER DOCHY, Province of West Flanders

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Preface

This master thesis is covered within the Species Action Plan of the Yellowhammer *Emberiza citrinella*, commissioned and financed by the province of West Flanders. The academic framework was provided by the Research Institute for Nature and Forest (INBO). Our research focussed on the use of winter food plots by the Yellowhammer *Emberiza citrinella,* a bunting that is listed as “threatened” on the Red List of Flemish Breeding Birds. Refinement of our knowledge about this seed-eating farmland bird will contribute to a more efficient approach of future conservational measures.

In the winter of 2012-2013, I went on a farmland bird count with the local bird working group of Natuurpunt. I only recently started watching birds, and wanted to extend my knowledge. No better way than going in the field with experienced bird watchers. During this walk I met my tutor, Olivier Dochy. He enthusiastically told me about his work and the efforts he had made for the Yellowhammer over the years. When he heard I was a Biology student at the University of Ghent, he told me: “In a few years, if you are looking for a master thesis, contact me because I have a few ideas”. This ultimately led to this wonderful and instructive project, wherefore I am very grateful to have been able to contribute to. I will certainly keep track of the progress on conserving this species.

A lot of people were involved directly or indirectly in this project. I came into contact with a lot of different people. The interest, enthusiasm and dedication of many volunteers were a real inspiration to me.

Front page: colour-ringed Yellowhammer (YWGM) at our study plot G_5 in Heuvelland
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Every successful individual knows that his or her achievement
depends on a community of persons working together.

~

Paul Ryan

Sander Ostyn
Ghent, 16th August, 2016

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1 Introduction

1.1 Background on birds of the lowland farmland

1.1.1 Collapse of Europe's farmland bird populations

From the most ancient times, agriculture has represented the dominant form of land use throughout much of western Europe. A tipping point in agricultural biodiversity however, occurred during Post-war changes when not only yields increased, but also the capacity for self-sufficiency increased (Kleijn & Sutherland, 2003; Wilson et al., 1999). Major changes in the farm management were caused in response to governmental policies and through technological advances (Robinson & Sutherland, 2002). This evidently put a lot of stress on many groups of organisms associated with farmland. Bird populations in particular, showed a notable decline in numbers and range because of this agricultural intensification (Kleijn & Sutherland, 2003; Robinson & Sutherland, 2002).

Farmland provides both wintering and breeding habitat for nearly 120 bird Species of European Conservation Concern, the largest number of such species supported by any habitat (Donald et al., 2001). Approximately 80% of farmland bird species are experiencing serious population declines. In Great Britain, more than a third of these formerly common farmland birds have been added to the Red and Amber Lists of birds of conservation concern (Siriwardena et al., 1998a). In Flanders, even more than half of the remaining farmland birds are listed as threatened on the Red List of Flemish Breeding Birds (Devos et al., 2004). Declines in farmland bird species are most pronounced amongst granivorous species, i.e. those with a substantial seed component in the diet (Wilson et al., 1999). There is strong evidence that agricultural changes can be linked to the declining farmland bird populations (Chamberlain et al., 2000; Donald et al., 2001). The majority of farmland specialists have continued to decline since the late 1980s, even though the rate of change in agriculture has slowed (Fuller et al., 2000). This means that that the new carrying capacity has not yet been reached. Since birds are considered as good indicators of overall farmland biodiversity, their recent decline sounds the alarm bell (Donald et al., 2001).

In the period 1974-76, many farmland species started to decline markedly (Siriwardena et al., 1998a). By grouping birds according to their life-history or ecological characteristics, Siriwardena et al. (1998a) found that a number of species, such as Treecreeper *Certhia familiaris*, Pied wagtail *Motacilla alba yarrellii* and Wren *Troglodytes troglodytes* showed a similar pattern of decline, although they have different ecological requirements. This reflects the change in a lot of components of agricultural intensification at the same time, affecting multiple bird species (Chamberlain et al., 2000). In the same period, species such as Chaffinch *Fringilla coelebs*, Carrion crow *Corvus corone* and Stock dove *Columba oenas* showed increasing population trends, indicating that certain aspects of intensification could be beneficial (Chamberlain et al., 2000). However, the period of most rapid change in agricultural development began in 1971, which is a three to five year delay in species decline. Chamberlain *et al.* (2000) suggests that through indirect mechanisms (e.g. food reduction) this delay is exactly what could be expected if there was a causal link between the onset of agricultural change and the bird population declines. Such population effects could arise from reduced breeding productivity (Siriwardena et al., 2000), reduced survival outside the breeding season (Siriwardena et al., 1998b), or a combination of both. Density-dependent factors could have compensated for this reduced breeding production or survival as long as (1) both breeding production and survival outside the breeding season were not affected simultaneously or (2) when initial effects on breeding or productivity were not too great (Chamberlain et al., 2000).

1.1.2 European policies & legislation concerning intensified farming

Different political systems across Europe gave rise to a considerable variation in agricultural intensity (Donald et al., 2001). In the European Union, the Common Agricultural Policy (CAP) regulates and sets guidelines for national agricultural policies (Vepsäläinen, 2007). The main objectives of CAP are to develop and intensify agricultural productivity to ensure a reasonable standard of living for farmers, to stabilise markets, to secure availability of food, and to ensure reasonable consumer prices (Vepsäläinen, 2007). Such price-support policies cause a higher agricultural intensity along with the harmful threats for biodiversity. A shed of light is brought into the CAP by the so-called agri-environment schemes (AES). The highly financed European AES are one of the responses towards the concerns over biodiversity loss (Kleijn & Sutherland, 2003). These schemes were conceived as an aim to reduce the negative influence of agriculture on biodiversity by paying farmers to apply environmentally friendly management practices (Kleijn & Sutherland, 2003; Rudisser et al., 2015). At least half of the costs of approved agri-environment schemes are co-funded by the EU, which makes them a financially attractive form of environmental protection (Kleijn & Sutherland, 2003). The effectiveness of the AES is still heavily debated. Review articles conclude that some studies show a positive effect of AES on the biodiversity (Batary et al., 2015; Kleijn & Sutherland, 2003). A number of studies found no change or even negative effects, which highlights the importance of regular evaluations (Kleijn & Sutherland, 2003). Well-considered progress in agricultural policies is required to permit coexistence of viable farming along with biodiversity (Donald et al., 2001).

1.2 Trends in arable farming with implications for farmland birds

Since the 1940s, farm management in western Europe has undergone some major changes (Robinson & Sutherland, 2002). Both government policy objectives and technological advances started having a great impact on the decline of biodiversity ever since (Robinson & Sutherland, 2002). The major influences are listed and explained hereafter (Fig.1).

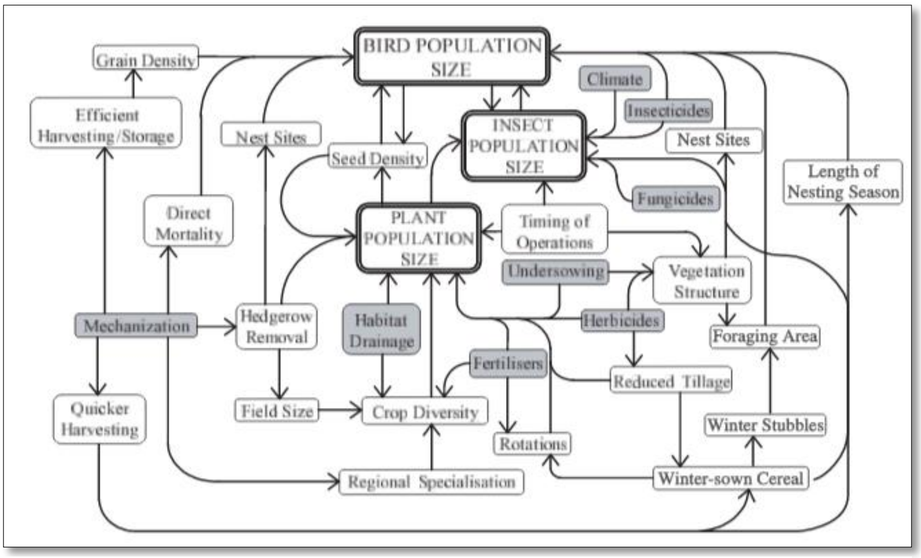

Fig.1; An overview of the potential causes of recent population changes in plant, insect and bird populations due to changes in arable management. Figure from (Robinson & Sutherland, 2002).

1) Mixed farming

The diversity of species is largely the product of habitat diversity and, within agricultural systems, a mixed enterprise with both livestock and arable production. This offers more habitat diversity than more advanced and specialised enterprises (Whispear & Davies, 2005). The arable component provides seed food for granivorous birds and the grass component generally provides more insect and soil invertebrate food for insectivorous birds. A number of species (Grey partridge *Perdix perdix*, Skylark *Alauda arvensis*, Tree sparrows *Passer montanus*, buntings,...) are very dependent on these arable lands. They feed on seeds of crops and annual weeds and might get lost when the landscape doesn't contain such arable lands (Whispear & Davies, 2005). Insectivorous and granivorous species that feed on perennial seeds of grasslands and other habitats (Chaffinch *Fringilla coelebs*, European greenfinch *Chloris chloris*, Goldfinch *Carduelis carduelis,...*) are less affected by the loss of arable farming (Whispear & Davies, 2005). Not only the loss of an arable component, but also changes in grassland management cause seed food availabilities to drop.

2) Crops

The intensification and mechanisation of agriculture has led to a dramatic increase in average arable field size. It has become more efficient to sow the same crop over several fields within one block. However, this drastically decreases habitat diversity. The switch from spring to autumn sowing had the most dramatic impact on farmland birds (Glemnitz et al., 2015; Eggers et al., 2011). When crops are sown in spring, they can provide bare tillage and sparse swards in the nesting season (Whispear & Davies, 2005). Late nesting species can benefit from this, because these crops are being harvested later on. They also enable the retention of stubbles throughout winter, which provides seed food for birds. Post-harvest stubbles used to be more abundant, but largely disappeared with the introduction of autumn sowing (Glemnitz et al., 2015). This resulted in strong declines in granivorous farmland specialists.

3) Pesticides & herbicides

The first hormonal herbicide was introduced in the 1940's, and by 1955 already 37 different compounds had been approved for agricultural use (Robinson & Sutherland, 2002). By 1997, over 344 pesticide compounds were available (Robinson & Sutherland, 2002). The bulk of declining farmland birds feed on seeds, and most of these birds feed their chicks with insects (Whispear & Davies, 2005). The use of pesticides directly or indirectly affects the abundance of seed and insect food on farmland. This can be either by (1) direct removal of invertebrates by insecticides, (2) removal of food plants for insects by herbicides and (3) removal of plants that provide food for birds by herbicides (Whispear & Davies, 2005). Farmland birds that rear their nestlings in areas with greater abundance of the key insect groups (areas that received significantly fewer pesticides), show a better body condition (Glemnitz et al., 2015). As mentioned before, over-winter stubbles are an important source of food during winter. However, the efficiency of herbicides in removing weeds, together with the efficiency of modern combine harvesters in removing the crop means that many over-winter stubbles lack the food resource required (Whispear & Davies, 2005).

4) Field boundaries and margins

The sizes of fields have generally increased, especially on arable land. This resulted in the loss of field boundary and field margin habitats, which can be a valuable source of nesting habitat, seed food and insect food for some species (Glemnitz et al., 2015; Robinson & Sutherland, 2002, Whispear & Davies, 2005). Hedgerows did not cope with the widespread tractor/combine use either. Many were removed to allow for a more efficient use. Those that did make the cut had to be kept 'tidy' or short-trimmed (Robinson & Sutherland, 2002). Although many of the declining farmland birds nest in 'un-tidy' hedgerows and field margins along these arable fields, this factor has not been identified as the main reason for their decline (Whispear & Davies, 2005). The impact is mainly directed towards the fact that farmland birds lose a rich source of insect life both in terms of potential foraging areas, as well as overwintering habitat for many insects (Whispear & Davies, 2005). High quality breeding habitats for birds, such as the Yellowhammer *Emberiza citrinella*, are linked to the provision of suitable boundary features (Morris et al., 2001).

1.3 Winter as a critical period

For many years, research and conservational efforts have been focussing on preserving and improving breeding conditions for farmland birds (Moreira et al., 2005). However, for the majority of declining granivorous farmland birds, measures to improve the breeding performance per nesting attempt are not likely to reverse the immediate demographic causes of the declines (Siriwardena et al., 2000). In recent decades, there is growing evidence that changes in the overwinter period might be of equal, or even higher, concern in saving farmland bird species (Evans & Smith, 1994, Henderson et al., 2004; Siriwardena et al., 1998b). Siriwardena *et al.* (2000) showed that annual survival of many farmland species has been the demographic rate that is most often related to population changes. This suggests that periods during which most mortality occurs, are those key times of the year during which environmental changes have affected farmland bird populations. According to the authors "such periods are likely to occur outside the breeding season, and, at least for resident species, in harsh late winter conditions when metabolic demands are high and food supplies have been depleted" (Siriwardena et al., 2000). A reduction in food availability during winter is therefore put forward as an important causal factor in population declines (Kleijn et al., 2014; Siriwardena et al., 2000). Bird species that depend on seeds during winter, such as Tree sparrow *Passer montanus,* Common linnet *Carduelis cannabina* and several bunting species, seem to be particularly affected (Newton, 1998; Robinson & Sutherland, 2002). Measures that enhance winter food resources in agricultural areas are therefore more and more implemented in agri-environment schemes.

Winter food availability is critical in the over-winter survival of many granivorous bird species. At the same time, several factors, including autumn-sown cereals, technological advances in harvesting machinery and more effective weed control, caused a notable fall in over-winter stubble fields (Evans, 1997; Gillings et al., 2005, Henderson et al., 2004; Moorcroft et al., 2002; Robinson & Sutherland, 2002). A lot of granivorous passerines almost exclusively select these stubble fields as a winter foraging habitat. For most granivorous passerines, mortality appears to be much higher in late winter because food resources become depleted as winter passes (Robinson & Sutherland, 2002). At the end of February and beginning of March, many granivorous farmland bird have to pass the so-called 'hungry gap' (Siriwardena et al., 2008), a period of food shortage. Finding food becomes hard because both winter food has become scarce and invertebrates are hardly to be found yet (Kleijn et al., 2014). If winter food for farmland birds is provisioned properly and effective, it has the potential to halt, stabilize, or even reverse the population declines (Siriwardena et al., 2007). A study from 2007 showed the positive effects of supplementary winter seed food on several breeding populations of farmland birds (Siriwardena et al., 2007). Declines of several species such as the Yellowhammer *Emberiza citrinella*, Robin *Erithacus rubecula* and Dunnock *Prunella modularis*) were less steep when food was provided at several feeding sites during winter (Siriwardena et al., 2007).

1.3.1 Food preferences during winter

In order to provide the appropriate food, one must increase the knowledge on the ecology of farmland birds during winter. Some studies have been done on the winter food preferences of birds, but there is however still no consensus. There is no food resource or seed mixture that fits the requirements of every farmland bird species. Different species have different ecological requirements when it comes to winter food.

Stubble fields seem to be an important habitat for several seed-eating birds in winter (Gillings et al., 1004; Mason & Macdonald, 1999; Moorcroft et al., 2002). They can be very rich in different food sources, such as spilt crop product (cereal grain or oilseeds), seeds of grasses and several dicotyledonous arable weeds (Wilson et al., 1996). However, because most plants only set seed prior to the onset of winter, seed resources on winter stubble fields are non-renewable (Grime et al., 1989 as cited in Moorcroft et al., 2002). Therefore, the carrying capacity of a habitat is either determined by the initial density of winter food, or that following depletion (Goss-Custard & Durell, 1990 as cited in Moorcroft et al., 2002). Distributions of many farmland species, such as European greenfinch *Chloris chloris*, Common linnet *Carduelis cannabine*, Skylark *Alauda arvensis*, Grey partridge *Perdix perdix* and several bunting species, tend to be highly skewed towards stubble-fields (Wilson et al., 1996). Cereal winter grains on the contrary are neither popular amongst granivorous passerines nor with birds that forage on invertebrates, except for skylarks (Buckingham et al., 1999; Robinson & Sutherland, 1999). This implies that cultivation of those fields reduces densities of both invertebrates and seeds, and therefore holds few food resources for either type of forager. Sadly, recent trends in agricultural land-use are changing towards the autumn sowing of cereals instead of the, from a farmland bird's point of view, more beneficial stubble fields (Wilson et al., 1996).

