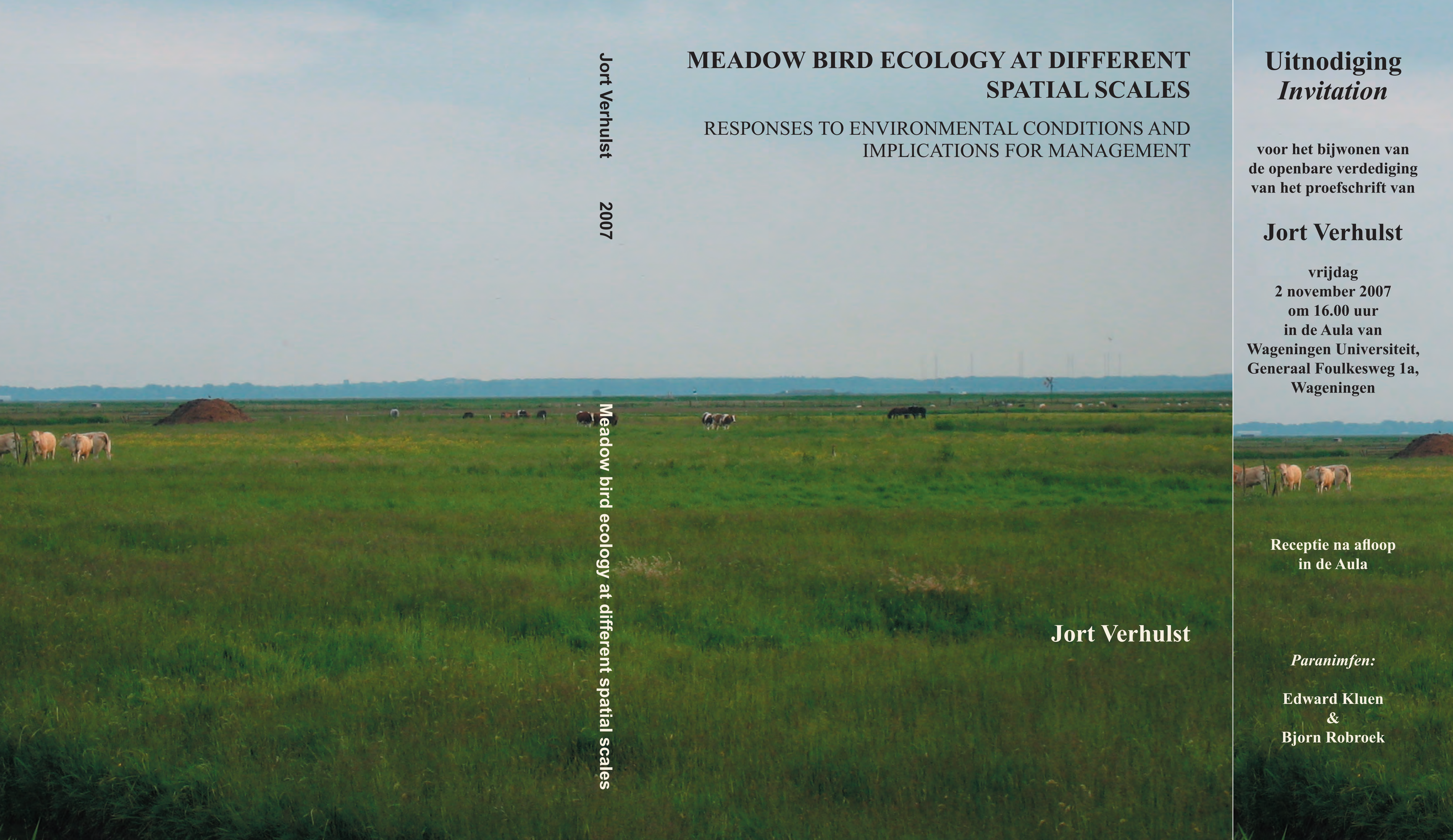

Jort Verhulst 2007

Meadow bird ecology at different spatial scales

MEADOW BIRD ECOLOGY AT DIFFERENT SPATIAL SCALES

RESPONSES TO ENVIRONMENTAL CONDITIONS AND IMPLICATIONS FOR MANAGEMENT

Jort Verhulst

Uitnodiging
Invitation

**voor het bijwonen van
de openbare verdediging
van het proefschrift van**

Jort Verhulst

**vrijdag
2 november 2007
om 16.00 uur
in de Aula van
Wageningen Universiteit,
Generaal Foulkesweg 1a,
Wageningen**

**Receptie na afloop
in de Aula**

Paranimfen:

**Edward Kluen
&
Bjorn Robroek**

MEADOW BIRD ECOLOGY AT DIFFERENT SPATIAL SCALES

RESPONSES TO ENVIRONMENTAL CONDITIONS AND IMPLICATIONS FOR MANAGEMENT

WEIDEVOGELECOLOGIE OP VERSCHILLENDE RUIMTELIJKE SCHAALNIVEAUS

EFFECTEN VAN OMGEVINGSFACTOREN EN CONSEQUENTIES VOOR HET BEHEER

Jort Verhulst

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Dit onderzoek is uitgevoerd binnen de onderzoekschool SENSE (School for the Socio-Economic and Natural Sciences of the Environment).

MEADOW BIRD ECOLOGY AT DIFFERENT SPATIAL SCALES

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Jort Verhulst

Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
Prof.dr. M.J. Kropff,
in het openbaar te verdedigen
op vrijdag 2 november 2007
des namiddags te 16:00 uur in de Aula.

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Meadow bird ecology at different spatial scales - responses to environmental conditions and implications for management

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Abstract

Dutch wet grasslands host high densities of meadow birds. Especially striking are the huge numbers of breeding wading birds. Half of Europe's black-tailed godwits *Limosa limosa* and one third of the oystercatchers *Haematopus ostralegus* breed in the Netherlands. However, since the second half of the 20th century, increases in farming intensity have resulted in the loss of heterogeneity at multiple spatial scales. Wet grasslands were increasingly drained, fertilized and reseeded which caused severe declines in many meadow birds. Agri-environment schemes were initiated to halt the declines but their effectiveness is debated. This thesis focuses at the effectiveness of the Dutch agri-environment scheme aimed at meadow birds and the mechanisms that influence the effectiveness. We evaluated the effectiveness of widely implemented agri-environment schemes aimed at breeding meadow birds and found more territories of meadow breeding waders on fields with the postponed mowing scheme. However, these differences were better explained by differences in soil moisture and groundwater level. We therefore suggest that the effectiveness of agri-environment schemes aimed at the conservation of waders might be enhanced by including raised groundwater levels into scheme prescriptions. Subsequently, we surveyed birds in extensively and intensively managed and abandoned farmland in Hungary. We found that abandoned and extensively managed farmland had highest bird numbers but farmland birds had been replaced by forest birds in abandoned farmland. Therefore, we conclude that conservation efforts aimed at farmland birds should focus on maintaining extensive farming systems. Back in the Netherlands, we quantified spatial habitat use of two meadow bird species in the breeding phase. Both species used areas of < 1 ha, and thus the effectiveness of agri-environmental measures might be enhanced when they create heterogeneity within fields. Our next study focused at nest site selection of meadow birds and how this is influenced by differing environmental conditions and the presence of heterospecifics (i.e. other meadow bird species). We found that all waders nest in association with each other and two waders selected sites with a high groundwater level. This confirms our previous findings concerning the importance of high groundwater levels for meadow breeding waders. In our final study we focused at the role of heterogeneity in determining wader densities. We found that the more heterogeneous fields had higher wader densities and they seemed to be attractive to families of black-tailed godwits. Additionally, we found that fields with prolonged grazing harboured high densities of waders. Therefore, we suggest that initiatives aimed at meadow birds should increase in-field heterogeneity. In conclusion, we found that relatively simple agri-environment schemes that are feasible for farmers were not effective in the preservation of breeding meadow birds. We did find higher densities of meadow birds in fields with higher groundwater levels and in heterogeneous fields. Therefore, we argue that more radical forms of agri-environment schemes, incorporating both water levels and in-field heterogeneity, are required to maintain the high densities of meadow birds in the Netherlands.