1.3.2 The rise of a new phenomenon: "Winter Bird Crops"

Agri-environment schemes and general farming practices are starting to adopt the enhancement of winter food resources as a conservation measure (retention of over-winter stubbles, actively planting seed-rich crops,...). A study from Henderson et al. (2004) studied the effect of so-called WBC's (winter bird crops), i.e. crops that are planted and sown with the sole purpose of providing extra winter food for farmland birds. This way, seeds are very concentrated and have the potential of making even small areas attractive as a valuable resource. Densities of birds on the WBC's were remarkably higher than on winter wheat and cereal stubbles, except for Skylarks (Henderson et al., 2004), demonstrating the possible benefits of these types of crops. WBC's differed both in bird species and the densities of birds it could harbour (Henderson et al., 2004). They were particularly popular amongst different types of seed-eating finches and buntings that preferred seeding cereals because of the large, starchy seeds. This indicated the importance of selecting appropriate seed mixtures in order to maximise the benefits for certain target groups of conservation. Experiments with winter bird crops in the Netherlands are hopeful as well (Stip et al., 2013). First analyses have shown a positive effect of winter bird crops on the number and diversity of farmland birds during winter and therefore its potential as an effective conservation measure.

A more recent study from 2014 in the Netherlands claims that regaining farmland birds, at least during winter, is fairly easy (Kleijn et al., 2014). Everything that helps in offering more food during the over-winter period would attract more farmland birds. They experimented with several seed mixtures in order to look for preferences. Apart from the Common linnet *Cardualis cannabina* and Reed buntings *Emberiza schoeniclus*, most bird species did not seem to have a clear preference for a type of seed mixture (Kleijn et al., 2014). This can be due to the fact that (1) less observations were obtained for these species or (2) they did indeed had no preference (Kleijn et al., 2014). This led to an overall conclusion of "more food leads to more birds". Even in absence of food crops that are sown for the purpose of farmland bird conservation, birds will still find food in the form of seeds from different types of grasses or weeds. However, one bird species, the Yellowhammer *Emberiza citrinella*, did not follow this rule. This one seemed more of a 'picky' eater and almost exclusively selected cereal grains (Kleijn et al., 2014)

1.3.3 Spatial use of farmland birds during the winter period

Still a major gap in the knowledge on farmland birds is the issue of the scale at which a habitat is used. It is one thing to provide farmland birds with extra winter food, such as seed mixtures and winter bird crops, but it is important to know how these patches are being used. Studies on the foraging movements of farmland birds during winter are relatively scarce.

A study from 2006 was the first one to quantify movements such movements (Siriwardena et al., 2006). This was done by investigating responses to clumped and isolated (artificial) food resources at fixed distances from each other (100m, 200m, 500m, 2km, 5k and 10km). Birds were fed with a mixture of millet and sunflowers (Siriwardena et al., 2006). They found threshold distances at which foraging behaviour drastically changed. Counts increased (e.g. Chaffinch *Fringilla coelebs*) or decreased (e.g. Yellowhammer *Emberiza citronella* and Reed bunting *Emberiza schoeniclus*) at patches beyond 500m from other patches. Support was found by the indirect evidence from data from colour-ring resightings and radio-telemetry. This suggested that birds tend to move less than 1km between food resource patches (Siriwardena et al., 2006). Important to notice is that seed mixtures were provided weekly. This led to food being available at all sites at all time and therefore prevented depletion of sites. A Defra-funded project in 2007 continued the research of Siriwardena *et al.* (2006) by studying the effect of food availability on foraging distances. Certain sites were supplemented with extra food whereas other remained in their natural state (Defra, 2007). Surprisingly, they did not find any significant difference for the reduced propensities of food supplementation on movements (Defra, 2007). Although food was supplemented and therefore abundant, birds still moved in-between several food plots. According to the author, this might reflect some kind of 'hard-wired' anti-predator strategy (Defra, 2007). Visiting multiple plots could spread the risk of predation. Based on calculated home ranges, results confirmed the threshold distance of 500m-1km between patches. They do however state that these distances are probably minimum values. They hypothesize that larger separations of food resources, in a more scattered area, will likely lead to birds travelling further and thereby bridging larger distances (Defra, 2007).

A similar study in 2006 studied the ranging behaviour of several passerines (Yellowhammer *Emberiza citrinella*, Tree sparrows *Passer montanus* and Chaffinches *Fringilla coelebs*) in a larger study area to detect movements over greater distance. Based on capture-recapture techniques, they studied the mean travel distances during winter (Calladine et al., 2006). Similar to the research of Siriwardena *et al.* (2006) and the Defra-funded project (2007), they found mean travel distances between 500m-1km. It is noteworthy to mention that there seemed to be a temporal effect between early- and late-winter in travel distances for Yellowhammers *Emberiza citrinella*. Distances were on average 90% greater in early-winter, possibly because of some sort of 'settling behaviour' (Calladine et al., 2006). Some important remarks when considering the two studies: Firstly, Calladine *et al.* (2006) made use of a greater study area, compared to Siriwardena *et al.* (2006). This could reflect the larger maximum distances that were found. Secondly, in Calladine *et al.* (2006), the study period was limited to early winter when food resources were abundant, which might possibly underestimate the foraging distances. Thirdly, Calladine *et al.* (2006) made use of feeding sites that existed for several years, which could have had a long-term impact on the foraging patterns of local birds (Siriwardena et al., 2006). The actual situation, in which the location of winter food plots differs annually and might deplete over time is not reflected in those studies. However, in our small-scaled landscape, food plots are less predictable and reliable.

The effect of individual differences, such as age and sex, on foraging behaviour are only rarely studied in birds, especially passerines. Among those studies, most effects seem to be age-related (Enoksson, 1988; Figuerola et al., 2001; Gustafsson, 1988). A study on Coal Tits *Parus ater,* found major influences of adults on foraging site selection during winter (Gustafsson, 1988). Dominance of adults over young birds caused them so select the best patches and thereby expulse young birds to patches of sub-optimal quality. Similar results were found at wintering grounds of Robins *Erithacus rubecula* (Figuerola et al., 2001). Young birds are displaced to less suitable winter habitat since the best wintering areas are monopolized by adults birds.

1.4 Importance of surrounding landscape elements at winter food plots

The importance of habitat structures during the breeding season of farmland birds has been widely studied (Burgess et al., 2015; Whittingham et al., 2005). However, little is known about which environmental elements determine winter distributions of farmland birds. The importance of cover, provided by landscape elements in winter, has been studied in several tit species (Walther & Gosler, 2001). In case of a high food availability, tits forage close to protective cover in order to reduce predation risk. They would thereby neglect more attractive food patches as some sort of 'safety-first' strategy (Walther & Gosler, 2001). Robinson & Sutherland (1999) were among the first authors to study which elements of cover are preferred during winter. They found that, apart from seed availability, distance to the nearest hedgerow was an important factor in preferred habitats (Robinson & Sutherland, 2002). Yellowhammers *Emberiza citrinella*, as well as Tree sparrows *Passer montanus* and Common linnets *Carduelis cannabina* were found to forage close to hedges. Foraging next to hedgerows was irrespective of seed densities at those areas (Robinson & Sutherland, 1999). A report from 2003 also tried to assess the habitat use of Yellowhammers *Emberiza citrinella* and Chaffinches *Fringilla coelebs* in winter by comparing results of radio-telemetry and field observations. Preferences were determined based on the habitat structures in the immediate vicinity of location fixes (Calladine et al., 2003). Both field observations, and radio-telemetry found scrub, i.e. brushwood, long/tall vegetation and bramble, to be ranked highest among both Yellowhammers bird species. Cereal stubbles were ranked second.

1.5 Keeping in mind: country specific aspects

Great Britain is the key player in studies concerning the relation between food availability and the effect on farmland bird abundances (Kleijn et al., 2014). Agriculture in Great Britain happens on a much larger scale compared to our regions. Farm companies are larger, which facilitates the fitting of several protective measures. Their agricultural landscape is characterized by extensive plots and a crop rotation that is mostly dominated by winter crops (Kleijn et al., 2014). It is therefore advised to interpret conservational efforts with care, because the same measures could not hold up in our type of landscape that is characterized by a more small-scaled agriculture. An example of this nonlinearity is the study of Teunissen *et al.* (2009) in the Netherlands. They experimented with so-called Skylark plots. This is a protective measure, originated in Great Britain, that creates several plots (4mx4m) within a large winter crop plot to create foraging and breeding opportunities for Skylarks *Alauda arvensis* (Teunissen et al., 2007). Unfortunately, the Skylark plot measure that seemed effective in the English agricultural landscape did not hold up in the Netherlands (Kleijn et al., 2014; Teunissen et al., 2007). Supplementary research in small-scale landscapes is therefore needed.

1.6 Synthesis

When trying to stabilize or reverse the declining population trends of many granivorous farmland birds, conservation should not only focus on measures that improve breeding success but also those that aim at increasing over-winter survival. In order to adapt certain conservational efforts, a better knowledge on their ecology must be attained. The impact of agricultural intensification is certainly not negligible, e.g. switch from spring-sown towards autumn-sown crops, better harvesting techniques that reduce the amount of spilt crop product, better weed-control, etc. They all contribute to winter food resources being further stretched. The use of winter bird crops have the potential of counteracting this trend. By paying attention to the date of sowing and ploughing, winter bird crops might help closing the hungry gap towards the end of winter. Further research should however focus on the issue of the scale on which farmland birds operate in winter (Kleijn et al., 2014; Siriwardena et al., 2006). Only few studies have been done in order to determine foraging distances and movements during winter. Movements in the extensive British farmlands tend to range between 500m-1km (Calladine et al., 2006; Defra, 2007; Siriwardena et al., 2006). When food plots are more scattered and less reliable, it is important to know whether birds will adapt their foraging distances, or neglect plots because they are too far apart. Habitat preferences for farmland birds in winter is mainly determined by the presence of cereal grains or stubbles (Gillings et al., 2005; Moorcroft et al., 2002). However, surrounding landscape elements such as hedgerows (Robinson & Sutherland, 1999) or scrub (Calladine et al., 2003) have proven to be additional factors in determining a good winter site.

1.7 Yellowhammer project & thesis framework

1.7.1 The Species Action Plan

This thesis is covered within the Species Action Plan, commissioned and financed by the province of West Flanders, in collaboration with the Research Institute for Nature and Forest (INBO) and the University of Ghent. The Species Action Plan aims at a sustainable maintenance and, when possible, an enhancement of the biodiversity in the province of West Flanders (Dochy, 2015). It is framed within the provincial biodiversity policy on species protection.

In order to execute the correct measures, one must decide which species to protect. Although each species has its own ecology and habitat preferences, they have some aspects in common (Dochy & Hens, 2005). Considering farmland birds, we can distinguish two types: (1) those that prefer an open landscape and (2) those that rely on a more small-scaled landscape (Dochy & Hens, 2005). A small-scale landscape is marked by landscape elements, such as hedgerows, scrubs, bushes, orchards, field margins etc. (Dochy, 2014). This type of landscape is gradually disappearing. Many species, among whom the Yellowhammer *Emberiza citrinella*, depend on this type of landscape for their breeding activities. Since species are more appealing to one's imagination than habitats do, the Yellowhammer serves as a flagship species in conservation projects (Dochy et al., 2007). The Yellowhammer is therefore a symbolic species for a small-scale landscape. Improving its habitat conditions not only benefits the species, but also the reintroduction of its valuable habitat. A small-scale landscape that is preferred by the Yellowhammer, also houses tons of other rare and threatened species; e.g. Brown hairstreak *Thecla betulae*, Slow worm *Anguis fragilis*, Garden dormouse *Eliomys quercinus*, Stone parsley *Sison amonum*, etc. (Dochy, 2014). By putting effort into protecting the habitat of Yellowhammers, many other species may experience indirect positive effects.

The Yellowhammer is a protected bird species in Flanders according to the Decree of the Flemish government of 15th May 2009 concerning species conservation and species management. Measures for the Yellowhammer are concentrating on the improvement of their habitat quality. Once this is attained, one can look at increasing the amount of habitat and connecting separated populations (Dochy, 2014). According to Dochy & Hens (2005), measurements for the Yellowhammer should focus on providing food and protection. This is summarized as the "Big Three": (1) Providing summer food which leads to an increased offer of protein-rich insects, (2) Providing winter food in the form of large starchy seeds (cereal grain, grass,...) and (3) Providing cover for safe breeding and shelter (Dochy, 2014). By doing this, the province wants to stop a further decline of the occupied surface area (km^2), number of breeding territories and wintering birds by 2020.

In concrete terms, this is done by the following five goals of the Species Action Plan:

- Improvement of the breeding habitat
- Providing winter food
- Creating insect-rich zones
- Refinement of the knowledge
- Sensitization

1.7.2 Current winter measures for the benefit of the Yellowhammer

As mentioned earlier, providing food is a critical factor in ensuring the survival of the Yellowhammer during the winter period. The province of West Flanders already anticipates on this matter by setting aside some winter food plots. Measures are covered within the winter perimeter, in a radius of 2km, around the known breeding cases (2010-2013) (Dochy, 2014). This research will contribute in refining the knowledge on foraging movements and habitat preferences of the Yellowhammer during the winter period.

Fig.2: Bristle oat *Avena strigosa*. © Dieter Coelembier

A quite new measure that has been added to the list, is the one of using bristle oat as a winter food crop. Bristle oat *Avena strigosa* (Fig.2) is a type of cereal crop that is native to the Mediterranean region. During the Bronze Age, bristle oat was cultivated in practically entire Europe but was eventually replaced by other, more productive types of *Avena* (Coelembier et al., 2015). Bristle oat became low-profile, until the past few years when it regained its popularity. More often, it is being used as a cover crop instead of an intermediate crop. It is advantageous for the farmer because he can sow both his regular crops as well as the bristle oat as a cover crop afterwards. In the beginning, farmers received subsidies and grants to stimulate the sowing of this cover crop (Coelembier et al., 2015). Because it is generally accepted that sowing this crop is part of a good agriculture, stimulation by payment is fading. Cover crops serve as a mulch (cover) and thereby prevent the runoff from fertile soil. It also serves as soil amendment and prevents nitrate from leaching. Bristle oat in particular has a reducing effect on the root lesion nematode *Pratylenchus penetrans* (Coelembier et al., 2015). They are frost-susceptible and can easily be ploughed under and incorporated into the soil without any known problems for the following cultivation (Coelembier et al., 2015).

By coincidence, birders found that early sown bristle oat could still set seed in mid-winter, attracting large numbers of granivorous birds, including Yellowhammers (pers. comm. R. Guelinckx, F. Verdonckt, D. Coelemebier and O. Dochy). In the eastern part of Flanders, there have been experiments with bristle oat for several years (Coelembier et al., 2015). In the springtime of 2013, a new project in the West Flemish regions was launched to investigate the possibilities that the crop had to offer. This was done by Dieter Coelembier (VLM; "Vlaamse Landmaatschappij"), the initiator of the project, with financial support of "Regionaal Landschap Ijzer en Polder" and "West-Vlaamse Heuvels". After the first positive results, they insisted on incorporating the use of bristle oat as a cover crop for farmland birds into the SAP (pers. comm. D. Coelembier). Farmers were eligible for the project if they had parcels within the small distribution area of the Yellowhammer and one, or several, of those parcels were situated alongside woody/thorny landscape elements (Coelembier et al., 2015). The sowing seed (ca. €1,50/kg at 50kg/ha) is provided within the project but has to be sown before the 1st of September in order to have the setting of seed. This can only be done if the main cultivation is harvested early on (main cultivation mostly winter barley *Hordeum spp.* or winter wheat *Triticum spp.*). The bristle oat can only be ploughed from the 15th of March the following year (Coelembier et al., 2015). By applying this measure, this crop might be a good solution to bridge the hungry gap (Siriwardena et al., 2008) towards the end of winter. It is now the 3rd year that the campaign stands.

1.8 The Yellowhammer as a study species

1.8.1 Characteristics

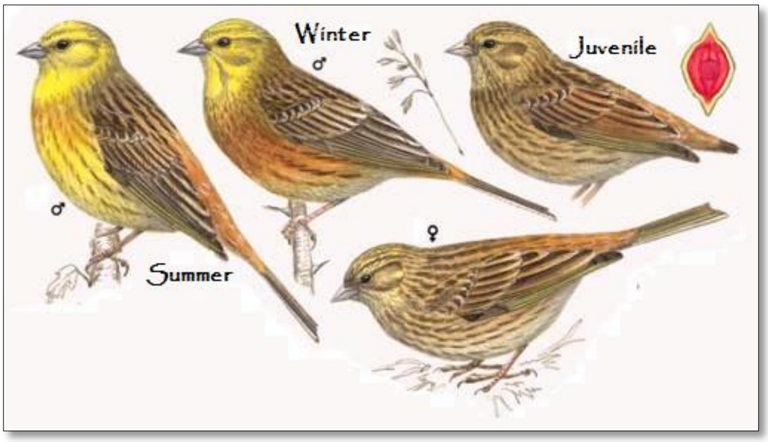

Fig.3: Yellowhammer in its different plumages.
Source: http://www.planetofbirds.com/Yellowhammer-emberiza-citrinella

Kingdom: Animalia
Phylum: Chordata
Class: Aves
Order: Passeriformes
Family: Emberizidae
Genus: Emberiza
Species: *Emberiza citrinella*

The Yellowhammer is a rather large and fairly long-tailed bunting with a slightly forked tail, belonging to the bunting family Emberizidae. Their bill is grey and the legs are flesh-brown. Both sexes have clear white outer tail-feathers which are conspicuous during take-off and landing. The chestnut brown rump is also a very clear characteristic in the field (Fig.3). The male Yellowhammer is characterized by a bright (lemon) yellow head and underparts, and a darkly streaked mantle. The females are much browner and duller. Their olive-coloured head is more streaked, so are the underparts. Juveniles are darker and less yellow.