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MEADOW BIRD ECOLOGY AT DIFFERENT SPATIAL SCALES

RESPONSES TO ENVIRONMENTAL CONDITIONS AND IMPLICATIONS FOR MANAGEMENT

Jort Verhulst

Farmland biodiversity in Europe

A large part of Europe's biodiversity is found on farmland (e.g. Bignal & McCracken 1996; Benton *et al.* 2002). Many species have benefited from the transformation of vast areas of forest and shrubland to semi-natural open ecosystems (Pain & Pienkowski 1997; Donald *et al*. 2002). Due to the extensive character of farming, many species were able to adapt to these new habitats and expanded their range from natural steppes (e.g. Larks Alaudidae) or wetlands (e.g. waders Charadrii; Cramp & Simons 1983). Some species (groups) even reached much higher densities in these newly created habitats compared to their original ones (Glutz von Blotzheim *et al.* 1977).

Since the agricultural revolution of the second half of the 20th century, changes in farming intensity are occurring at a very high rate (Krebs *et al.* 1999; Stoate *et al.* 2001; Robinson & Sutherland 2002). Many species of different taxa have not been able to adapt to the new circumstances and experienced severe declines (e.g. Donald *et al.* 2001; Robinson & Sutherland 2002; Benton *et al.* 2003). Especially the declines in farmland birds, of which nearly 120 species are 'Species of European Conservation Concern', have been well documented (Tucker & Heath 1994; Newton 2004).

Agricultural policies

The increased intensity in farming partly took place because of technological advances and was partly stimulated by policies of national governments and the Common Agricultural Policy (CAP) of the European Economic Community (EEC), the predecessor of the European Union (EU; Robson 1997; Robinson & Sutherland 2002). After WW II, the main goals of the agricultural policies of most European countries were to meet strategic food requirements and to reduce poverty amongst food producers. These goals were accomplished by guaranteeing fixed prices to agricultural producers, by imposing levies on cheaper imports and by granting export refunds to trade surpluses competitively on the world market. Further, the EU made capital grants available which encouraged mechanization amongst farmers (Donald *et al.* 2002).

These policies were very successful in terms of producing food. By the early 1980ies, EU production of many agricultural products already exceeded demands (Donald *et al*. 2002). Subsidizing the huge agricultural production, the CAP became the EU's largest expenditure. In 2006, the CAP budget was as high as €55 billion, accounting for about 45 % of the total EU budget (European Communities 2006). The costs of the CAP are divided over three budget item: direct payments to farmers (63%), intervention prices (15%; by guaranteeing fixed prices) and rural development (22%). Pretty *et al.* (2000) converted the external costs of UK agriculture to a hectare basis and came to about £ 208 per hectare of grassland and arable land per year, while external benefits were estimated to be in the order of £ 20 – 60 per hectare (Pretty *et al.* 2001).

In terms of reducing poverty amongst food producers, production related subsidies were less successful. Many small farmers (in the southern EU states) were too small to qualify for subsidies. This is illustrated by the fact that 80% of CAP funds are being received by only 20% of the producers. Further, the number of people working in the agricultural sector dropped by over 50% between 1970 and 1997 in the EU12 (Donald *et al*. 2002). Many (small) farmers stopped and the average farm size increased considerably. Thus, production subsidies greatly stimulated scale-enlargement.

Finally, the production subsidies directly or indirectly had considerable effects on the structure of Europe's farmland. Increases in field size, pesticide and fertiliser applications, stocking levels and drainage as well as declines in habitat diversity and non-productive land, conversion of grasslands to arable farming and the replacement of hay with silage crops were particularly harmful to farmland biodiversity (for references see Donald *et al.* 2002). Next to intensification, abandonment of farmland in marginal areas farming areas is a threat to farmland biodiversity (Bignal & McCracken 1996; MacDonald *et al*. 2000; Verhulst *et al*. 2004; Spiegelberger *et al*. 2006). Further threats to farmland biodiversity are afforestation (Bignal & McCracken 1996).

Agri-environment schemes

During the 1970's and 1980's there was increasing concern over the adverse effects of farming on the environment. In 1985, the EU agricultural policy first explicitly addressed the impact of agriculture on the environment in a Green Paper published (CEC 1985). The reform of the EU agricultural policy in that year included a novel set of measures for environmental protection. Member States were allowed to pay national aid in environmentally sensitive areas. In 1992, EEC Regulation 2078/92 was introduced, requiring all EU member states to apply agri-environment measures according to environmental needs and potential. Agri-environment schemes vary markedly between countries within the EU. The main objectives include reducing the use of agro-chemicals, protecting biodiversity, restoring landscapes and preventing rural depopulation. Between 50% and 75% of the costs of approved agri-environment schemes are co-funded by the EU, making this regulation a financially attractive form of environmental protection. Annual spending on agri-environment schemes was less than 5% of the total CAP budget in 2004 (Donald *et al.* 2006). Over the period 1994 - 2003, approximately € 24 billion had been spent on agri-environment schemes (Kleijn & Sutherland 2003).

By 2001, 20% of the agricultural land in the EU was covered by agri-environmental measures. This percentage surpassed the 15% target to be achieved by the year 2000, which was set out in the 5th Environmental Action Programme. However, 86% of the expenditure was accounted for by five Member States only. Uptake of programmes is generally low in highly productive and intensive agricultural areas. Biodiversity in these areas may come under even increasing pressure (CEC 2001).

Some ten years after the introduction of EU-stimulated agri-environment schemes, very little was known about the impacts these schemes had on biodiversity. Reviewing their effectiveness in biodiversity conservation, Kleijn & Sutherland (2003) found that over 75% of the evaluations originated from the UK and the NL, where only 6% of the budget had been spent. In the majority of studies, the research design was inadequate to reliably assess the effectiveness of the schemes. Where an experimental approach was used, designs were usually weak and biased towards giving a favourable result.

Overall, 54% of the examined species (groups) demonstrated increases in species richness or abundance compared with controls, 6% showed decreases, 17% showed increases for some species and decreases for other species, and 23% showed no change. The response varied between taxa. For the 19 studies on birds that included a statistical analysis, four showed significant increases, two showed decreases and nine showed both increases and decreases in species richness or abundance (Kleijn & Sutherland 2003). Despite the uncertainty about the effectiveness of agri-environment schemes, at present they do represent the only available mechanism to reverse the declines in farmland biodiversity in the EU (Vickery *et al*. 2004). Therefore, they are of key interest if the 2010 targets to reduce or halt biodiversity loss, agreed in the EU at the 2001 Gothenburg Summit, are to be met (Donald *et al*. 2006).

Recently, the amount of publications on both agri-environment schemes in general and the effectiveness of schemes is rising (Fig. 1.1). Most publications still derive from the UK but the rest of Europe seems to be catching up. Next to publications on the effectiveness of schemes, an increasing amount of studies focuses on scheme design and on factors that influence scheme effectiveness.

The situation in the Netherlands

Wet meadows and their avifauna typical of the Netherlands

At a European scale, wet meadows are predominantly found in the Netherlands. These wet meadows are home to a characteristic community of bird species. The Dutch wet meadows either lie on heavily drained peat soils (Provinces of Utrecht and Zuid-Holland) or on old peat deposits at sea level that are covered by a layer of marine clay (Provinces of Friesland and Noord-Holland; Beintema *et al*. 1997). The main farming type is dairy farming.

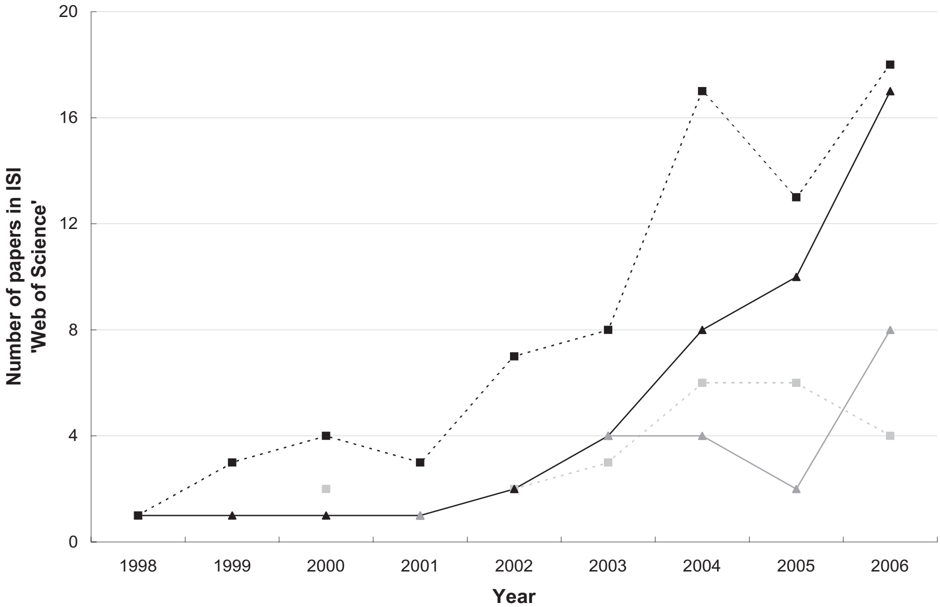

Figure 1.1. The number of published papers in the ISI Web of Science with agri-environment schemes or agri-environment measures as search terms (black lines) and the previous terms combined with either effective*, efficacy or evaluat* (grey lines). Dashed lines with squares: studies originating from the UK; solid lines with triangles: studies from Europe – the UK.

Wet meadows on peat soils came in existence when extensive areas of marshlands were drained and cultivated during the Middle Ages (Beintema 1986). Originally, these areas had been used for arable farming mainly (buckwheat, vegetables and cereals). However, drainage led to oxidation and shrinkage of peat soils, and the surface dropped progressively. This process ended when the surface became too low to allow further drainage. Then, dairy farming replaced arable farming and the fields that had the surface lying almost on the groundwater level were used as grasslands (Beintema 1986). On the soils where marine clay was deposited on peat, dairy farming also developed. Due to the high water retaining capacity and upward capillary pressure of the underlying peat, these clay soils were too wet for arable farming. The Dutch wet grasslands differed from others in Europe because of their high fertility, and their high water table that slows down the growth of the vegetation in spring and prevents early access of livestock and machinery (Beintema & Müskens 1987). Over time, many bird species adapted to this habitat. An overview of these so-called meadow birds and their Dutch and European population sizes is presented in table 1.1. Especially striking is the large number of black-tailed godwits *Limosa limosa* that nest in the NL.

Table 1.1. Dutch and European (including Russia) breeding population of meadow birds (in 1000 pairs; population estimates from Burfield *et al*. 2005). Species in bold: more than 25% of European breeding population in the NL; Species underlined: more than 10% in the NL. Population trends in the NL derived from Teunissen & Soldaat (2005); ++ strong increase, + moderate increase, 0 stable, - moderate decline, -- strong decline. Teunissen & Soldaat did not present the trends of mallard and ruff. Therefore, these species' trends were derived from Beintema *et al*. (1997) and Burfield *et al*. (2005).

Species	Dutch population	European population	Trend NL
<u>Mallard</u> *Anas platyrhynchos*	350 – 500	3.300 – 5.100	+
Shoveler *Anas clypeata*	8 – 9	170 – 210	-
Garganey *Anas querquedula*	1,6 – 1,9	390 – 590	0
Tufted duck *Aythya fuligula*	14 – 18	730 – 880	+
Oystercatcher *Haematopus ostralegus*	80 – 130	300 – 450	-
<u>Lapwing</u> *Vanellus vanellus*	200 – 300	1.700 – 2.800	-
Black-tailed godwit *Limosa limosa*	45 – 50	99 – 140	-
Redshank *Tringa totanus*	20 – 25	280 – 610	+
Curlew *Numenius arquata*	6,4 – 7,4	220 – 360	-
Snipe *Gallinago gallinago*	1,25 – 1,50	930 – 1.900	-
Ruff *Philomachus pugnax*	0,10 – 0,14	200 – 510	--
Skylark *Alauda arvensis*	50 – 70	40.000 – 80.000	--
Meadow pipit *Anthus pratensis*	70 – 80	7.000 – 16.000	-
Yellow wagtail *Motacilla flava*	40 – 50	7.900 – 14.000	0

Like in the rest of Europe, agricultural intensification also greatly accelerated in the Netherlands in the second half of the 20th century. Annual fertilizer inputs increased from 40 kg nitrogen per hectare around 1900 to 400 kg per hectare in the mid 80s (Beintema *et al*. 1985). From the 1950s onwards, agricultural intensification was accelerated by the implementation of large-scale reallocation programmes by the national government. Historically, land ownership had become highly fragmented but now land was reassigned in order to create large, contiguous units under single ownership. The accompanying large-scale infrastructural changes such as drainage and new road and bridge construction, greatly improved farming efficiency but proved very destructive to farmland biodiversity (Beintema *et al*. 1997). Since the 1980s, several of the intensity parameters such as fertilizer applications (presently about 200 kg ha^{-1} $year^{-1}$) and the number of dairy cattle (at present 1.6 million against 2.5 million in 1983; Fig. 2.2) have been reduced to levels of the 1960s (Faostat 2006). The total milk production however has remained more or less stable as declines have been compensated by an increase in milk production per dairy cow (Faostat 2006; Fig. 2.2).

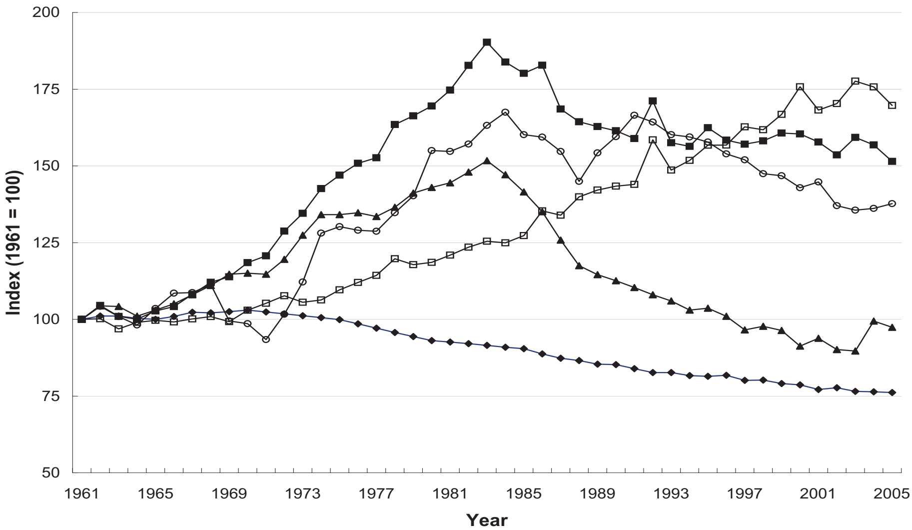

Figure 2.2. Indices of several production parameters related to dairy farming in the Netherlands. The symbols represent the following (between brackets the amounts for 1961): **Diamonds** - area of permanent pasture and meadow (1.287.000 ha), **Filled squares** - total milk production in the NL (6.953.000 liters), **Open squares** - milk production per cow in the NL (42.191 liters), **Triangles** - total number of dairy cattle in the NL (1.648.000), **Open circles** - stocking rate (2.81 dairy cattle/ha).

Over the 20th century, every level of agricultural inputs has had its specific meadow bird community. Beintema *et al*. (1997) illustrate this by describing the fate of several species in a wet meadow area in the centre of the NL, the Eem valley. At present, black-tailed godwit and lapwing are the most abundant meadow bird species. However, their populations peaked with the farming intensity level of the 1950s. Around 1900, black-tailed godwits were not abundant. Ruff *Philomachus pugnax* and corn crake *Crex crex* on the other hand are presently absent but were the most abundant species around 1900. This gradient in presence clearly represents the different species' preference for intensification levels.