Red List category of the Yellowhammer:

Europe – Least Concern (IUCN List of Threatened Species, www.iucnredlist.org, 2015)
UK – Threatened (RSPB, www.rspb.org.uk, 2015)
Belgium (Flanders) – Threatened (Red List of Flemish Breeding Birds, www.inbo.be, 2004)
Belgium (Wallonia) – Least Concern (Liste Rouge des Oiseaux nicheur, biodiversite.wallonie.be, 2010)
Netherlands – Non Threatened – (Rode Lijst, www.sovon.nl, 2007)
France – Near Threatened – (UICN, Liste Rouge des espèces menaces en France, 2011)

1.8.2 Habitat

The Yellowhammer occupies a wide range of habitats all over Europe. Originally, it was a bird of semi-open areas and a typical inhabitant of transition zones in temperate regions. The Yellowhammer perfectly adapted to a small-scaled arable and mixed farmland where small-scale landscape elements are abundant. Among them: solitary trees, bushes, scrubs, (thorny) hedges, stubble fields, woody stripes, orchards and field margins or ditches with a mix of herbs (Dochy, 2014; Dochy & Hens, 2005). A type of habitat that is drastically disappearing due to the up scaling of agriculture.

1.8.3 Behaviour

The Yellowhammer is mainly sedentary and only seldom migrates during winter season (ringing data KBIN, Lippens & Wille, 1972)). Only northern populations explore warmer places during autumn. Outside the breeding season, Yellowhammers can form groups that differ greatly in size. These winter groups often consist of other seed-eaters as well and are formed during late summer – early autumn. They are primarily formed by young birds, adults join later on (Clarysse, 2003). In February, when temperatures start to increase, male birds leave the group in the morning and evening to explore the region, looking for suitable breeding territories. Females tend to leave the groups later on.

1.8.4 Diet

In winter, Yellowhammers forage almost exclusively on cereal grain, such as *Triticum spp., Secale cereal, Avena spp., Hordeum vulgare* etc. (Robinson, 2004). In contrast to many other farmland birds, Yellowhammers are quite refined (Holland et al., 2006; Kleijn et al., 2014). They prefer starchy seeds (cereal grain). By identifying the remains in faecal pellets, Robinson (2004) found that up to 97% of their diet consisted of cereal grain, supplemented with some weed seeds, such as *Amaranthaceae, Carophyllaceae, Poaceae* & *Polygonaceae* (Robinson, 2004). Maize stubbles and oil-rich seeds (rape, sunflower,...) are avoided (Perkins et al., 2007, Dochy & Hens, 2005).

1.8.5 Population trend and distribution

In Europe, the Yellowhammer is the most common and widespread bunting (Snow & Perrins, 1998; Whispear & Davies, 2005). The majority is sedentary and occurs from Scandinavia up to Spain and Kazakhstan, and from Ireland up to Central-Siberia. The species has also been successfully introduced in New-Zeeland in the 19th century. Three subspecies occur throughout Europe: *E. citrinella citrinella* (Northern Spain – Scandinavia), *E. citrinella caliginosa* (western Great-Britain) and *E. citrinella erythrogenys* (Eastern-Europa, Russia and the Baltic states).

In Flanders, the Yellowhammer used to be common and widespread as well (Devos et al., 2004). However, in the last decades, the species encountered some serious reduction of its area. The total Flemish population is estimated on 3400-4000 breeding pairs which is a severe reduction compared to the 10.000-11.000 estimated pairs in the period of 1973-1977 (Devos et al., 2004). In Limburg and Flemish Brabant, we still find some core populations, but elsewhere it is mostly relict populations or the borders of large populations from neighbouring countries (Fig.4). In the province of West Flanders, there are still an estimated 100 breeding territories (Dochy, 2014)

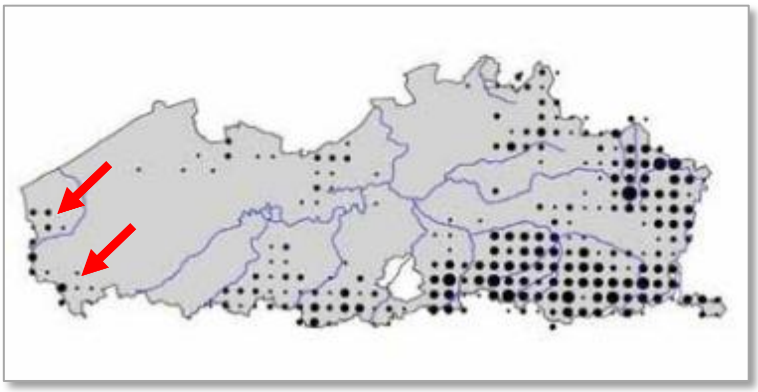

Fig.4: Spread & density of the Yellowhammer in Flanders in 2000-2002. Arrows indicate our study areas. Source: Devos et al., 2004

2 Objectives

Improving our knowledge on ranging behaviour, movements and habitat preferences is an important step in adjusting current conservational measures. Especially the scale at which those activities are performed is still a major gap in the current knowledge. This study will be performed in two regions in the southwest of West Flanders. Both regions differ in spatial distribution of winter food plots, being either clumped or more scattered. Research questions will be answered by either colour-ring resightings and radio-telemetric data (objective 1) or based on simultaneous count data (objective 2). Objective 3 will be answered based on observations in the field and experiences of our bird ringers.

2.1.1 Objective 1.
Spatial use: How do Yellowhammers make use of winter food plots?

A first aspect in research on spatial use is studying the movements of Yellowhammers. The movements are here defined as the amount of different plots used over the course of winter. Can we find evidence for the anti-predator strategy, as hypothesized by (Defra, 2007)? Do birds move between multiple plots or are they true to the most qualitative plot? And if Yellowhammers move, are these movements located between the most qualitative plots? Since seeds deplete over the course of winter, we expect Yellowhammers to move between winter food plots rather than remain faithful to one plot. Assuming that Yellowhammers visit multiple plots, we hypothesize that birds will exchange plots of sub-optimal quality for a better one. We will also test the effect of individual differences (sex- or age-related) on foraging movements.

A following topic when studying spatial use, is ranging behaviour. Does ranging behaviour vary with clumpiness of food resources? Ranging behaviour will be determined based on measured distances between the location of resightings. In other words, the distances between the plots where an individual has been tracked. Are foraging distances larger in a scattered region? Are covered distances in small-scale landscape greater compared to studies with artificial feeding sites in Great Britain? Distances will be modelled as 1) all foraging distances, 2) the three largest foraging distances and 3) the maximum covered distances. In accordance with the hypothesis of Defra-funded project (2007), we expect foraging distances to be larger in our regions, compared to those found in Great Britain. On top of that, we hypothesize that there to will be a regional effect on foraging distances between both of our regions. The least scattered area will result in smaller ranging behaviour and vice versa.

2.1.2 Objective 2.
What is the relative effect of food abundance and surrounding landscape elements on Yellowhammer abundances?

We will develop a model in which we try to predict Yellowhammer abundances based on local effects (food condition) and more regional effects (surrounding landscape parameters). We hypothesize that food condition above all else will contribute the most to being a preferred site as found by Whittingham et al. (2005). We expect there to be an additional effect of hedgerow distance to the plot, similar as results found by Robinson & Sutherland (1999). Thereby, food abundant plots with a hedgerow nearby will be preferred.

2.1.3 Objective 3.
Methodological support in monitoring Yellowhammers during winter

Can horizontally-stretched mist-nets serve as a capturing method in bad weather conditions? Vertical mist-netting is a widely used technique for catching passerine birds. However, we expect the use of this method to be less fortunate during winter. Horizontally-stretched mist-nets is a relatively unknown technique that will be applied to cope with unreliable weather conditions.

3 Material & methods

3.1 Study sites

This research was conducted in the winter of 2015-2016 (December to February). The winter food plots that are involved in this research, consist of a selection of plots that are located within the 2km winter perimeter (Dochy, 2014) of Yellowhammers. All plots can be found from 50°46' to 50°59' N and 2°35' to 2°49' E.

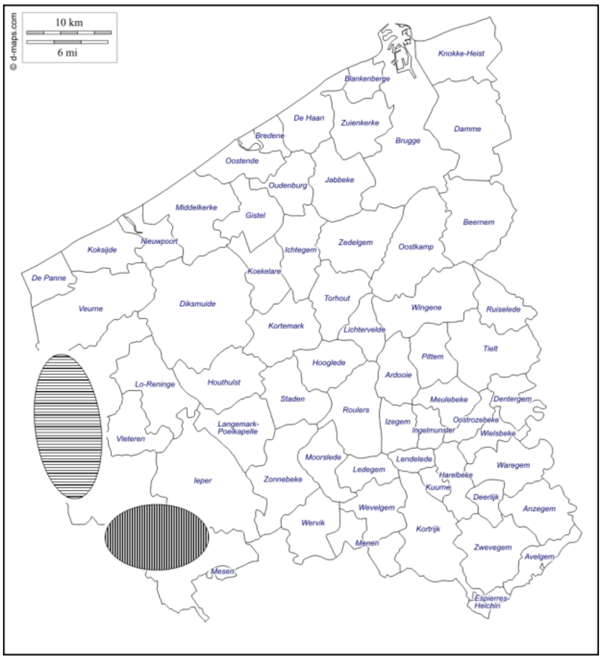

Fig.5: Map of West Flanders with our 2 study regions:
Horizontally striped circle = northern region
Vertically striped circle = southern region

A total of 30 winter food plots were used for the purpose of this study. They are divided over two regions in West Flanders. The northern region, extending from Roesbrugge, Beveren-aan-de-Ijzer up to Poperinge (Fig.5). The southern region centred around Heuvelland (Fig.5). Details on the spatial distribution of our plots can be found in the Appendix. Mean distances between are plots are 2.47 ± 1.36km (south) and 5.38 ± 3.95km (north). Winter food plots in the northern region are more stretched over the landscape. Looking at the northern plots, we see that two plots (JH_4 & JH_16) are located very distant from the other plots. Exclusion of these plots gives mean distances of 3.60 ± 2.35km between northern plots. The southern region is characterized by the winter food plots being more clumped together. Distances in-between field plots of both regions are significantly different ($P<0.001$), irrespective of inclusion of JH_4 and JH_16. We therefore consider the northern region as our scattered plot distribution. Winter food plots are under management of Natuurpunt, ANB (Agency for Nature and Forests), the Province of West Flanders or local farmers on contract. Plots were not intentionally selected for this study. The regional effect of clumpiness is therefore coincidental rather than intentional. However, in order for plots to be considered as potential winter food plot, they have to be located within the range of Yellowhammers as well as be located near woody elements (pers. comm. O. Dochy).

Other research on ranging behaviour of Yellowhammers in winter was done using artificial feeding stations and baited sites to simulate their food resources. We did use actual food plots that are less reliable and predictable. This allows food resources to naturally increase or deplete over time. Winter food plots can not only be distinguished by region, but also by the crop type. Plots either had cereal grains (spring or winter wheat *Triticum spp.*) or bristle oat *Avena strigosa.*

3.2 Data collection

3.2.1 Ringing

As a first technique to study Yellowhammer movements during winter, we used colour-ringing. Resightings of colour-ringed individuals by volunteers can be used as an additional location fix, next to the radio-telemetric data. Another purpose, that is beyond the extent of this master thesis, is the study on Yellowhammer territories during the breeding season of 2016-2017. This project will study whether our winter food plots help local breeding Yellowhammers.

Birds were caught at six key sites within the study area, three sites per region. In the northern region, Yellowhammers were ringed at G_4, JH_3 and JH_8. In the southern region at G_5, G_2 and G_3 (See Appendix). Ringing sites were initially selected by the bird ringers. They were chosen, based on the occurrence of Yellowhammers during winter and their practicality for catching birds. Some changes had to be made to our initial plan in order to capture as many Yellowhammers as possible early on in winter (see 3.2.1.1). A total of sixteen ringing sessions (north: 7 & south: 9) were completed between 28 December 2015 and 12 March 2016 (Table 1). A total of 163 Yellowhammers have been caught, ringed (and tagged). At each capture, birds were: (1) aged, (2) sexed, (3) measured for wing length, (4) measured for weight and (5) given a fat score (according to Svensson, 1992). Birds were either aged as “young birds” (hatched during 2015) or as “adult birds (“hatched prior to 2015). Details can be found in Table 2 for both colour-ringed (a) and tagged (b) Yellowhammers. Birds were caught using a different set of capture methods.

Table 1. Overview of date when yellowhammers have been ringed and tagged

Date	Yellowhammers ringed	Yellowhammers tagged	Region
19-12-2015	2	2	South
23-12-2015	1	1	South
28-12-2015	4	4	North
1-1-2016	2	2	South
6-1-2016	8	7	South
17-1-2016	10	3	South
20-1-2016	18	5	North
21-1-2016	4	4	North
11-2-2016	12	1	North
26-2-2016	25	none	South
1-3-2016	16	none	North
8-3-2016	1	none	North
10-3-2016	33	none	South
11-3-2016	1	none	North
12-3-2016	26	none	South
Total	**163**	**29**	

Table 2 (a). Overview of the Yellowhammers colour-ringed at our ringing sites, 28 December 2015 - 12 March 2016

	South			North			
	Young	Adult		Young	Adult		
Male	37	15	**52**	32	5	**37**	89
Female	33	22	**55**	18	1	**19**	74
			107			56	**163**

Table 2 (b). Overview of the Yellowhammers tagged at our ringing sites, 28 December 2015 - 12 March 2016

	South			North			
	Young	Adult		Young	Adult		
Male	5	3	**8**	7	3	**10**	18
Female	4	3	**7**	3	1	**4**	11
			15			14	**29**

3.2.1.1 *Capture method*

1) Clap-net

The original idea was to use clap-nets for capturing the Yellowhammers. In the weeks prior to the start of the project, the selected sites for capturing were prepared. This involves clearing a part of the soil to avoid struggle of the vegetation with the nets. A (non-active) setup, similar to the actual one, was used in order to create habituation. Neighbouring volunteers pre-baited the area surrounding the clap-net setup to attract granivorous birds. This was done every two to three days. When the actual capturing would occur, birds would be used to the net as well as the food that is regularly provisioned. We assumed that other species, such as Chaffinches & European greenfinch, would be attracted to the bait and Yellowhammers would automatically follow. However, this method failed. It would probably have been a successful method, if it weren't for the soft winter temperatures. Food was abundant, and the effect of baiting failed. We then switched to two other methods (depending on the location): mist-netting and horizontally-stretched mist-nets.

2) Mist-net (Fig.6a)

Mist-nets are the most commonly used technique for capturing passerines, but are more dependent on weather conditions. That is the reason why we initially opted for the clap-net method, but also because of time limitation (battery drain of the transmitters). Rain and wind can make this technique useless by increasing the visibility of the nets. Mist-nets were therefore used when conditions were beneficial and the location permitted the placing of these nets (best used against a dark background; dense, high hedges). Birds are caught when they fly into the net. This way, they become entangled and end up in a pocket of netting supported from a shelf-string (Sutherland & Green, 2004. For this method we used Ecotone mist-nets 716 (netting denier: 700; mesh size: 16) with lengths 7m, 9m, 10m and 12m (Ecotone, Gydnia, Poland).

3) Horizontally-stretched mist-nets (Fig.6b)

Mist-nets were loosely stretched over the crops by several bamboo sticks at both ends of the net. Because the nets were stretched just on top of the crops, birds could either be trapped when landing into the crops or when walking under the nets and flying back up. In contrast to the vertical mist-nets, birds entangle but do not end up in the pockets. Therefore, birds had to be extracted rather quick before they untangled themselves and took off. For this method Ecotone we used mist-nest 1022 (netting denier: 1000; mesh size: 22) with length 12m (Ecotone, Gydnia, Poland).

Fig.6 (a) vertical mist-netting (b) horizontally-stretched mist-nets

3.2.1.2 *Colour combinations*

Each individual was marked with four rings: three colour-rings and one metal ring (2.8mm). We chose to colour-ring Yellowhammers with two colour-rings on the left tarsus, and one colour-ring on top of a metal ring on the right tarsus (Fig.8). This combination of colour-ringing (CC-CM) has not been used in other ringing projects in the Western Palearctic Region (cfr. www.cr-birding.org). This way we could avoid conflict with other projects.