Dutch policy to counteract negative effects of intensified farming

In the 1970s, it became clear that the establishment of nature reserves, the traditional way of protecting nature, could not maintain the large and important populations of birds breeding in wet grasslands (Beintema *et al.* 1997). For that reason, the national parliament decided to start a new policy and the Dutch 'Relatienota' became operative in 1975. On the one hand, this act aimed to establish reserves where optimal conditions for farmland birds could be realized. On the other hand however, the limited area of reserves was aimed to be complemented by management agreements with farmers (Berendse *et al*. 2004). Farmers were to be compensated for income loss if they agreed to postpone mowing and grazing, reduce drainage and lower levels of fertilizer application and stocking rates. Although the 'Relatienota' became operative in 1975, it was not until 1981 that the first participants were contracted. The area under agreement became substantial (>20.000 ha) only after 1990. Postponed mowing was the dominant agreement, and farmers were not allowed to carry out any agricultural activities from April 1st until a set date in June or July.

When in 1992 Regulation 2078/92 was introduced, the management agreements that postpone mowing or grazing became the major Dutch agri-environment scheme. In 2000, 'Programma Beheer' a new subsidizing programme, was introduced. The 'Subsidieregeling agrarisch natuurbeheer' (SAN) concerned farmland biodiversity. For meadow birds, additional agri-environment schemes were introduced such as creating shallow pools, providing shoulders and paying per-clutch. The creation of shallow pools provides foraging and roosting opportunities to waders arriving in early spring. Shoulders are strips of vegetation of at least 0.1 ha that are mown two weeks later than the rest of the field. They are supposed to provide feeding opportunities and shelter for the meadow bird chicks. With the per-clutch payment scheme, farmers do not face management restrictions but are paid per meadow bird clutch found on their fields. On fields under this scheme, farmers and volunteers cooperate to protect nests of the most frequently encountered wader species against trampling by cattle or destruction by farming activities (Musters *et al*. 2001). All agri-environment schemes are entered for a period of six years.

The effectiveness of the postponed mowing scheme and the previous management agreements had been monitored but studies in general were poorly set up, did not contain statistical analyses, did not experience similar environmental conditions or were biased towards a higher biodiversity at the onset of the scheme as compared to the controls (Kleijn & Sutherland 2003). Results of these studies were generally positive. However, in 2001 Kleijn *et al*. (2001) published a study in which they showed that the postponed mowing scheme adversely affected two out of four meadow bird species as compared to control fields. Additional studies by Kleijn & van Zuijlen (2004) and Willems *et al*. (2004) analyze meadow bird trends and show that trends on postponed mowing scheme fields do not differ from or are more negative than on controls fields. Observed higher densities on postponed mowing scheme fields appeared already present at the onset of the schemes.

Scheme design and evolution

Management agreements from the 'Relatienota' were generally implemented by individual farmers. However, since 1994 agri-environment collectives have become increasingly important in the implementation of the Dutch agri-environment program. Agri-environment collectives apply for agri-environment schemes for collectives of member farmers. They may increase ecological knowledge of members by providing training courses and may increase the effectiveness of schemes by stimulating farmers to allocate schemes to fields where they are most effective. In 2004, agri-environment cooperatives were active on approximately 55% of the Dutch farmland (Oerlemans *et al*. 2004).

From 2000 onwards, the collective packages that agri-environment collectives may enter consist of a variety of schemes. The minimum area of a collective package is 100 ha. Separate measures of these packages do not need to be adjoining but can be scattered through conventional farmland. However, the ratio AES – conventional farmland needs to be at least 1 – 6. In this way, a mosaic is created at landscape scale. From 2002 until 2006, including the postponed mowing scheme in that package was not required but for the 2007 applications this was again a requirement. On fields with the postponed mowing scheme, farmers can apply farmyard manure for extra subsidy. In most collective packages per-clutch payment is the major component because this scheme hardly conflicts with intensive farming practices.

A recent initiative that involves intensive steering at larger scales (300 – 500 ha) is mosaic management. It has been developed by several agri-environmental collectives to improve the breeding success of black-tailed godwits. Prior to the breeding season, management plans are being made to create a mosaic of fields with different sward heights at small scale during the period most relevant to godwit chicks. Managers of bordering reserves also take part in these plans. As black-tailed godwit chicks mainly feed on flying insects that they pick from high vegetation (Beintema *et* al. 1995; Schekkerman 1997), a mosaic should contain at least one hectare of tall grass (*c*. 20 cm) per black-tailed godwit family. Further management adjustments in mosaics are amongst others mowing at slower speed and flexibility in the agreements concerning the mowing.

From 2003 – 2005, mosaic management was scaled up in a national project where amongst others Birdlife Netherlands were involved in. In this period, breeding success of black-tailed godwits was intensively monitored and compared with control areas without mosaic management. Chick survival in the mosaics was not higher than in the controls (Schekkerman *et al*. 2005) possibly because the years of study were characterized by cold springs and the area with tall grass was not different between the two types of areas. Overall breeding success was slightly higher but that was due to an increased hatching success caused by more intensive clutch protection. Reproduction rate was insufficient to maintain stable populations in both area types (Schekkerman *et al*. 2005).

Despite several types of meadow bird schemes being implemented on approximately 150.000 ha at present, meadow bird populations are still in steep decline (Table 1; Teunissen & Soldaat 2005, 2006). Therefore, the Dutch government plans to increase this area with another 100.000 ha up to 2010 (Laporte & de Graaff 2006). This extra 100.000 ha is supposed to consist of largely the same scheme types, despite the current doubt around the effectiveness of agri-environment schemes. Also, the area with mosaic management grows rapidly with 1.700 ha in 2003, 7.500 ha in 2005 and 14.000 ha in 2006 (www.grutto.nl).

Motivation and contents of this thesis

At the time Kleijn *et al*. (2001) reported on the lack of positive effects of Dutch meadow bird schemes, Peach *et al*. (2001) provide clear results of a scheme in southern England that proves very effective in preserving cirl buntings *Emberiza cirlus*. As a result, the effectiveness of European agri-environment schemes comes under heavy discussion (as mentioned previously). This discussion might have influenced the EU towards granting the project 'Evaluating current European Agri-environment Schemes to quantify and improve Nature Conservation efforts in agricultural landscapes' (EASY). My PhD-research has been carried out in the framework of this project, which was carried out in five EU countries (Hungary, Germany, Netherlands, Spain, and United Kingdom) and Switzerland.

In the first year of the EASY project, each country has executed an evaluation study of the most widely applied agri-environment scheme of that country. For the Netherlands, these were meadow bird schemes. At that time, the Dutch meadow bird policies had recently been altered but not yet been evaluated. In the subsequent years, I have studied some of the processes that influence the effectiveness of meadow bird schemes. The effectiveness of schemes could substantially be improved if we could improve our basic ecological understanding of meadow birds. The ecology of meadow birds is well-studied but spatial habitat use and nest-site selection so far have received relatively little attention. How soil-related environmental factors influence nest site selection of breeding meadow birds has not yet been studied in intensively used agricultural grasslands. Similarly, how meadow birds respond to the specific configuration of fields in a polder where each field is managed differently is not clear. These topics have clear management implications. For instance, if we know what conditions are favoured by meadow birds, we can either allocate schemes to fields with those specific conditions. Also, we can try to restore the conditions within specific fields to make them more suitable for breeding meadow birds. Further, determining the territory size of single breeding birds allows us to determine whether special measures should be implemented at the farm scale, at separate fields or even at parts of fields? In each separate study, the management implications of the results are being discussed.

Outline

Chapter 2

Chapter 2 evaluates of the effectiveness of agri-environment schemes implemented by agri-environmental collectives in 2003. We compared the numbers of birds and their territories on aggregations of scheme fields with that on conventionally managed farms where no special attention was paid to the (meadow) birds. Aggregations of scheme fields consisted of at least one field with the postponed mowing scheme and the remaining fields were managed in accordance with the per clutch payment scheme.

Chapter 3

Chapter 3 describes the relation between farming intensity and bird diversity in Hungary. We compared extensively and intensively managed, and abandoned vineyards. Extensively managed vineyards were small-scaled, whereas intensively managed ones were large-scaled Abandonment of marginal farmland is a serious threat to farmland birds, with approximately 15-20% of farmland being affected. The second part of this study was carried out in grasslands where we discriminated between extensive (0.4 cattle/ha), intensive (1.0 cattle/ha), highly intensive (2.0 cattle/ha and fertiliser application) and abandoned categories. As differences between farming intensity were large, considerable differences were to be expected.

Chapter 4

Chapter 4 describes results of a study exploring the criteria meadow birds use when selecting their nest sites. Therefore, we sampled a set of biotic and abiotic factors thought to be important to meadow birds and examined spatial associations between meadow bird territories and environmental factors. Additionally, we determined whether between-species breeding associations occurred in meadow birds. Using historic territory mapping data from a large number of meadow bird areas, we examined which species-pairs were spatially correlated.

Chapter 5

In Chapter 5, we focus on the spatial scale that meadow birds use their territory. We extensively studied individually marked meadow birds of two different species (i.e. lapwing and redshank) and were able to determine the range of distances birds stay relative to their nests. Breeding lapwings were followed for two consecutive hours, allowing us to study micro-habitat use additionally. With redshanks, we aimed to get as many independent observations as possible. Because they were inactive in the breeding period in general, most observations have been made when birds had chicks.

Chapter 6

Chapter 6 reports of a study that determines the effects of management, field characteristics and sward height on the spatial distribution of meadow birds. In four study areas of 100 ha, meadow birds were surveyed several times per week. Their general distribution was compared before and after mid May, when >75% of the fields were mowed. We compared responses of different species to mass mowing and determine whether they were attracted to the remaining unmowed fields. Additionally, we examined whether presence of fields with divergent features or management influence the spatial distribution of meadow birds.

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DIRECT AND INDIRECT EFFECTS OF THE MOST WIDELY IMPLEMENTED DUTCH AGRI-ENVIRONMENT SCHEMES ON BREEDING WADERS

Jort Verhulst, David Kleijn & Frank Berendse (2007)
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In the Netherlands, agri-environment schemes are an important tool to halt the ongoing decline of meadow birds and, in particular, waders breeding on wet meadows. The effectiveness of the main scheme, postponed mowing (PM), is heavily debated because it does not result in higher breeding bird densities. Recently, agri-environmental collectives have become involved in coordination of scheme applications and additional measures have been introduced. One of them is per-clutch payment (PCP): farmers are paid per wader clutch, without being restricted in their farming practices. We evaluated the effectiveness of the combination of the two measures (PM & PCP) by determining the number of birds and territories on 12.5 ha plots where both measures (on average 1.6 ha PM and 10.9 ha PCP) were being implemented. Conventionally managed grasslands served as controls. Additionally, on the field with postponed mowing and a paired control field, we measured a number of environmental factors that might influence wader distribution. On plots operating a combination of postponed mowing and per-clutch payment, more territories of all bird species were found and more redshanks *Tringa totanus* were observed. The same pattern occurred on fields with per-clutch payments. On fields with postponed mowing, we found more territories of the most abundant wader species but on conventional fields we observed more lapwings *Vanellus vanellus.* The positive effects of postponed mowing on wader territories were most probably caused by small differences in soil moisture and groundwater level between the two field types, as inclusion of these factors in the General

Linear Model rendered all scheme effects insignificant. Postponed mowing affected the form and amount of fertilizer applied to the fields as well as available N, but none of the other environmental factors that were measured. Additional analyses identified groundwater depth, penetration resistance and prey density (earthworms, Lumbricidae, and leatherjackets, Tipulidae larvae) as main factors determining wader density. Our results show that conservation measures consisting of postponing mowing and per-clutch payments implemented by agri-environment collectives do not support a higher abundance of waders but do support marginally higher breeding densities of waders compared to conventional farms. These differences were probably due to differences in soil moisture and groundwater depth. The effectiveness of agri-environment schemes directed towards conservation of waders might be enhanced by including raised groundwater levels into scheme prescriptions.

Introduction

In the Netherlands meadow birds are declining rapidly, both in range and population size (SOVON Vogelonderzoek Nederland 2002; Teunissen *et al*. 2003). As in other north-western European countries, this has largely been attributed to agricultural intensification (e.g. Beintema *et al*. 1997; Donald *et al*. 2001). In the Netherlands, the most widely implemented agri-environment schemes (AES), the meadow bird agreements, aim to counteract this negative trend. Currently meadow bird agreements are being implemented on approximately 150.000 ha and the Dutch government plans to increase this area with another 100.000 ha up to 2010 (Laporte & de Graaff 2006). These agreements aim to conserve breeding waders in particular, because internationally important numbers of black-tailed godwits *Limosa limosa* and oystercatchers *Haematopus ostralegus*, respectively 50% and 30% of the European breeding population, breed in the Netherlands (Hagemeijer *et al*. 1997).

Since 1994, agri-environment collectives have become increasingly important for the implementation of the Dutch agri-environment programme. Agri-environment collectives apply for agri-environment schemes on behalf of member farmers. They aim to increase ecological knowledge among members by providing training courses and they may increase the effectiveness of schemes by encouraging farmers to allocate schemes to fields where they are likely to be most effective. In 2004, farmers in about 55% of the Dutch farmland could join a local agri-environment collective (Oerlemans *et al*. 2004). Collective packages are established for areas of at least 100 ha and usually consist of a variety of measures. All schemes are entered for a period of 6 years.

In this study, the collective packages included a minimum area of between 10 and 20% under the postponed mowing scheme (e.g. Beintema *et al.* 1997). This scheme is designed to reduce disturbance during the breeding season and improve hatching and chick rearing conditions. Therefore, farmers are not allowed to carry out any agricultural activity from 1 April until a set date in June or July. The scheme is applied to the same field for the duration of the scheme. In return for extra subsidy, farmers can apply farmyard manure on these fields. On the remaining area of the collective package, other measures can be implemented such as creating shallow pools or leaving strips unmown on early-mown fields. Farmers can also receive payments per clutch protected. In this case, farmers or volunteers note the locations of all clutches on a map and members of the collectives check the presence of the clutches twice per season. Payment is based on the number of clutches adequately protected against agricultural activities. Thus, when fields are mown farmers have to leave a narrow strip of unmown vegetation around the nest and when fields are grazed clutches should be protected with metal frames or electric wires. Apart from this, farmers do not face management restrictions (see Musters *et al.* 2001). As this measure has little impact on intensive farming practices, it is the most popular option in most collective packages and constitutes the major component of agri-environment schemes.

Hatching success and chick survival of waders were reported to be higher on land where postponed mowing was implemented (Beintema & Müskens 1987; Schekkerman & Müskens 2000) and hatching success was also found to be higher on fields with per-clutch payments (Musters *et al.* 2001). Since most wader species demonstrate natal philopatry and breeding site fidelity that increases with increased breeding success (Gratto *et al*. 1985; Buker & Winkelman 1987; Thompson & Hale 1989; Groen 1993; Jackson 1994; Thompson *et al.* 1994), we may expect higher densities of breeding birds on fields with postponed mowing or per-clutch payments. However, several studies have been unable to find any positive effects of postponed mowing on bird settlement densities (Kleijn *et al.* 2001; Kleijn & van Zuijlen 2004; Willems *et al.* 2004). This may be due to unforeseen side-effects on environmental factors such as groundwater level, soil penetration resistance and the abundance of earthworms (Galbraith 1989; Green 1988; Kleijn *et al*. 2001; Kleijn & van Zuijlen 2004). Future research should evaluate the consequences of these indirect effects on waders.