Fig.7: Colours used (except for purple & dark blue)
source: http://en.ecotone.com.pl/

Colour rings had an inner diameter of 2,8 mm and a height of 9 mm according to: “Mostly used colour rings sizes for Western Palearctic bird species” (www.cr-birding.org). Six different colours were used in this project: *dark green, black, yellow, red, orange* and *white* (Fig.7). The colour rings were borrowed from the University of Antwerp (UA) added with colour rings from Ecotone (Ecotone, Gydnia, Poland). Using three colour-rings and a total of six colours, we had a total of 216 (6^3) available combinations.

The colour-ring on the right tarsus was reserved as the indicator of the plot where the bird was captured and ringed (cfr. six ringing sites). The colour-rings on the left tarsus were used to recognize each Yellowhammer individually. When more than 36 Yellowhammers were caught at a certain ringing site, combinations of other ringing sites were used as a supplement.

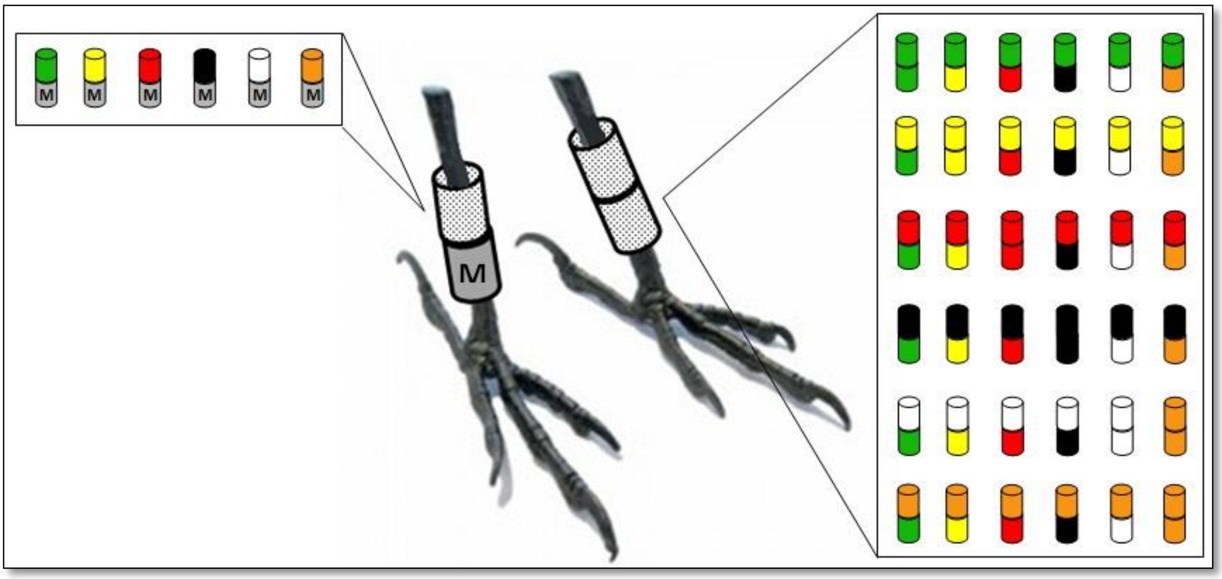

Fig.8: Scheme of possible colour combinations with "M" being the metal ring.

3.2.2 Radio-telemetry

1) PIP tags

Studies on ranging behaviour mostly rely on remote sensing techniques (Calladine et al., 2006). Yellowhammers are small birds, so we had to make use of small transmitters instead of remote sensing telemetry (Calladine et al., 2006). A total of 29 Yellowhammers were fitted with a PIP tag (Biotrack, Wareham, UK). Radio transmitters should not exceed 3% of the total body weight of the bird (ca. 25gr).

***The PIP tag** is a 'two-stage' transmitter circuit board with separate oscillator and amplifier/antenna matching circuits. It has an independent pulse-forming circuit (a stable multivibrator) and is built from some of the smallest surface mount components available, including a surface mount crystal. The inclusion of this small crystal is the main advance in the Pip, and enables 0.3g to be shaved off the weight of our small tags. For the very smallest tag, this represents a weight reduction of nearly 60%. The transmitter is named after Britain's smallest species of bat (Pipistrelle), retrieved at www.biotrack.co.uk.*

Unfortunately, there is a trade-off between battery life, tag weight and pulse settings. In order to achieve a battery life of two months (half-December until half-February) and stay within the acceptable weight range, we had to compromise on battery type and pulse settings. An Ag376 battery was therefore our best option. We opted for the combination with pulse length 15ms and pulse rate 40ppm. The pulse length determines the sound of the signal on your receiver. This is important when the bird is at a larger distance or behind some obstacles. The sound of the signal on the receiver will be much "thinner" than that of a longer pulse length. The pulse rate should be chosen according to the application. The faster the pulse rate, the faster you can find the true direction of your target individual. The temporal resolution of the location data will be higher. We chose intermediate settings in which we could track the birds rather fast and still had an adequate signal on our receiver. Tag radio frequencies were chosen between 150 MHz and 152,9 Mhz (obligatory in Belgium). The antenna had a length of 20 cm, made out of a thin and very flexible material.

2) Leg-loop harnesses

We used Rappole-Tipton harnesses, instead of tail-mounted tags. In contrast to tail-mounting, the harnesses are placed near the 'centre of gravity'. When ordering, we chose for the placement of a front tube (inner diameter: 1,0mm) and a back tube (diameter: 1,5mm) that would make the attachment easier and would prevent the transmitter from flipping once it is fitted on the bird. (Fig.9a).

We used a very thin (~0,5 mm) white elastic sewing thread (Prym Consumer, Stolberg, Germany) to make the leg-loop harnesses. First, the elasticity allows for an easy attachment to the bird (Streby et al., 2015). Second, the elasticity allows for an approach of the one-size-fits-all when variation in body mass isn't too large (Streby et al., 2015). Finally, the thin elastic sewing thread allows the harness to degrade and fall off several weeks after deployment (Streby et al., 2015). The harness span was determined using the algometric function in Naef-Daenzer (2007).

$$\boxed{\textit{harness span} = 14{,}16 + 8{,}34 \times \textit{body mass}^{0{,}437}}$$

The body weight of Yellowhammers during winter is approximately 25g (according to ringing data). This resulted in a harness span of 48,21 mm (24,1 mm on each side). After some trial and error in the field, with different sizes of the harness span, we decided to make them a little bit more tight. Those with a harness span of 21-22 mm seemed to give the best results (not too tight, not too loose). The sewing thread was knotted and lubricated (instant-glue) at the tips of each of the tubes to make the structure permanently fixed (Fig.9b, 9c).

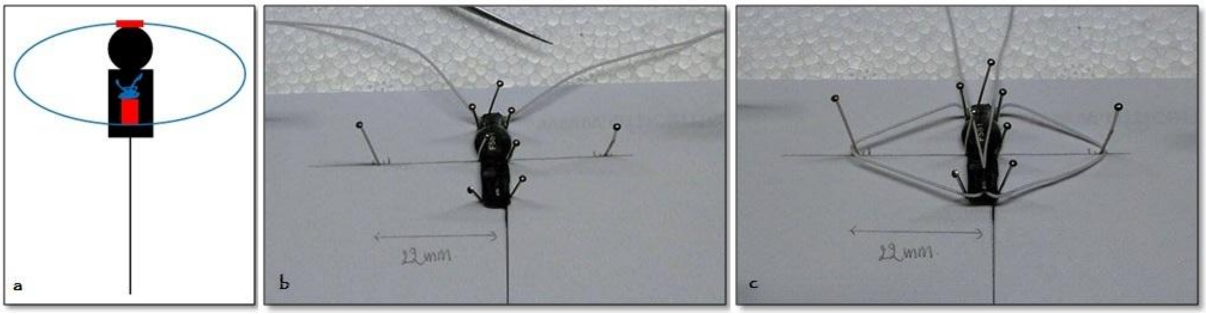

Fig.9: (a) Design of the transmitter with front tube (ø 1mm) and back tube (ø 1,5mm). (b) Lubricating the elastic sewing thread at both end of the front tube. (c) Knotting and lubricating the elastic sewing thread at both ends of the back tube.

Attaching the transmitter to the bird is very easy and quick due to the elastic strands (Streby et al., 2015). The leg-loops can be slipped over the legs, while making sure the antenna points in the same direction as the tail. Properly attached transmitters should allow some 2mm play between the device and the bird's back, as well as 5mm play when gently pulling the antenna backward (Naef-Daenzer et al., 2005). Before releasing the bird, the frequencies were tested (sometimes transmitters can shift 0-2 kHz when attached to the body (Naef-Daenzer et al., 2005).

Fig.10 Photo of a tagged Yellowhammer. © Diederik D'hert

3) Receiver & antennae

Tagged individuals were tracked using an ATS model R410 Scanning Receiver (Fig.11a), borrowed from the University of Antwerp (UA). We used two types of antennae. Firstly, a Magmount antenna (Biotrack, Wareham, UK) (Fig.11b). The Magmount antenna is an omni-directional antenna that scans circumferential. Secondly, a Hand-held Three-element Yagi antenna (Fig.11c), also borrowed from the University of Antwerp. Signal reception is strongest when the Yagi has the same orientation as the received radio-waves. This way tagged individuals can be localised in a more accurate manner. When necessary, we followed the signal in order to ascertain a reliable location (=in the surroundings of the food plot or not?). When signals seemed too steady, we followed the signal in order to confirm if tags were still attached or if the bird was still alive.

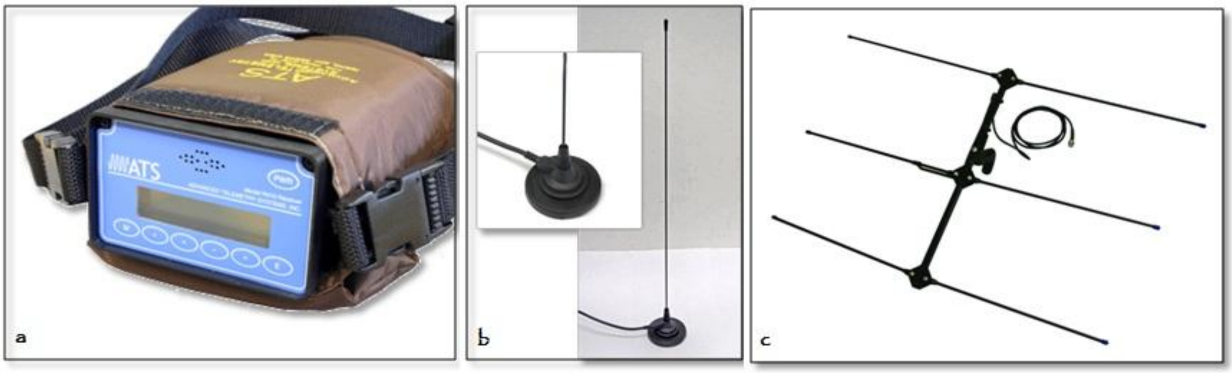

Fig.11: (a) ATS model R410 Scanning Receiver. (b) Magmount antenna. (c) Hand-held three-element Yagi antenna.

4) Collection of radio tracking data

Field plots were visited weekly from the last week of December until the end of February. Two complete searches were made each week while the tags were active, one day in the southern region, another day in the northern region. Complete coverage of all food plots ranged between three to seven hours. The length of searches depended on two factors. Firstly, the date: at the beginning of the fieldwork only few Yellowhammers had been tagged and towards the end some tags had stopped transmitting or birds had simply left the study area. Secondly, the region: the northern region had less plots to visit compared to the southern region. Our food plots were visited in a random order to exclude a bias in our data by checking certain plots at the same time of the day. To limit CO_2 emission, plots were subdivided into five "sub-regions", each containing several plots. We randomly ordered the sequence of sub-regions using the online randomizer at “Random.org-List Randomizer”. Plots within each sub-region were visited in a fuel-efficient way.

The radio tracking typically went as follows:

1. The first food plot was checked at about 9:30am. When driving in between plots, the Magmount antenna was placed on the rooftop of the car. However, we found no tagged individuals at places in-between food plots. Depending on the openness of the area, signals could be retrieved from 0.5 up to 5km.

2. At the winter food plots, all frequencies were looped two to three times with the Magmount antenna. If possible, this was done while still in the car to avoid disturbance. Frequencies of Yellowhammers on the spot were noted. Subsequently, those frequencies were tracked individually with the Three-element Yagi antenna. Individuals were localized in the best possible way. More important than precisely locating though was assessing whether the bird was at the food plot or not.

3.2.3 Simultaneous counts

In order to get an idea on Yellowhammer densities at our winter food plots, we performed a simultaneous count every two weeks, at 10am on Sunday morning. Yellowhammers in winter tend to be most active during this time of day (pers. obs. O. Dochy). A research in 2000 also showed that Yellowhammers change their foraging strategy during winter months November to February (Van der Veen, 2000). They feed early and the morning and decrease their foraging rates until late-afternoon (Van der Veen, 200). This would coincide with peaking predator activity of Sparrow hawks *Accipiter nisus* during early-afternoon, while it was more evenly spread over the day during other months (Van der Veen, 2000). Two counts, at the 29th of November and 13th of December, were performed to get an idea of the food plots where most seed-eaters had gathered so we could adjust our ringing activities. They were also considered as test-phases to see how smoothly cooperation with volunteers went so we could make adjustments before the first official count at the 29th of December. By counting at as many food plots as possible at the same time, we avoided overestimation of the winter population. Every plot was handled by at least one experienced bird watcher, accompanied by one/few beginners. Because of our dependence on volunteers, we were not able to man every plot at the same time. That is why counting birds happened in two stages.

- Stage 1. At 10 o’clock sharp, notes were made on the minimum amount of birds present at that exact time. Birds that arrived later were not included in the count while it is not possible to know whether they come from neighbouring, counted or uncounted, plots. This way we did not overestimate population sizes.
- Stage 2. After 10 o’clock, a second simultaneous count was done for the remaining, still uncounted, plots. Birds that left the plot in-between both simultaneous counts could therefore not be counted.

3.2.4 Quantification of plot quality and environmental factors

3.2.4.1 *Plot quality*

On each plot visit, a score was given to indicate the overall plot quality based on food condition. In order to get this score, crop development was checked along with the state of the seeds and the overall food availability. Several inflorescences (at least six) were checked, both at the borders and sides of the plot. Scores range from one to five (Table 3), with five as the optimal quality a plot can attain. We assume cereal grain and bristle oat plots with the same code to be equal. They do however differ in time of seed setting. Weeds and other herbaceous plants in-between our crops were not considered to improve plot quality since the Yellowhammer is a ‘picky’ eater and almost exclusively feeds on starchy grains (Holland et al., 2006; Kleijn et al., 2014).

Table 3. Descriptions of the codes that were used for quantification of food availability

Code	Description
State 1	No inflorescence, only vegetative state. No further development will occur.
State 2	Inflorescence is present, but still scarce. The food crop is developing, the ear is empty.
State 3	1) Seed is developing. Ear is no longer empty, but in presence of stamen and pistil 2) Food resources have become scarce and are almost completely depleted
State 4	1) The seed is ripening. It still has a mushy structure and has to harden. 2) Food is still available but is gradually depleting.
State 5	Ideal stage: the seeds are fully formed and have a hard, fixed structure. Food is abundant.

3.2.4.2 *Environmental factors*

Small landscape elements were mapped in a 200m radius around each plot. This is based on the fact that disturbed Yellowhammers mostly searched cover in the direct surroundings (<200m). Buffer zones were created using QGIS 2.14.0 Essen. Both land-use and the landscape elements were carefully indicated on coloured printouts of the food plots and their buffer zones. Afterwards, landscape elements were digitalized and surface area, lengths and distances were calculated in QGIS 2.14.0 Essen. No major changes in agricultural practices have been recorded throughout the study.

Small-scale landscape elements (Table 4) were based on the simplified habitat rankings preferred by the Yellowhammer in Calladine *et al.* (2003) and findings of Mason & Macdonald (1999). As for environmental variables, we included hedges, solitary trees and scrubs. Hedges were categorized as those with thorns **(KHD)** (e.g. hawthorn *Crataegus spp.,* blackthorn *Prunus spinosa*) and those without thorns **(KH)**. We considered a hedge as a continuous entity without interruptions. Trees with a height less than 5m were put at the same level as hedges without thorns **(KH)**. In both codes, the letter B was added to indicate the presence of one/multiple large trees (>5m) within the hedge: **KHDB** or **KHB.** Solitary large trees were indicated with **KBH,** unless it was a dense collection of trees, then it was categorized under **B** (forest). The last category **(HR)** was typified as messy and neglected patches such as scrubs, brambles, brushwood and/or long tall vegetation that can serve as cover. A summary of the codes above can be found in Table 4

Table 4. Descriptions of the codes that were used for indicating landscape elements

Code	Variable*	Description
KH	Hedge	Thornless hedges and/or small trees (< 5m)
KHD	Hedge	Thorny hedges without small trees (< 5m)
KHB	Hedge	Thornless hedges and/or small trees (< 5m) with large trees (> 5m) amongst
KHDB	Hedge	Thorny hedges without small trees (< 5m) with large trees (> 5m) amongst
KBH	Tree	Sollitary large trees (> 5m)
B	Tree	Forest
HR	Scrub	Scrubs, brushwood,bramble, long tall vegetation

*The column variable represents the elements (codes) that were taken together as one variable in the analyses to avoid over-parameterization

In the analysis, we used following variables to explain Yellowhammer distributions:

(1) Food condition, crop type and their interaction
(2) The distance to the nearest hedgerow
(3) The distance to the nearest tree
(4) The surface area of scrubs

3.3 Statistical analysis

For the statistical analysis, we performed the model constructions in R (R-Studio Team. Boston, 2015). Visualisation was done using ggplot2 (Wickham, 2009). We used packages MASS (Venables & Ripley, 2002), lme4 (Bates et al., 2015) and nlme (Pinheiro et al., 2016). Part 1 (3.3.1) is based on data we obtained from radio tracking and resightings of tagged individuals in the field. Reisghtings of colour-ringed, but non-tagged, Yellowhammers were scarce and therefore excluded from the analyses. Part 2 (3.3.2) is based on count data from our simultaneous counts.