This paper reports the results of a study that aimed to evaluate the effects of meadow bird agreements implemented by agri-environment collectives on settlement densities of birds of wet grasslands. We focused on combinations of the two most widely implemented schemes, the postponed mowing and per-clutch payment schemes. We compared wader abundance and settlement densities on paired 12.5 ha plots. The control plots consisted entirely of conventionally managed fields without any AES. In addition, we examined the effectiveness of the separate schemes in more detail. We determined whether fields with the postponed mowing scheme differed from controls in key environmental factors known to be important to waders. As the per-clutch payment scheme does not affect agricultural management, we did not survey environmental factors on these fields. Finally, we identified which environmental factors best explain the observed differences in wader abundance and settlement densities between postponed mowing scheme fields and conventionally managed fields. The waders included in this study were the four most frequently observed species: black-tailed godwit, lapwing *Vanellus vanellus*, redshank *Tringa totanus* and oystercatcher. Since it is often assumed that wader-friendly management has beneficial side-effects on other wet grassland birds, we also recorded the total number of bird observations and territories on the study sites.

Methods

Study areas

In the western part of the Netherlands, 19 pairs of 12.5 ha-plots were selected in three regions supporting relatively high wader densities (Eempolders 52°14'N; 5°21'E, 6 pairs; Alblasserwaard/Vijfheerenlanden 51°55'N; 4°56'E, 7 pairs; the western part of Utrecht 52°10'N; 4°51'E, 6 pairs). The Eempolders area is clay soil whilst the other two areas are predominantly peat soils. In all regions dairy farming was the main form of agriculture and our study was conducted exclusively on grasslands. All participating farmers had entered the AES as part of a collective application coordinated by agri-environment collectives, which helped with site selection. The AES plots consisted on average of 1.6 (s.d. = 0.6) ha postponed mowing scheme and 10.9 (s.d. = 0.6) ha per-clutch payment scheme. Within a pair, the field with the postponed mowing scheme and its paired control field were not exactly the same size but observations were restricted to an area equal in size to the smaller of the pair. To ensure that birds had had time to respond to the changes in management induced by the AES, we selected farms that had adopted the schemes for longer periods (on average, schemes were entering their fifth year in 2003; range 3 – 6 years).

Generally, farmers postponed mowing on one or two fields; on the remaining fields the per-clutch payment scheme was implemented. AES study plots were established by selecting (clusters of) fields with the postponed mowing scheme and these fields were then supplemented with fields with the per-clutch payment scheme to reach the required size of 12.5 ha. The control plots were selected on conventionally managed farms in the vicinity where waders received no special attention. There was no voluntary nest protection. Control plots experienced similar environmental conditions (e.g. soil type, water table, structure of the landscape, proximity to nearest disturbance such as houses, roads, trees). Pairs of plots within a region were on average 3.5 km apart (range 450 – 9700), and the treatment and control fields within a pair of plots were on average 260 m apart (range 20 – 935).

Bird survey

Breeding birds were surveyed using a territory mapping approach (Bibby *et al*. 1992). Each field within a pair was visited on the same day by the same observer and all sites were visited four times during the breeding season from 1 April – 15 June. All observations by sight or sound were recorded on maps. Subsequently, all observations of one species were transferred to a species map and territories were drawn around observations made during each of the four visits. Nest sites were allocated to sites where territorial behaviour was observed (e.g. singing or displaying male, actual nests; Teunissen & van Kleunen 2000).

Survey of environmental conditions

Just prior to the breeding season, we surveyed a set of environmental factors on one field in both the AES and the control plots. In the AES plots, we selected a field operating the postponed mowing scheme since the accompanying management modifications were expected to lead to changes in environmental conditions (Kleijn *et al*. 2001). In the control plots, we selected the field that appeared most similar to the surveyed field in the paired AES plot in terms of location relative to buildings, trees and water channels. We measured penetration resistance of the soil, pH, amount of available nitrogen (N), prey density (earthworms, Lumbricidae, and leatherjackets, Tipulidae larvae), soil moisture and groundwater depth.

Penetration resistance of the upper 5 cm of the soil was measured at the field edge and centre using a penetrometer with a 1 cm^2 cone (Eijkelkamp, Giesbeek; P1.51-1). To determine pH, available nitrogen and prey density, we took three soil samples on transects at 10 m intervals along the field edge and three samples in the field centre. Samples were taken with 15 cm - diameter tubes inserted 10 cm deep into the soil. Earthworms and leatherjackets were extracted in the field, counted, and dry weight in grams per m^2 was determined after 48 hours at 70 ˚C to give a measure of prey density. Soil samples were processed in the laboratory to determine pH, amount of available N (NO_3^- + NH_4^+ in mg per kg dry soil) and soil moisture (percentage of dry soil) at the edge and centre of the plots. All analyses used the mean value of edge and centre samples. In Dutch polders, groundwater level is generally kept at a constant level throughout the growing season. However, individual farmers can lower groundwater levels to some extent and fields may differ in height above surface water level. Therefore, we measured groundwater depth (cm) below surface in the centre of each field.

Additionally, through liaison with all participating farmers, we established how much nitrogen was applied and in what form (anorganic fertilizer; liquid or farmyard manure), and the main reason for selection of a particular field for participation in the postponed mowing scheme.

Analyses

All analyses were carried out on the total numbers of territories and observations (summed over the four visits) per plot. The relative number of birds observed gave information on preferences for field types for foraging as it gives the pooled number of observations for breeding and non-breeding individuals. Analyses were performed on the four most frequently observed waders, both individually and pooled. Clearly, the different ways we present the results are not independent of one another (i.e. territories & observations). To examine whether the schemes had any side-effects on non-target species, analyses were also carried out for all bird species pooled given as densities per 10 ha to allow comparison with other studies.

We examined the effects of the postponed mowing scheme and the per-clutch payment scheme separately as well as their combined effects. One field operating the per-clutch payment scheme was converted to an arable field during the breeding season, therefore this pair was excluded from the analyses examining the effects of the per-clutch payment scheme. This pair was not omitted from the analyses examining the effects of the postponed mowing scheme.

All data were analysed using log-linear models employing the Poisson distribution (McCullagh & Nelder 1989) followed by a likelihood ratio test (or *G*-test; Payne *et al*. 2002). Models contained the factors region, pair, management and the interaction between region and management. Region and pair were considered replicates. When necessary, overdispersion was accounted for by inflating the variance of the Poisson distribution with a constant factor. In this case the deviance ratio, following an approximate F distribution, was used as test statistic.

Soil moisture or groundwater depth are important factors influencing settlement densities of meadow birds (Kleijn & van Zuijlen 2004). Under taller swards, soil moisture is expected to be higher than under short swards. However, as we measured the environmental factors in March, we assumed that differences were not yet present. To test whether the effects of agri-environment schemes could partly be explained by soil moisture or groundwater depth, we carried out additional analyses that included these factors as covariates in the original model.

To find out which environmental factor best explained the differences in number of wader observations and territories between the two fields in a pair we used the procedure RSearch (Payne *et al*. 2002). This procedure evaluates all possible regression models with one to all candidate terms and presents the models with the best fit. Pair was always included as a forced term. The AES term was not included in this model as differences in management probably caused differences between the two field types. Models consisting of significant terms only were considered. We selected the model that had the lowest Akaike information criterion, the highest adjusted R^2 and contained fewest terms as the best model describing the response variate.

Further, we explored the mutual relations between the different environmental factors using Pearson's two-tailed correlation analysis. Finally, because this study compared bird densities on scheme and control fields at one point in time, we cannot exclude the possibility that any observed higher bird densities on scheme fields were (partly) due to the preferential implementation of agri-environment schemes on fields with high bird numbers (selection effect; Kleijn & Sutherland 2003). To estimate whether the motivation of farmers might have affected the outcome of the study, we divided the farmers participating in the scheme in two groups: one that took bird density into consideration when choosing the location of the postponed mowing fields and the other that did not use birds as a selection criterion. We subsequently analysed whether the within-pair difference in bird abundance (AES - Control) was larger for the first group compared to the second group using an unpaired two sample T-Test.

Results

Effects of AES on waders and all species

The pooled number of observations of all wader species did not differ significantly between plots with the combination of measures at a 12.5 ha scale and conventionally farmed plots (Fig. 1a; $F = 13.84$, df = 1, $P = 0.268$, n = 18). Likewise, the observed number of individuals of all bird species did not differ between the two plot types ($F = 11.04$, df = 1, $P = 0.316$, n = 18). However, the number of territories of all observed bird species was significantly higher on the plots with a combination of the two schemes than on the control plots (Fig. 1b; $G = 6.00$, df = 1, $P = 0.014$, n = 18). The higher number of territories of the four wader species on the 12.5 ha scale was marginally significant (Fig. 2.1b; $F = 6.92$, df = 1, $P = 0.057$, n = 18).

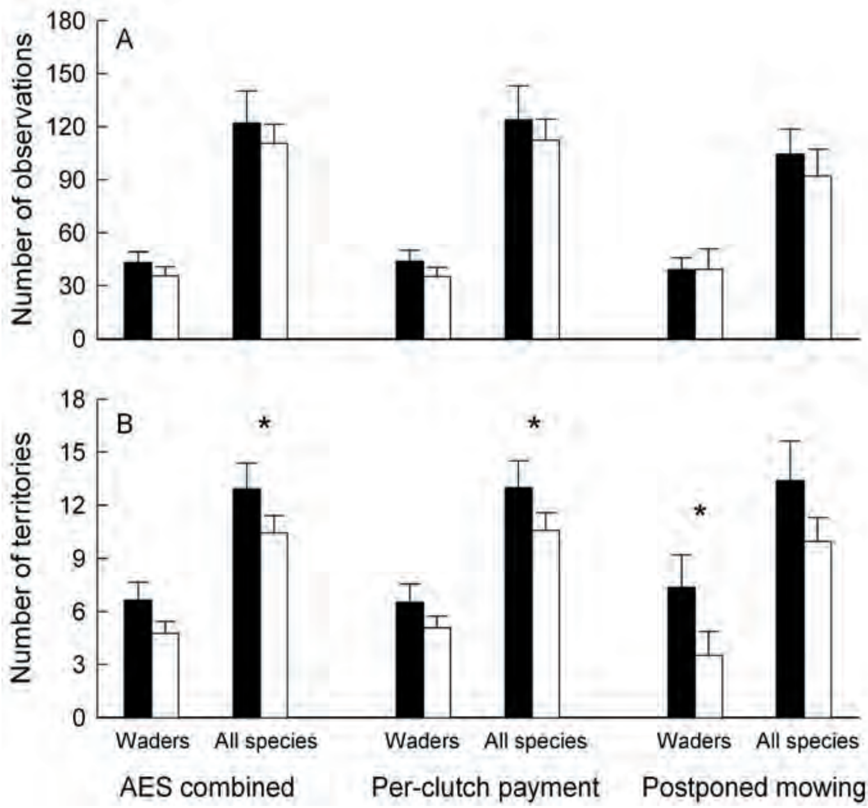

Figure 2.1. Mean number of observations (A) and territories (B) per 10 ha (+ se) of all species and wader species. Results are shown for the combination of the two measures (12.5 ha; n = 18), and for the per-clutch payment scheme (10.9 ha; n = 18) and the postponed mowing scheme (1.6 ha; n = 19) separately. Filled columns, scheme plots; open columns, conventionally managed plots. * $P < 0.05$

When focussing on the per-clutch payment scheme separately, the results resemble the results at the 12.5 ha scale. Again, no significant differences were found for the number of observations of all species (Fig. 2.1a; F = 10.85, df = 1, P = 0.346, n = 18). The number of territories of all species was higher on the per-clutch payment scheme plots compared to conventional plots (Fig. 2.1b; G = 4.59, df = 1, P = 0.032, n = 18); the number of wader territories was marginally significant (Fig. 2.1b; G = 3.48, df = 1, P = 0.062, n = 18).

On the postponed mowing scheme plots no differences were found for the pooled numbers of observations of all bird species (Fig. 2.1a; F = 0.57, df = 1, P = 0.723, n = 19) or waders (Fig. 2.1a; F = 0.69, df = 1, P = 0.614, n = 19). In contrast to the results at the 12.5 ha scale and the per-clutch payment scheme, the number of territories of all species did not differ significantly (Fig. 2.2b; G

= 1.52, df = 1, P = 0.217, n = 19) but the number of wader territories was higher on fields with the postponed mowing scheme relative to the conventional control plots (Fig. 2.2b; G = 5.26, df = 1, P = 0.022, n = 19).

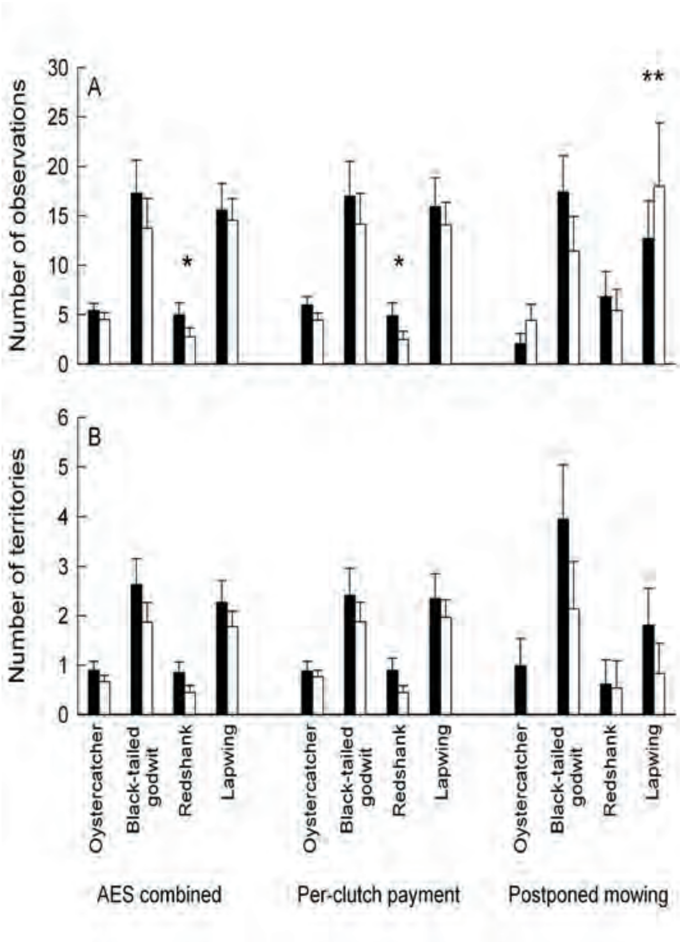

Figure 2.2. Mean number of observations (A) and territories (B) per 10 ha (+ se) of oystercatcher, black-tailed godwit, redshank and lapwing. Results are shown for the combination of the two measures (12.5 ha; n = 18), and for the per-clutch payment scheme (10.9 ha; n = 18) and the postponed mowing scheme (1.6 ha; n = 19) separately. Filled columns, scheme plots; open columns, conventionally managed plots. * $P < 0.05$, ** $P < 0.01$

Effects of AES on individual wader species

We found significantly higher densities of redshank on the fields with the combination of the per-clutch payment and the postponed mowing scheme (Fig. 2.2a; F = 14.07, df = 1, P = 0.044, n = 18). However, in one of the three regions higher densities were observed on conventional fields as was indicated by the interaction term (F = 13.81; df 1; P = 0.025). Redshanks had marginally more territories on 12.5 ha plots with combined measures than on 12.5 ha plots with conventional farming (Fig. 2.2b; G = 2.84, df = 1, P = 0.092, n = 18). The numbers of observations and territories of black-tailed godwit, lapwing and oystercatcher did not differ between combined AES and conventional farmers (Fig. 2.2a & 2.2b).

Similar to the results at the 12.5 ha scale, redshank occurred in significantly higher densities on the fields with the per-clutch payment scheme (Fig. 2.2a; F = 14.41, df = 1, P = 0.024, n = 18). Again, in one of the regions redshank density was higher on conventional fields (interaction term: F = 12.42; df 1; P = 0.016). The observed number of other bird species did not differ between the per-clutch payment scheme and control fields. None of the four wader species was observed with a higher number of territories on plots with the per-clutch payment scheme (Fig. 2.1b).