3.3.1 Spatial use of winter food plots

3.3.1.1 *Movements*

Movements of a bird are defined as the amount of different plots visited over the course of winter. We tested whether these movements were dependent on sex, age, region or their interactions. A subset was made of tagged individuals that had at least three resightings (=25 Yellowhammers). We used Generalised Linear Models (GLM's) to test the hypotheses. Since we use count data, a Poisson distribution was selected. We applied Likelihood ratio tests (LRT), comparing the model with and without the least significant term. The LRT-test has a χ2- distribution with one degree of freedom under the null hypothesis. Model selection in the following sections happened in the same way.

3.3.1.2 *Effect of plot quality on Yellowhammer movements*

In order to test this, we made a contingency table where we counted the amount of Yellowhammers that changed fields in-between fieldwork days and ordered them according to the condition they moved to. They could either have flown to a plot with a condition that is a) worse, b) equal or c) better. We counted the number of events and calculated their percentages. Fixed effects are both quality of the initial plot and the change in quality in-between consecutive field visits. We used a Generalised Linear Mixed Model (GLMM) in which we included bird identity as a random effect.

3.3.1.3 *Distances*

In section 3.3.1.1 we will assess whether Yellowhammers move during the winter period. In case they do move between winter food plots, we want to know which distances they can cover. Location fixes of Yellowhammers that did not move in-between plots were therefore excluded from these analyses. We used Linear Mixed Models (LMM's) to look at the impact of our fixed effects (sex, age, region and their interactions) on:

1) <u>All distances.</u> This is the average distance an individual moves in-between consecutive days of tracking.
2) <u>The three largest distances per individual</u>. This measure is used to look at the largest distances individuals cover in-between consecutive days of tracking.
3) <u>The maximum covered distance per individual.</u> This is the distance between the two outermost plots an individual has been tracked. It reflects the maximum area an individual covers during winter.

Distances were log transformed. Bird identity was included as a random effect. We followed a Gaussian distribution and used Likelihood ratio tests (LRT) during model selection.

3.3.2 Yellowhammer distributions and the relation with food availability and environmental structures

We used Generalised Linear Mixed Models (GLMM) to develop a model in which we try to predict Yellowhammer abundances based on the food availability and several surrounding landscape elements. Abundances are derived from the count data we obtained during our simultaneous counts. The total amount of Yellowhammers fluctuates during winter. Therefore we included an offset function of the logarithm of the total amount of counted Yellowhammers during each simultaneous count (which is considered as the estimated population at that moment). Total abundances for each simultaneous count can be found in Table 5 (page 37). We used a Poisson distribution and included plot identity as a random effect. Fixed effects in the model were food availability (food condition and crop type) and landscape variables (distance to the nearest tree, distance to the nearest hedgerow and surface area of scrubs). Distances to the nearest tree and hedgerow are the smallest distance between the centroid of the winter food plot and respectively the nearest tree or hedgerow.

4 Results

4.1 Data exploration

There were 30 study plots included in this research, which can be divided in two groups according to their crop types: cereal grain and bristle oat. Fig.12 Shows a distribution of the plots with the amounts per region.

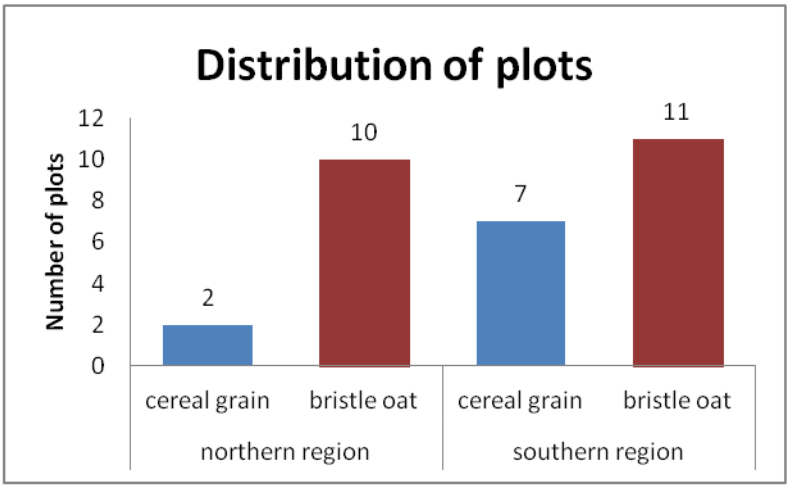

Fig.12: Distribution of our plots among the 2 regions

We found a significant effect of region on the time span that tagged Yellowhammers were observed ($\chi 2(1)=6.25$, P=0.020). The time span of observation depends on the date of ringing. The earlier a bird has been ringed and tagged, the longer it could have been tracked during winter. Birds in the northern region had a significantly lower observation time span. Due to some technical and personal problems, ringing in the northern region had to be postponed for several days (see also Table 1). It is important to take this in mind when interpreting further results. There was no imbalance in the amount of males/females ($\chi 2(1)=1.32$, P=0.250) or young/adult birds ($\chi 2(1)=1.72$, P=0.189). This means that each sex and age class had equal chances of being captured.

There were 218 resightings for our 29 tagged Yellowhammers. Dates of tagging can be found in Table 1. Resightings are spread over a total of 18 days of tracking (9 per region). Only one individual has never been tracked after tagging (Fig.13). No southern tagged individuals have been recaptured in the northern region and vice versa.

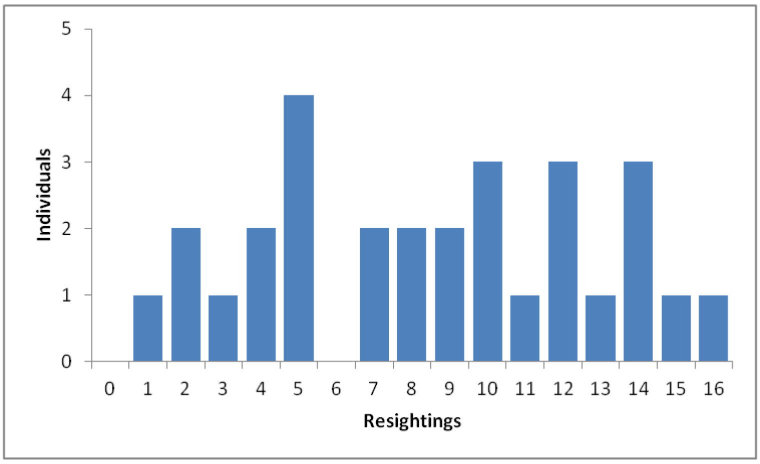

Fig.13: The number of resightings relative to the amount of individuals

Fig.14(a) shows a histogram of distances that were covered between two consecutive field visits for individuals in both regions. Distances are directly linked to the distances between our plots since we did not track birds in-between our plots. Most of the distances were zero, indicating that individuals did not move plots. When we take out the residents (distance=0km), we obtained the histogram that can be seen in Fig.14(b). Most distances in the southern region range from 1.0-1.5km. Distances in the northern, more scattered, region mainly range from 2.0-2.5km.

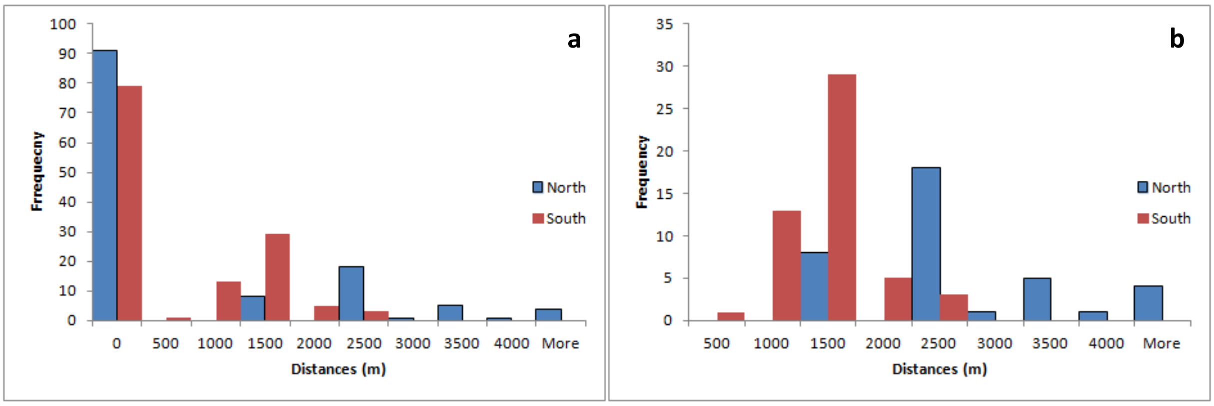

Fig.14: Histogram of distances that were covered by (a) all tagged individuals and (b) tagged individuals without residents (distance=0km) in-between field visits.

The total number of counted Yellowhammers (per region) during each simultaneous count can be found in Table 5. Maximum abundances were counted at 24th January 2016, with a total estimate of 760 Yellowhammers.

Table 5. Overview of Yellowhammer abundances counted during simultaneous counts

	Abundance		
Date	South	North	Total
27-12-2015	130	297	**427**
10-1-2016	199	220	**419**
24-1-2016	359	401	**760**
7-2-2016	233	264	**497**
28-2-2016	203	130	**333**

4.2 Movements

No effect was found on the amount of plot visits for either observation time span ($\chi 2(1)=0.09$, $P=0.765$) or the amount of resightings ($\chi 2(1)=0.93$, $P=0.334$). A longer observation time span, i.e. earlier date of ringing, did not affect the amount of plots visited. Neither did the number of resightings. Those parameters were therefore not included in further analyses. When looking at the number of plots visited, we found that Yellowhammers visited on average 2.58 ± 1.21 winter plots. The amount of different plots visited ranges from 1-6. The results of our GLM did not reveal any effects of sex, age, region or their interactions on the movements. Details of significance levels for our fixed effects can be found in Table 8.

4.3 Yellowhammer movements compared to plot quality

In order to test the hypothesis that Yellowhammers exchange their current plot for one with a better quality, we made a contingency table (Table 6). When a bird left a plot, there were three options. They either flew to a plot of worse quality, better quality or one of equal quality. We were not able to perform a GLMM since there is too little variation (T able 6). We performed a Fisher's-Exact test onto the contingency table to determine significance among the proportions of movements. Results show a clear dependence of the initial plot quality and the quality of the plot they move to (P<0.001). Following, a bubble plot was created to visualize the data (Fig.15). It is clear that the majority of the movements (i.e. 71.26%, which corresponds to 62 out of 87 events) occured between food plots of quality five. As Table 3 indicated, this is the optimal quality a food plot can achieve. So if Yellowhammers moved in-between plots during winter, in most cases did they fly to another food plot of optimal quality.

Table 6. Contingency table with yellowhammer movements compared to plot quality

	worse	equal	better
Condition 1	0	0	1.15%
Condition 2	0	0	0
Condition 3	0	1.15%	8.05%
Condition 4	0	0	4.60%
Condition 5	13.79%	71.26%	0

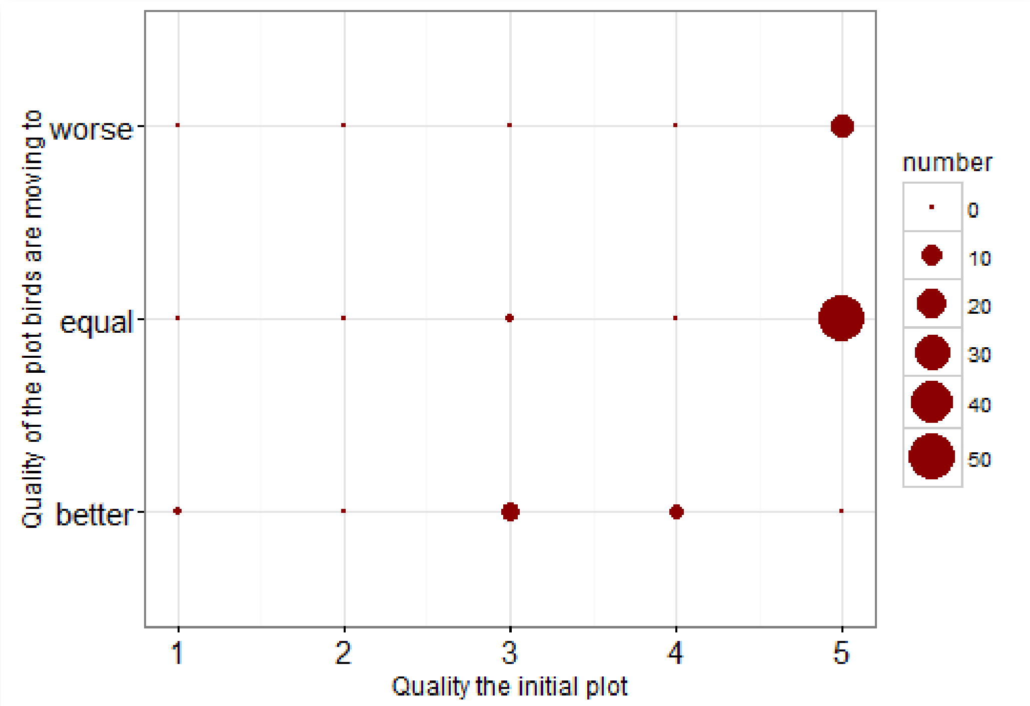

Fig.15: Bubble Plot of Yellowhammer movements during winter, with increasing plot quality (1-5). Bubbles in the upper left and lower right corner are evidently zero, since there is no worse/better quality.

4.4 Distances

Table 7 gives an overview of the distances obtained for each of our tested models with the number of individuals (N), mean, minimum and maximum distances. Zero distances of tagged Yellowhammers that did not move in-between tracking days were excluded. Since we only want to know "if" Yellowhammers move, what distances do they bridge.

Table 7. Overview of covered distances in kilometers over the entire period Yellow-hammers were tracked

Model	N	Mean ± SE	Min.	Max.
Model 1: mean distances of all individuals	24	1.70 ± 0.95	0.37	4.53
mean distances (northern region)	13	2.53 ± 0.91	1.11	4.53
mean distances (southern region)	11	1.12 ± 0.37	0.37	2.08
Model 2: largest distances of all individuals	24	1.92 ± 1.09	1.13	4.53
largest distances (northern region)	13	2.78 ± 1.07	1.35	4.53
largest distances (southern region)	11	1.19 ± 0.20	1.13	2.08
Model 3: maximum distances	24	2.20 ± 1.10	0.76	4.53
maximum distances (northern region)	13	2.97 ± 1.03	1.46	4.53
maximum distances (southern region)	11	1.55 ± 0.62	0.76	2.28

4.4.1 All covered distances

The mean distance, calculated based on all covered distances, of tagged individuals over the winter period was 1.70 ± 0.95km (Table 7). The results of our LMM showed a significant effect of region ($\chi 2(1)=37.35$, $P<0.001$) with a positive relation for Yellowhammers in the northern, scattered, region. Mean distances for both regions can be found in Table 7. Details of the significance levels can be found in Table 8.

4.4.2 Three largest distances

We subsequently modelled the mean of three largest measured distances. The mean largest distances during winter were 1.91 ± 1.10. We found that Yellowhammers in the northern region covered larger distances in-between tracking days ($\chi 2(1)=18.49$, $P<0.001$). Mean largest distances for both regions can be found in Table 7. Details of the significance levels for other fixed effects can be found in Table 8.

4.4.3 Maximum covered distances

The maximum covered distance is the distance between the two outermost food plots where the individual has been tracked over the entire winter period. The maximum covered distance gives an idea of the area that Yellowhammers can cover. The average maximum distance for all tagged individuals was 2.20 ± 1.10km (Table 7). Once again, we found an influence of region on the maximum area a Yellowhammer covers during winter ($\chi 2(1)=14.31$ $P<0.001$). Mean maximum covered distances for both regions can be found in Table 7. Yellowhammers in the southern, more clumped, region tend to have smaller maximum covered distances compared to individuals in the northern region.

Table 8. Overview of our statistical analyses using Generalised Linear Models (1) and Linear Mixed Models (2,3, 4). P-values with an asterisk indicate significance. Degrees of freedom was always 1.

Model	(1) Movements			(2) Mean distances			(3) Largest distances			(4) Maximum distances		
Effect	LRT (Chi²)	P		LRT (Chi²)	P		LRT (Chi²)	P		LRT (Chi²)	P	
Sex:Age:Region	0.00	0.948		-	-		-	-		-	-	
Sex:Age	0.31	0.578		1.84	0.175		0.14	0.709		1.08	0.298	
Age:Region	0.13	0.715		0.09	0.764		0.15	0.821		1.8	0.179	
Sex:Region	2.55	0.110		0.74	0.391		0.46	0.498		1.68	0.36	
Age	0.16	0.687		1.84	0.175		0	0.982		1.77	0.183	
Sex	0.20	1.000		2.68	0.102		0.41	0.524		2.81	0.093	
Region	1.34	0.247		37.35	**<0.001**	*	18.49	**<0.001**	*	14.31	**<0.001**	*

4.4.4 Relative effect of food abundance and surrounding landscape elements on Yellowhammer distributions

Yellowhammer abundances were predicted by including several variables concerning food availability and landscape elements. Using a GLMM with stepwise backward selection, we found a significant effect for the interaction of food condition and crop type ($\chi 2(1)=8.37$, P=0.004). No significant impact was found for any of our environmental variables (Table 9). Yellowhammer abundances were significantly larger with increasing food condition at our cereal grain plots (Fig.16). No Yellowhammers were counted at plots with a condition less than three. We also see that at condition three, Yellowhammer abundances do not differ all that much between both crop types. Abundances will be low at plots with little to no qualitative food available, regarding whether it is cereal or oat. However, when we look at increasing conditions, the effect of crop type becomes more visibly. Optimal cereal food plots are chosen above plots with optimal oat, with densities up to three times as large.

Table 9. Overview of our statistical analysis using Generalised Linear Mixed Models

Model	(5) Abundances		
Effect	LRT (Chi²)	P	
Condition:Crop	8.37	**0.004**	*
Tree	0.67	0.412	
Scrub	3.27	0.07	
Hedge	3.46	0.063	

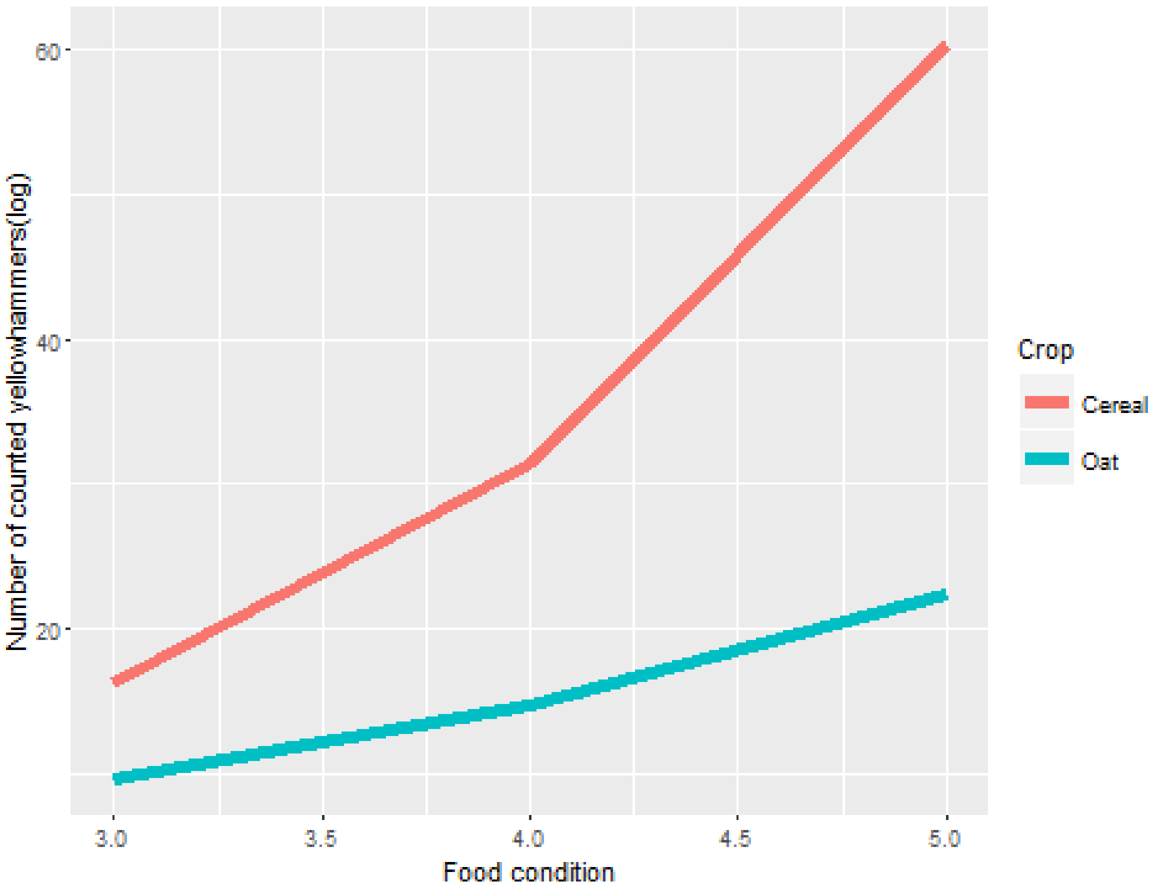

Fig.16: Effect of food condition and crop type on Yellowhammers abundances at a study plot

5 Discussion

5.1 General

Yellowhammers in winter are not faithful to one and the same plot. However, they do not change plots all that often. Many birds were found at the same plots as on previous tracking days. Tagged Yellowhammers that did switch plots, mainly moved between plots of optimal quality. Plots of sub-optimal quality are only rarely passed by, and if so only temporarily. Birds can make a clear distinction between the quality of plots. There is a high preference for plots that have abundant ripe seeds compared to plots with nearly ripe seeds, or plot where seeds started to deplete. When looking at ranging behaviour of Yellowhammers during winter, we found the regional effect to explain most of the variation in differences in foraging distance. Mean foraging distances, as well as the largest distances and the maximum covered distances differed between our northern and southern region. Yellowhammers in a region with scattered plot distribution are found to bridge larger distances in winter.

Yellowhammer abundances at our winter food plots are found to be higher at cereal grain plots of optimal condition. This reflects an interaction effect of both condition and crop type. This local effect is in agreement with results of our radio-telemetric observations in which Yellowhammers mainly move between qualitative winter food plots. Regional effects of surrounding landscape elements were however not detected.

5.2 Spatial use of winter food plots

Tagged Yellowhammers visited on average two to three food plots during the winter period. This indicates that most of our tagged Yellowhammers were not faithful to one and the same winter food plot. However, variation in movements is rather high, with the number of fields visited ranging from one to six different plots. Although not specifically tested, mobility is likely to be determined by the amount of qualitative food plots available at a any given time. Observation time span of individuals had no effect on the extend of movements. Birds that were tagged later on in winter were not found to visit more or less fields. Neither was there an effect of the amount of resightings. Individuals that were tracked more often, were not found at more plots compared to an individual of less resightings.

We did not find conclusive evidence for the anti-predator strategy as suggested by the Defra-funded project in 2007. They found no reduced tendency in movements during winter when food was abundant (supplemented). They hypothesized that this could be an anti-predator strategy in which visiting multiple plots along a circuit reduces attraction of predators. However, we found no support for suchlike feeding circuits. The majority of Yellowhammers (140 out of 220, about 60%) did not move plots in-between tracking days. Some individuals even remained at the same winter food plot during the entire winter. Chances of finding an individual at the same plot within its feeding circuit, irrespective of timing of plot visits, is rather small. When food becomes less accessible, staying at one and the same plot where food is easy to find, could indicate a lower energy consuming searching method (Norberg, 1977). This behaviour has been studied in Coal tits *Parus ater* at periods of increased snow cover (Brotons, 1997). Weather conditions were however mild for the time of the year, not affecting prospects of food achievement. On the other hand, 40% of Yellowhammers did move in-between plots. In most cases, movements were located between winter food plots of optimal quality. Irrespectively of food abundance at their plot, birds still moved towards another plot with equally qualitative food, similar as in the Defra-funded project (2007). Flying in-between plots might be an energetic demanding cost in reducing the risk of predation, as they hypothesized. Although this would support the anti-predator strategy, overall levels of observed mobility were too low to acknowledge the hypothesis. There also seems no need for such strategy since Yellowhammers already avoid predators by decreasing their daily foraging routines in the afternoon, when predator activity peaks (Van der Veen, 2000).

The extend of Yellowhammers movements in winter is highly variable. In contrast to research on Collared flycatchers *Ficedula albicollis* at their wintering grounds, this variability could not be explained by differences in sex (Hargati et al., 2012). Male Yellowhammers did not monopolize optimal food plots causing females to forage in-between sub-optimal plots. The variability in moving or being sedentary could not be explained by an age-related difference either as has been found in Coal tits *Parus ater* (Gustafsson, 1988) or Nuthatches *Sitta europaea* (Enoksson, 1988). There was no effect of larger separations of food plots on the amount of plots that were visited.

5.3 Ranging behaviour

When interpreting results on ranging behaviour, we have to take into account that this is only based on Yellowhammer movements. We have shown that Yellowhammers generally express low levels of mobility during winter. However, if birds move, foraging distances are influenced by the clumpiness of food plots. Mean distances, the largest distances and the maximum covered distances all confirm that scattered food resources lead to larger foraging distances. This shows that Yellowhammers are capable of adapting their ranging behaviour to the spatial distribution of food resources in a small-scale landscape.

Foraging distances were not only found to differ between both of our regions, but also compared to results from studies in Great Britain. Yellowhammers in those studies were found to cover average distances of 500m (Calladine et al., 2006). Some additional colour-ring resightings revealed movements of up to 1km. These studies however made use of feeding sites (at 100m, 200m, 500m, 2km, 5km and 10km) which made food abundant and accessible at all times. A Defra-funded project in 2007, studied the effect of food supplementation on foraging behaviour in Yellowhammers. They found that foraging distances were similar, irrespective of food abundance. Mean distances of 0.5-1km, derived from calculated home ranges, confirmed the studies of Sirwardena et al. (2006) and Calladine et al. (2006). The authors did however hypothesize that distances would probably be greater in areas where plots are separated by larger distances (Defra, 2007). Our results can confirm their expectations that Yellowhammers do indeed cover larger distances when food plots are more spatially distributed. Average foraging distances ranged from roughly 1 to 2.5km, with an average of 1.7km for both regions. Although authors in Great Britain stressed that their values represent minimum distances, we found values that were significantly higher. Flights of more than 2.5km between plots were no exception. Especially in the northern, scattered region, where distances of more than 4.5km were recorded.

5.3.1 Methodological remarks on radio-telemetric data collection

Although we retrieved some satisfactory data on winter ranging behaviour in Yellowhammers, measures of movement and calculated distances are probably underestimations. Firstly, we obtained radio-telemetric data by tracking PIP tagged Yellowhammers at our winter food plots. Resightings, in which we successfully tracked an individual, are dependent on receiving a clear signal on the receiver. Several aspects, such as buildings, dense vegetation and foraging on the ground disrupt the signal (Fuller et al., 2005). Yellowhammers that were not found during tracking days were not necessarily absent or predated. Non-tracked individuals could have been located outside our study area, but just as well be hidden in the vegetation searching cover during our period of presence. Secondly, no data is available in-between our tracking days. Additional location fixes by colour-ring resightings by volunteers were very scarce which leads to gaps of about 6-7 days (in each region) in which we have no data on Yellowhammer movements.

5.4 The relative effect of food abundance and surrounding landscape elements on Yellowhammer abundances

In order to understand the distribution of Yellowhammers in winter, it is valuable to study their food and habitat preferences. The results of our model indicated a significant effect of the interaction between food condition and crop type in which cereal grain plots of optimal quality are favoured. We did not find additional effects of environmental landscape elements (Table 8).

High preference for plots with abundant food is the result of high energetic demands during winter (Liknes & Swanson, 2000). Metabolic rates are highest in winter, which leads to the necessity of higher food uptake. According to literature, habitat selection in winter is mainly driven by seed densities (Moorcroft et al., 2002; Robinson & Sutherland, 2002; Whittingham et al., 2005). As can be seen in Fig.17 Yellowhammer densities clearly increase with food condition. This relation is stronger for cereal grain plots, than for bristle oat. This is in correspondence with results of several studies on winter food preferences of Yellowhammers in which cereal grains were highly favoured (Moorcroft et al., 2002; Perkins et al., 2007). Moorcroft et al. (2002) found seeds of wheat (*Triticum* spp.), as has been sown on our food plots, to be ranked highest. They also found preferences for cereal grains to be higher at the start of winter compared to late-winter (Moorcroft et al., 2002) since Yellowhammers are less efficient at finding buried grains on the plot (Robinson, 1997 as cited in Moorcroft et al., 2002). Similar as Corn Buntings, Yellowhammers might move towards other types of habitat as winter progresses and seeds become less available (Brickle, 1998 as cited in Moorcroft et al., 2002). Although not specifically tested in this study, Yellowhammers seem to move towards bristle oat plots as winter progresses (field observations), making them a good candidate crop to bridge the hungry gap during late-winter (Siriwardena et al., 2008).

Contrary to findings in Robinson & Sutherland (1999), we found no additional effect of landscape elements surrounding our winter food plots. They found Yellowhammers to forage closer to hedges (Robinson & Sutherland, 1999), which lowers predation risk. Neither distance to the nearest hedgerow nor distance to the nearest tree were found to be significant. Studies in tit species have shown that in winters where food is abundant, they apply a ‘safety-first’ strategy (Walther & Gosler, 2001). This strategy causes them to select sub-optimal patches with better cover over the most qualitative patches. We found no evidence for such strategy in wintering Yellowhammers. However, based on field observations in which Yellowhammers search cover in landscape elements in close proximity to the winter food plots, we assume that variation between our plots was too small to detect an effect. Important to note is that set aside winter food plots have already been pre-selected based on their location (not in area that is too open or too forested) and the presence of at least one hedgerow nearby (pers. comm. O. Dochy). This could explain the uniformity between food plots.

Another explanation is the fact that, in contrast to quantifying food conditions, categorizing small-landscape elements is less straight-forward. The surface area of scrub surrounding our winter food plots had no influence in predicting Yellowhammer abundances in contrast to findings in Calladine et al. 2003, where scrub was ranked highest in determining preferred habitat characteristics. However, they determined habitat use as landscape elements in the immediate vicinity of location fixes for tagged Yellowhammers (Calladine et al., 2003) as we included the surface area of scrub in a radius of 200m around the food plots. Determining habitat preferences based on where a tagged individual is found, is probably a better method. However, in our study we mainly focussed at Yellowhammer presence at a plot rather than its exact location fix.

5.4.1 Methodological remarks on assessing food condition

Our proxy of food condition was based on observations of grain development rather than collecting and measuring seed densities. It seems as if our method for quantification is rather accurate in categorizing food plots. However, a better (labour-intensive) way to determine seed densities can be found in Moorcroft *et al.* (2002). They collected seeds on standing plants and those on, or just below, the surface (3mm) of the soil in a 15cmx15cm grid. This method studies food availability at a smaller scale and gives more precise predictions of food availability.

5.5 Horizontally-stretched mist-nets

At the beginning of our project, we had hard times capturing Yellowhammers. First of all, our proposed clap-net method failed to work since Yellowhammers, and granivorous birds in general, did not aggregate at our cleared, pre-baited locations. In order for birds to be attracted to the bait, food resources in the surrounding environment have to become limited. However, mild temperatures at the beginning of winter prohibited the effectiveness of our clap-net method. We then switched to using vertical mist-nets, the most widely used technique for capturing small to medium-sized birds (Whitworth, 2007). However, the main reason we did not initially chose this technique is its dependence on decent weather conditions. Wind and rain can significantly increase the visibility of the nets, leading to systematic avoidance of our target species (see also Fig.6a). Unfortunately, the end of December as well as the beginning of January were largely filled with such weather conditions.

We decided to experiment with the use of horizontally-stretched mist-nets. Mist-nets are loosely stretched with bamboo sticks at both ends of the net, directly over our crops. This way, birds that pass under the net and decide to take-off, as well as birds trying to land in the crops could be captured. Although the nets still seemed visible, birds were less intimidated and had no problems in approaching the horizontally-stretched mist-nets. Compared to vertical mist-netting, birds do not entangle in pockets which would normally ensure their capture. This causes many Yellowhammers to bounce off the nets and escape. In the cases that a bird becomes entangled, one has to be quick to retrieve it before giving it the chance to disentangle himself. Horizontally-stretched mist-netting has proven to be less dependent on weather conditions. They are hardly affected by rain and wind. Seen the urgent need of tagged Yellow-hammers, this method provided in the first captured Yellowhammers. However, vertical mist-netting in mild weather conditions, against the dark background of a hedgerow, is way more efficient. There is no need to intervene every time a Yellowhammer lands in the nets decreasing the disturbance. Horizontally-stretched mist-nets should therefore not be preferred above the commonly used vertical mist-netting.

5.6 Implications for management

An increased knowledge on the use of winter food plots by Yellowhammers in a small-scale landscape has clear implications for conservation prescriptions. Maintaining our winter populations will rely on ensuring several qualitative seed resources in the landscape. The scale at which distribution of seed resources should be arranged on, depends the target species (Calladine et al., 2006). As for Yellowhammers, our study suggests that birds can easily share resources within a radius of 1.5-2km. Larger covered distances were however no exception. A spatial distribution of winter food plots at a radius of 2km should be sufficient to ensure free mixing of individuals in-between seed resources. Neither radio-tracking nor colour-ring resightings revealed any exchange of individuals between the northern and southern region. Probably because distances were too large and regional food abundances sufficient enough. Applying this measure in the large blank area between both regions, might connect them.

We found winter food plot preferences to be highest for those plots with cereal grain. The importance of bristle oat should however not be neglected. In this research we looked at the use of winter food plots, rather than study the difference between both crop types. Nevertheless, based on observations in the field, we saw that densities of Yellowhammers significantly increased at bristle oat plots once seeds ripened later on in winter. Bristle oat is certainly a crop that should be followed up in the near future to see whether it has the potential of closing the hungry gap towards the end of winter (Siriwardena et al., 2008)

5.7 Proposal for further research

In order to asses inter-annual variation in the use of winter food plots by Yellowhammers, there is need for a broader study that extends to multiple years. More replicates of clumped and scattered regions would increase the statistical power to our tests on regional differences. However, a good study design will need to take into account the difficulties of finding appropriate replicate study areas and performing the labour-intensive data collection.

6 Conclusion

This research aimed at studying the use of winter food plots by a threatened bird species in a small-scale landscape. Compared to previous studies on ranging behaviour and movements, our study areas are characterized by larger plot separations and therefore more scattered food resources. Based on radio-telemetric data and colour-ring resightings, we found that Yellowhammer movements mainly occur between winter food plots of optimal quality. Although food is locally abundant, birds still visit other plots. Visiting multiple plots is considered a risk-spreading mechanism to avoid attraction of predators. However, the fact that the majority of our tagged Yellowhammers did not move in-between tracking days, or even during the entire winter, does not support this anti-predator hypothesis. This might indicate individual differences in spatial use of food plots during winter. Observed differences did however not seem to be age- or sex-related. Results of tagged Yellowhammers preferring qualitative food plots was confirmed by analyses of our simultaneous count data. Yellowhammer abundances can be best explained by the presence of qualitative cereal grains. We did not find evidence for the importance of surrounding landscape elements on winter food plot preferences. The most plausible explanation is that variation between plots was to low since winter food plots have already been pre-selected based on their location and the presence of landscape elements.

Study on the ranging behaviour of Yellowhammers show that birds can easily share resources at plots within a radius of 1.5-2km. Events in which Yellowhammers covered distances beyond 3-4km were however not exceptional. Differences in foraging distances were mainly explained by a regional effect. An area were food plots are more scattered, and plots separations are larger, has overall larger foraging distances.

Ensuring the availability of qualitative cereal grain seed resources at food plots is key in conserving the Yellowhammer at its wintering sites. Future management of winter food plots should consider that plots separations of 2km or more apart are sufficient to have Yellowhammers mixing freely between food resources.

7 Summary

7.1 English summary

In recent decades, many farmland birds had to cope with some drastic population declines. Granivorous bird species in particular have become victims of both government policy objectives and technical agricultural advances which lie at the very heart of these biodiversity declines. The switch to using autumn-sown cereals made stubble fields a rare phenomenon in our winter landscape. This results in many granivorous passerines having troubles finding a sufficient amount of qualitative food, especially towards the end of winter when most food sources have depleted. This creates a period of food shortage prior to spring, the so-called hungry gap, since invertebrates are not yet available. Winter bird crops that have the purpose of providing extra winter food might have the potential of being an effective conservation measure.

The province of West Flanders already applies this measure in their Species Action Plan for the Yellowhammer *Emberiza citrinella*. This plan aims at maintaining and enhancing biodiversity in the province. The Yellowhammer has been chosen as a flagship species in this specific project. The Yellowhammer is a threatened passerine bird from the bunting family that almost exclusively feeds on starchy cereal grains during winter. As part of the conservation measure, winter food plots have been set aside for over 10 years.

In order to adjust implications for conservation, it is important to know how these winter food plots are being used. The study is done in two regions in the southwest of West Flanders. Compared to previous studies Great Britain, our food plots are more scattered. Both regions however differ in the distances of plot separation. In comparison to the southern study site in Heuvelland where food plots are clumped together, our winter food plots in the northern study site around Beveren-aan-de-Ijzer are more linearly scattered. We will use this difference in spatial distribution to study regional effects on the use of winter food plots.

We used colour-rings, radio-telemetry and simultaneous counts as a way to track Yellowhammers during the winter months December to February. Over 160 Yellowhammers were colour-ringed and 29 of them received a PIP tag. This revealed information about foraging movements –and distances and their relation with plot quality and landscape elements. Plot quality was determined based on the presence of ripe seeds. The studied landscape elements on the other hand, were, at least partially, derived from other studies that looked at habitat preferences of Yellowhammers during winter. Having a better knowledge on how Yellowhammers use these plots, will help us to unravel the terms of a “preferred plot location”.

A relatively unknown technique was applied in order to capture Yellowhammers independent of weather conditions. Horizontally-stretched mist-nets in which nets are loosely stretched over the crops, were less impacted by rain and wind. Capture ratios were however too low to make this method effective. Seen the urgent need of Yellowhammers early in winter, when weather conditions were too poor for vertical mist-netting, this method provided us with the first birds we needed. If conditions are mild and surrounding landscape elements grant the use of vertical mist-netting, this method should however be favoured.

Yellowhammers were found to make a clear distinction between plots of nearly good quality and those in an optimal condition. Over 70% of the movements of our tagged birds were situated between such optimal winter food plots. Although visiting multiple plots of equally qualitative food resources is energy demanding, this might be for the benefit of spreading the risk of predation. Adding several food plots to a bird his feeding circuit might be an anti-predator strategy (Defra, 2007). However, most tagged Yellowhammers did not move plots in-between consecutive days of tracking. Chances of finding the same individual at the same plot within its assumed feeding circuit, irrespective of timing of plot visits, are rather small. Although most Yellowhammers make use of on average two to three plots, it assumes low levels of mobility. The high variability in the extend of movements could not be proven by an effect that is age- or sex-related. Mobility during winter was also independent of the spatial distribution of winter food plots.

Simultaneous count data supported the results from our radio-telemetric data. Food condition in relation to crop type (local effect) is the most determining factor in predicting Yellowhammer abundances. Cereal grains that provide starchy seed resources throughout winter are favoured over plots with bristle oat. We did however not find an effect of our surrounding landscape elements (regional effect). We assume that variation between our study plots was too low to detect this effect. This is likely because winter food plots have already been pre-selected based on their location and the proximity to a hedgerow.

Our results show that a scattered spatial distribution of winter food plots has an effect on foraging distances. A region in which plots are separated by larger distances, results in larger overall foraging distances. Plot separations of 1.5-2km were frequently covered by Yellowhammers in winter. Distances over 2km (even up to 4km) were no exception. We did however not find any exchange of tagged or colour-ringed birds between both regions. It is likely that regionally abundant food resources and the large blank area in-between both regions prevented any exchange of individuals. Setting aside winter food plots within a radius of 2km of each other may however help in connecting both regions.

Ensuring the availability of qualitative seed resources at food plots is key in conserving the Yellowhammer at its wintering sites. Qualitative cereal grain plots hereby play an important role in providing food. Future management of winter food plots should consider that plots separations of 2km or more apart are sufficient to have Yellowhammers mix freely between food resources. Our research shows that Yellowhammers can, compared to studies in Great Britain, easily cover distances beyond 0.5-1km in a landscape that is characterized by scattered, unpredictable food resources.

7.2 Nederlandse samenvatting

Talloze akkervogels hebben de laatste jaren te maken gehad met een serieuze afname in populatiegrootte. Vooral zaadeters zijn het slachtoffer geworden van nieuwe wetgevingen en technologische vooruitgang in de landbouwsector. Deze factoren liggen aan de bron van dergelijke achteruitgang van biodiversiteit. De omschakeling naar het gebruik van wintervariëteiten die reeds in de herfst worden ingezaaid, hebben ervoor gezorgd dat graanstoppels zeldzaam zijn geworden in ons landschap. Dit zorgt ervoor dat vele zaadetende zangvogels moeite hebben om voldoende kwalitatief voedsel te vinden. Voornamelijk naar het einde van de winter toe, wanneer voedselbronnen schaarser worden. Hierdoor wordt een periode van voedseltekort gecreëerd in de periode richting de lente. Tijdens deze ‘hungry gap’ wordt zaad moeilijk te vinden en zijn ongewervelden nog niet beschikbaar. Wintervoedselgewassen, die beogen het voedselaanbod in de winter te vergroten, kunnen hier een potentiële behoudsmaatregel vormen.

De provincie West-Vlaanderen past deze maatregel reeds toe in hun Soortactieplan voor de geelgors. Dergelijk plan is er om de biodiversiteit in de provincie te behouden en mogelijks opnieuw te laten toenemen. De geelgors *Emberiza citrinella* werd daarin geselecteerd als een soort die symbool staat voor het behoud van een kleinschalig landschap. De geelgors is een bedreigde zangvogel uit de gorzenfamilie die zich gedurende de winter bijna uitsluitend met zetmeelhoudende zaden van granen voedt. Als deel van de beleidsmaatregel worden al meer dan 10 jaar wintergraanveldjes aangelegd.

Om correcte aanpassingen te kunnen doorvoeren in het beleid rond de geelgors, is het belangrijk om te weten hoe de vogel deze veldjes met wintervoedsel gebruikt. De studie werd uitgevoerd in twee gebieden in het zuidwesten van West-Vlaanderen. In vergelijking met voorgaande studies in Groot-Brittannië, liggen onze veldjes meer versnipperd in het landschap. Daarnaast verschillen onze beide studiegebieden ook nog eens onderling. In vergelijking met het zuidelijk studiegebied in Heuvelland, liggen de veldjes in het noordelijke studiegebied nabij Beveren-aan-de-Ijzer meer lineair verspreid, terwijl de voedselveldjes in het zuiden meer gebundeld liggen. We zullen dit verschil in ruimtelijke plaatsing gebruiken om regionale verschillen in gebruik van de veldjes te bestuderen.

We maakten gebruik van kleurringen, radiotelemetrie en simultane tellingen om geelgorzen gedurende de maanden december tot februari op te volgen. In totaal werden meer dan 160 geelgorzen voorzien van kleurringen, waarvan 29 ook een zender omkregen. Dat zorgde voor het verkrijgen van informatie over foerageerbewegingen -en afstanden en hun relatie tot kwaliteit van de veldjes en de omliggende landschapselementen. De kwaliteit van de wintergraanvelden werd beoordeeld naargelang de aanwezigheid van rijpe zaden. De te onderzoeken landschapselementen werden, althans gedeeltelijk, gekozen op basis van voorgaande studies naar habitat voorkeur van de geelgors gedurende de winter periode. Een betere kennis over hoe geelgorzen deze wintergraanvelden gebruiken, kan ons helpen bij het bepalen van de voorwaarden voor een “geprefereerde plotlocatie”

Bij het vangen van geelgorzen pasten we een relatief ongekende techniek toe die minder afhankelijk is van de weersomstandigheden. Horizontaal gespannen mistnetten die losjes over het gewas worden gespannen, bleken minder impact te ondervinden van wind en regen. Vangstratio’s waren echter te laag om deze methode echt effectief te maken. Gezien de noodzaak aan geelgorzen in het begin van de winter, wanneer weersomstandigheden te slecht waren voor het gebruik van verticale mistnetten, bezorgde deze methode ons toch de eerste vogels die we nodig hadden voor ons zenderonderzoek. Als weersomstandigheden en aanwezige landschapselementen het toe laten om verticale mistnetten te gebruiken, wordt deze methode best geprefereerd boven de methode met horizontale mistnetten.

We vonden dat geelgorzen een duidelijk onderscheid kunnen maken tussen een veld van optimale kwaliteit en een veld van mindere kwaliteit. Meer dan 70% van de verplaatsingen van onze gezenderde vogels vond dan ook plaats tussen veldjes van optimale kwaliteit. Ondanks dat het bezoeken van meerdere veldjes meer energie vraagt, kan dit een manier zijn om het risico op predatie te spreiden. Het toevoegen van voedselveldjes aan een vogel zijn foerageerronde kan hierbij een anti-predator strategie zijn (Defra, 2007). Echter, de meeste geelgorzen hebben zich niet verplaatst tussen veldbezoeken. De kans om hetzelfde gezenderde beest op hetzelfde veld terug te vinden tijdens zijn foerageerronde, onafhankelijk van het tijdstip van het bezoek, is nogal klein. Hoewel geelgorzen meerdere veldjes bezoeken in de winter, weerspiegelt het toch een lage mobiliteit. De grote variatie in verplaatsingen kon niet verklaard worden door een effect van leeftijd of geslacht. Bewegingen tijdens de winter bleken ook onafhankelijk van ruimtelijke spreiding van de wintervoedselvelden.

Data van simultane tellingen bevestigen resultaten van de radiotelemetrie. Voedselkwaliteit, in samengang met het gewastype (lokaal effect), is de meest bepalende factor in het voorspellen van geelgors abundanties. Graanvelden die zetmeelrijke zaden voorzien doorheen de winter worden daarbij verkozen boven velden met Japanse haver *Avena strigosa*. We vonden geen effect van omliggende landschapselementen (regionaal effect). Er wordt verondersteld dat de variatie tussen onze veldjes te klein was om een effect te vinden, gezien veldjes reeds aangelegd worden naargelang hun locatie en de nabijheid van één of meerdere hagen.

Onze resultaten tonen aan dat een gespreide ruimtelijke ligging van de wintervoedselveldjes een effect heeft op foerageerafstanden. Een regio waarin plots gescheiden worden door grotere afstanden, leiden tot algemeen grotere foerageerafstanden. Afstanden van 1,5-2km tussen plots werden daarbij regelmatig overbrugd. Afstanden van meer dan 2km (tot zelfs 4km) waren geen uitzondering. We vonden echter geen uitwisseling van gezenderde of gekleurringde vogels tussen beide regio's. Het is heel waarschijnlijk dat het regionale abundante voedselaanbod, samen met ontbreken van veldjes tussen beide regio's in, voorkomt dat er uitwisseling is. Het aanleggen van wintervoedselveldjes tussen beide regio's, in een straal van 2km, kan bijdragen tot het verbinden ervan.

Het verzekeren van kwalitatieve voedselbronnen op onze veldjes is de sleutel tot het behouden van geelgorzen in hun overwintergebieden. Kwalitatieve graangewassen spelen hierbij een belangrijke rol in het voorzien van voedsel. Toekomstige beheersmaatregelen omtrent wintervoedselveldjes moeten in rekening houden dat afstanden van 2km, of meer, voldoende zijn om ervoor te zorgen dat geelgorzen zich vrij tussen de veldjes kunnen verplaatsen. Deze studie toont ook aan dat de geelgors, in tegenstelling tot in studies in Groot Brittannië, gemakkelijk afstanden van meer dan 0,5-1km kan overbruggen in een landschap waarin voedselbronnen meer versnipperd liggen.

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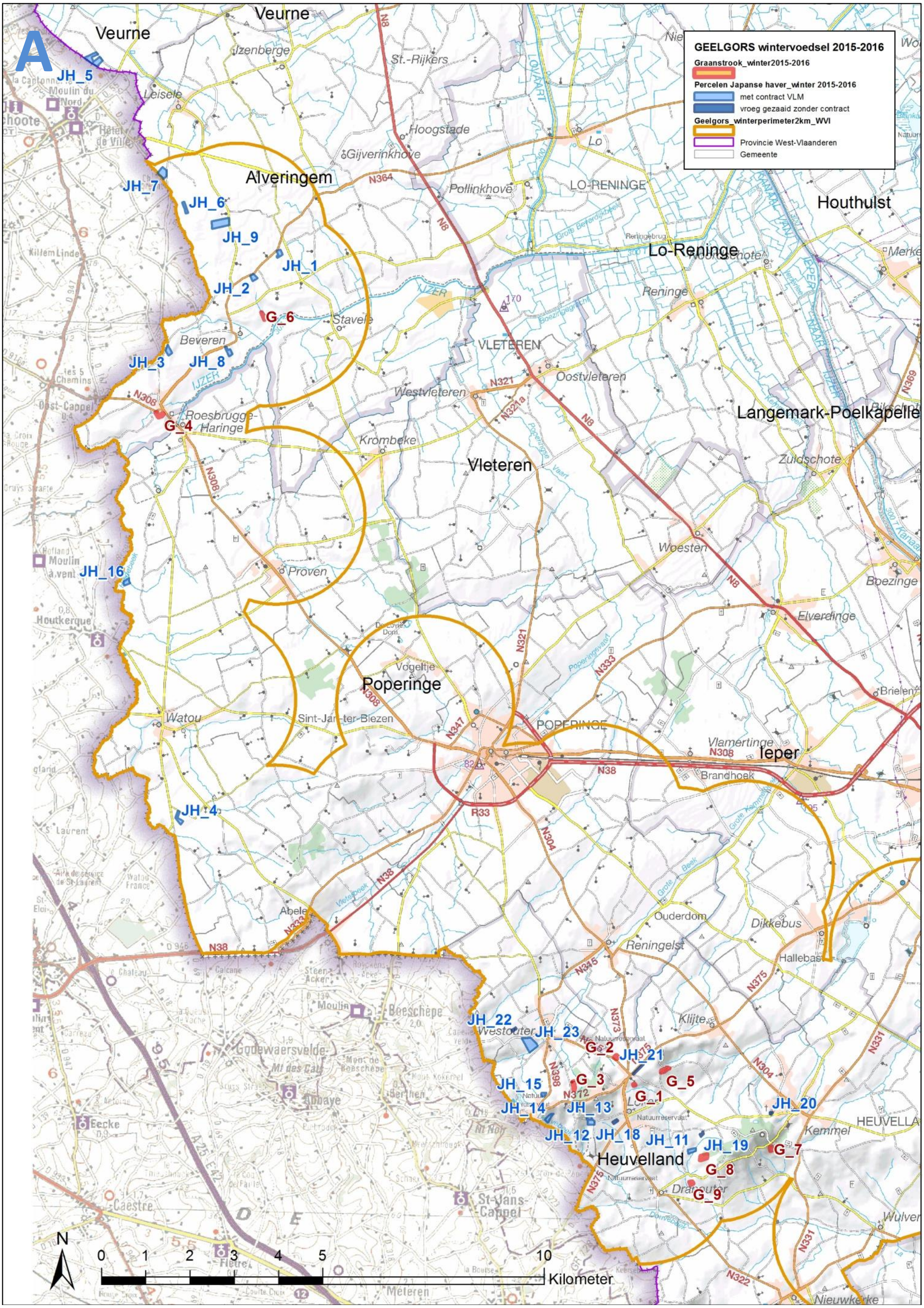
10 Appendix

A) **Map with an overview of all winter food plots**

B) **Detailed map of the southern region (Heuvelland)**

C) **Detailed map of the northern region (Beveren-aan-de-Ijzer.1)**

D) **Detailed map of the northern region (Beveren-aan-de-Ijzer.2)**


A
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Graanstrook_winter2015-2016
Percelen Japanse haver_winter 2015-2016
met contract VLM
vroeg gezaaid zonder contract
Geelgors_winterperimeter2km_WVI
Provincie West-Vlaanderen
Gemeente
Veurne
Alveringem
Lo-Reninge
Houthulst
Vleteren
Langemark-Poelkapelle
Poperinge
Ieper
Heuvelland
JH_1
JH_2
JH_3
JH_4
JH_5
JH_6
JH_7
JH_8
JH_9
JH_11
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JH_13
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JH_15
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JH_18
JH_19
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JH_22
JH_23
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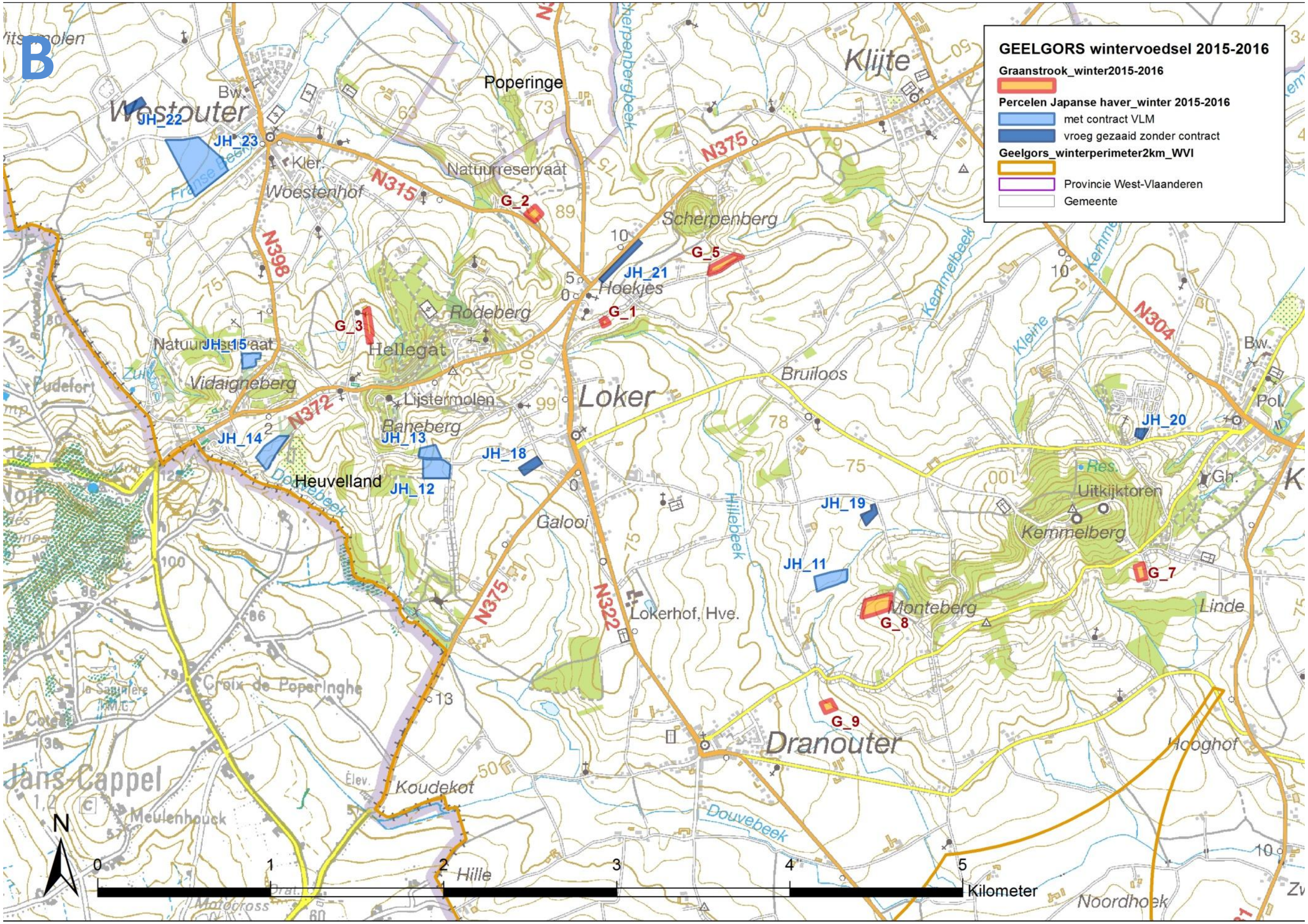
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Percelen Japanse haver_winter 2015-2016
met contract VLM
vroeg gezaaid zonder contract
Geelgors_winterperimeter2km_WVI
Provincie West-Vlaanderen
Gemeente
JH_22
JH_23
JH_15
JH_14
JH_13
JH_12
JH_18
JH_21
JH_19
JH_11
JH_20
G_1
G_2
G_3
G_5
G_7
G_8
G_9
Westouter
Poperinge
Klijte
Woestenhof
Natuurreservaat
Scherpenberg
Hoekjes
Rodeberg
Hellegat
Vidaigneberg
Lijstermolen
Baneberg
Heuvelland
Loker
Bruiloos
Galooi
Kemmelberg
Uitkijktoren
Monteberg
Linde
Lokerhof, Hve.
Dranouter
Hooghof
Koudekot
Douvebeek
Noordhoek
Hille
Jans-Cappel
Meulenhouck
Croix de Poperinghe
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N304
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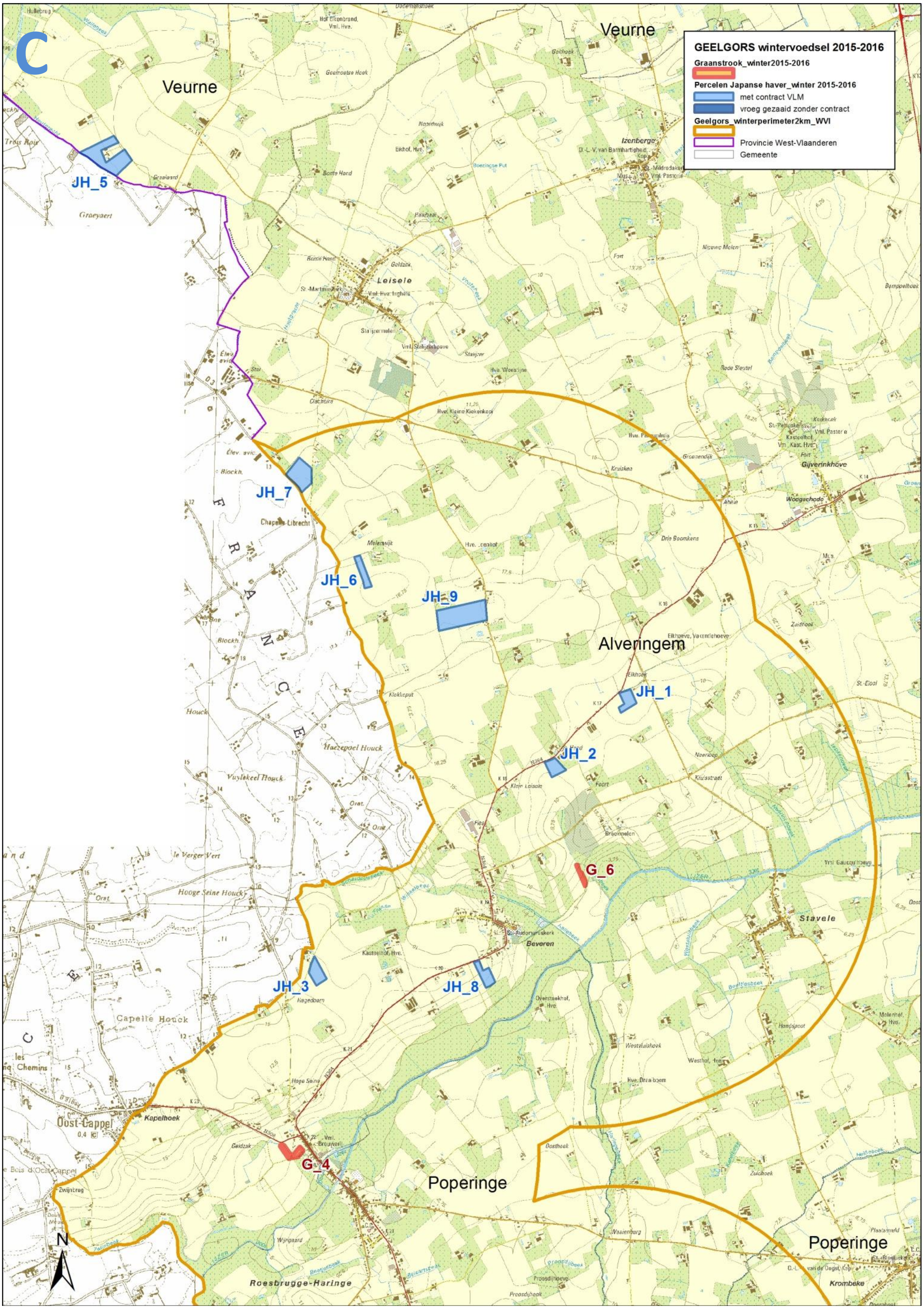
Kilometer


C
GEELGORS wintervoedsel 2015-2016
Graanstrook_winter2015-2016
Percelen Japanse haver_winter 2015-2016
met contract VLM
vroeg gezaaid zonder contract
Geelgors_winterperimeter2km_WVl
Provincie West-Vlaanderen
Gemeente
Veurne
Veurne
Alveringem
Poperinge
Poperinge
Leisele
Beveren
Stavele
Izenberge
Oost-Cappel
Roesbrugge-Haringe
Krombeke
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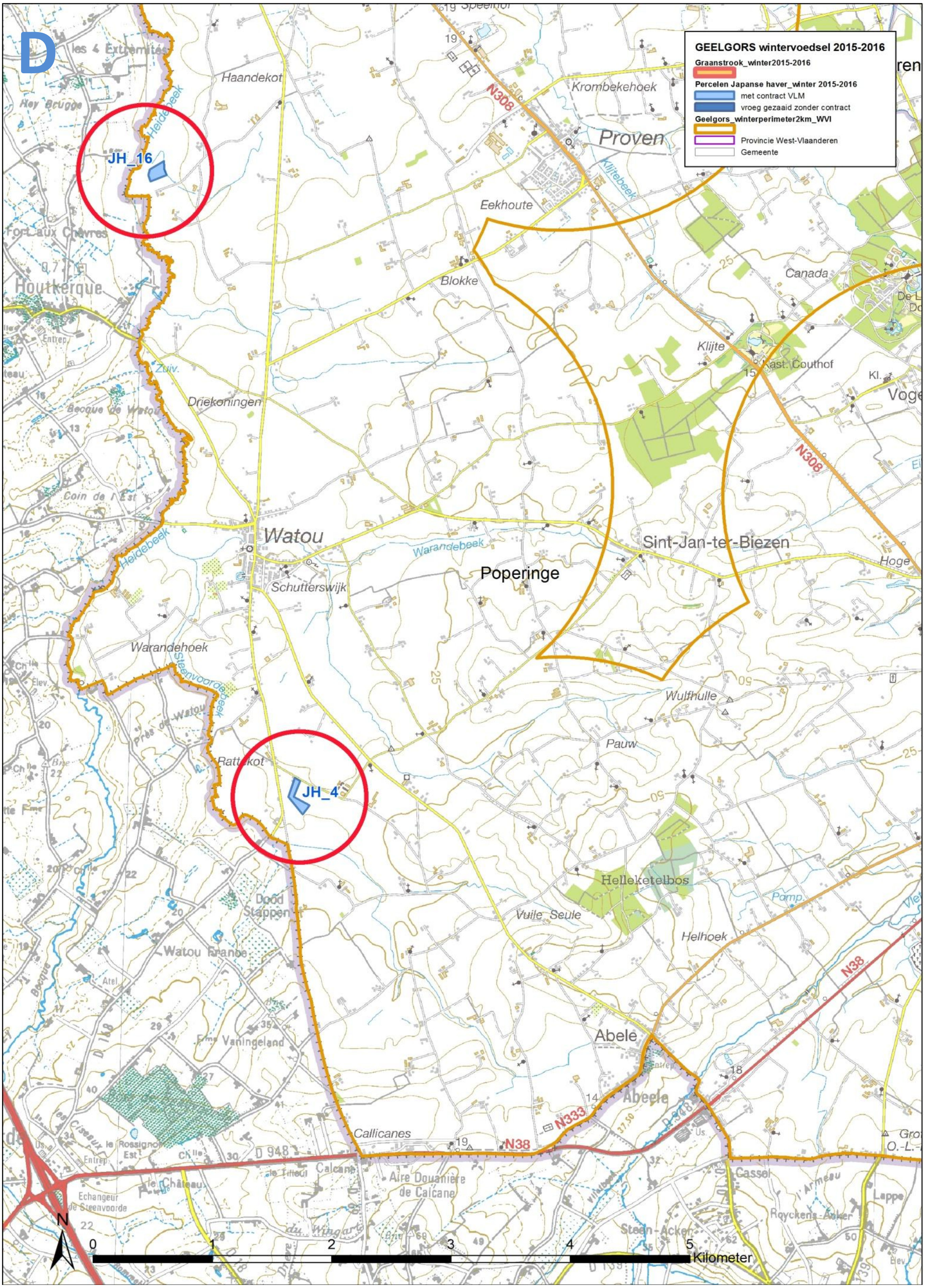
D
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Graanstrook_winter2015-2016
Percelen Japanse haver_winter 2015-2016
met contract VLM
vroeg gezaaid zonder contract
Geelgors_winterperimeter2km_WVI
Provincie West-Vlaanderen
Gemeente
JH_16
JH_4
Watou
Poperinge
Proven
Sint-Jan-ter-Biezen
Abele
0
1
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Kilometer
N