Lapwings occurred in significantly lower densities on fields with the postponed mowing scheme (Fig. 2.2a; G = 10.76; df 1; P = 0.001). However, a difference was only observed in one of the three regions (interaction term: G = 9.59; df 1; P = 0.008). Similarly, the number of oystercatchers tended to be higher on conventional fields than on fields with the postponed mowing scheme (Fig. 2.2a; G = 3.29, df = 1, P = 0.070, n = 19). In one of the regions more oystercatchers were observed on the postponed mowing scheme fields (interaction term: G = 6.35; df 1; P = 0.002) The number of black-tailed godwit observations was marginally higher on fields with the postponed mowing scheme (Fig. 2.2a; F = 3.60, df = 1, P = 0.076, n = 19). No significant differences occurred in the number of territories. For oystercatcher and redshank, the analyses could not be carried out because only three and five territories were found on postponed mowing scheme fields and their controls. The number of black-tailed godwit territories, almost double in number on AES fields, was not significantly different (G = 1.83, df = 1, P = 0.176, n = 19) due to the high variance.

Environmental conditions on fields with the postponed mowing scheme and in controls

Fertilizer application differed strongly between fields with the postponed mowing scheme and conventionally managed fields (Table 2.1). Even though there were no differences in the amount of organic fertilizers (liquid fertilizer + farmyard manure; F = 0.16, df = 1, P = 0.948, n = 19), fields with the postponed mowing scheme received significantly less liquid manure (F = 282.97, df = 1, P = 0.030, n = 19), but considerably more farmyard manure than conventionally managed fields (F = 1054.91, df = 1, P < 0.001, n = 19). Anorganic fertilizers were applied more on conventional farms (F = 471.41, df = 1, P = 0.014, n = 19) and in line with the differences in fertilizer application, soil available nitrogen was higher on conventional farms (F = 45.07, df = 1, P = 0.005, n = 19). Prey density (F = 3.14, df = 1, P = 0.567, n = 19), pH (G = 0.01, df = 1, P = 0.939, n = 19) and penetration resistance of the soil (G = 0.00, df = 1, P = 0.996, n = 19) were not significantly different between the two field types (Table 2.1). Although fields within all pairs had the same groundwater table (as indicated by soil maps, 1:50.000, Stiboka), groundwater depth proved to be marginally lower on postponed mowing fields (F = 6.68, df = 1, P = 0.080, n = 19). Nevertheless, this did not result in significant differences in soil moisture (F = 0.64, df = 1, P = 0.272, n = 19).

Table 2.1. Mean values (se) of a range of environmental factors judged to be important to waders on fields with the postponed mowing scheme (PM) and on conventionally managed fields. n = 19; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

	Significance	PM	Conventional
Penetration resistance ($100N.cm^{-2}$)		0.85 (0.02)	0.85 (0.02)
pH		4.68 (0.03)	4.74 (0.04)
Farmyard manure (kg $N.ha^{-1}$)	***	64.90 (3.03)	4.44 (1.05)
Liquid manure (kg $N.ha^{-1}$)	*	80.70 (3.31)	150.20 (4.27)
Anorganic fertilizer (kg $N.ha^{-1}$)	*	46.51 (3.27)	111.05 (3.32)
Available N (mg N.kg dry $soil^{-1}$)	**	71.21 (1.78)	90.79 (2.91)
Prey density (grams dry $weight.m^{-2}$)		7.40 (0.18)	9.04 (0.29)
Soil moisture (%)		47.05 (0.38)	45.29 (0.41)
Groundwater depth (cm below surface)		61.21 (1.27)	67.95 (1.39)

Table 2.2. Test statistics of the effects of the postponed mowing scheme (management), soil moisture and groundwater depth on the number of bird observations and territories. Model 1 includes only the factors 'region', 'pair' and 'management'. In Model 2, soil moisture and groundwater depth have been included as covariates in model 1. Shown are the 'log likelihood ratio statistic' G or in case of overdispersion the deviance ratio F (indicated with §). Only test statistics of the fixed factors management, groundwater depth and soil moisture are given. The directions of the effects are in brackets. * $P < 0.05$; ** $P < 0.01$, *** P < 0.001.

	Model 1	Model 2		
	Management	Moisture +	Groundwater +	Management
Observations				
All species§	0.13	1.63	3.84	0.16
Waders§	0.26	3.35	2.70	0.02
Black-tailed godwit§	3.60	1.28	1.80	0.65
Lapwing	10.76**	21.36***(-)	0.00	1.53
Redshank	0.76	0.37	2.21	0.00
Oystercatcher	3.29	5.36*(-)	8.27**(-)	1.49
Territories				
All species	1.52	0.92	0.71	0.47
Waders	5.26*	4.69*(+)	3.22	0.46
Black-tailed godwit	1.83	1.97	1.04	0.00

Including soil moisture and groundwater depth as covariates in the statistical model affected the significance of the effects of the postponed mowing scheme (Table 2.2). Differences in the number of lapwing observations and pooled wader territories were largely accounted for by differences in soil moisture or groundwater depth and the effects of the postponed mowing scheme were not significant for any of the bird parameters. The pooled number of wader territories was related positively to soil moisture. The numbers of lapwing and oystercatcher observations were related negatively to soil moisture. However, the number of oystercatcher observations related negatively to groundwater depth (measured in cm below surface).

Effects of environmental factors on waders

The best model explaining differences in the number of wader observations between field pairs by means of environmental variables explained 82% of the variation and consisted of only two factors: prey density (positive relationship, $P < 0.001$) and groundwater depth (negative relationship, $P = 0.001$). For wader territory numbers the best model explained 52% of the variation. Again, only two terms were included: groundwater depth (negative relationship, $P = 0.002$) and penetration resistance of the soil (negative relationship, $P = 0.037$).

Correlation analysis revealed a negative correlation of prey density and the amount of farmyard manure (Table 2.3) and a positive correlation between prey density and pH. Liquid fertilizer and pH were positively correlated, as were organic fertilizer and pH. Fertilizer application rate (liquid or organic) and prey density, and farmyard manure and pH were not significantly correlated.

Table 2.3. Pearson's two-tailed correlations between environmental factors. PR = penetration resistance, pH = pH, FM = farmyard manure, LM = liquid manure, OF = organic fertilizer, AF = anorganic fertilizer, AN = available nitrogen, PD = prey density, SM = soil moisture and GD = groundwater depth. For farmyard manure we only included those pairs where farmyard manure was applied. * *P < 0.05;* ** *P < 0.01*, *** $P < 0.001$.

	PR	pH	FM	LM	OF	AF	AN	PD	SM
pH	-0,299								
n	38								
FM	0,009	-0,149							
n	12	12							
LM	-0,372*	0,543**	-0,154						
n	36	36	12						
OF	-0,171	0,427*	0,483	0,745***					
n	35	35	12	35					
AF	-0,294	-0,016	-0,068	0,495**	0,273				
n	37	37	12	36	35				
AN	-0,034	-0,111	0,456	0,149	0,14	0,088			
n	38	38	12	36	35	37			
PD	-0,205	0,376*	-0,613*	0,209	0,047	0,038	0,127		
n	38	38	12	36	35	37	38		
SM	-0,226	-0,138	-0,102	0,013	-0,017	-0,079	0,667***	0,051	
n	38	38	12	36	35	37	38	38	
GD	0,188	0,037	0,399	0,189	0,243	0,134	-0,069	-0,083	-0,312
n	38	38	12	36	35	37	38	38	38

Selection effect

During interviews, six out of the nineteen AES farmers indicated that they had chosen the location of the postponed mowing scheme fields based on considerations regarding birds in general. Thirteen gave other reasons; most notably they selected fields located far from the farm, or fields that were on marginal or poorly drained soils. The difference in the number of observed waders between scheme fields and paired control fields was no greater for farmers that took existing bird abundance into account when allocating schemes compared to farmers that allocated scheme fields based on other criteria (t_{17}: 0.30, $P = 0.769$) (Fig. 2.3). Notably, the difference in wader territory numbers between paired scheme and control fields was significantly smaller for farmers who had allocated schemes to fields based on bird criteria compared to the remaining farmers with the postponed mowing scheme ($t_{16.79}$: 3.82, $P = 0.001$) (Fig.2.3).

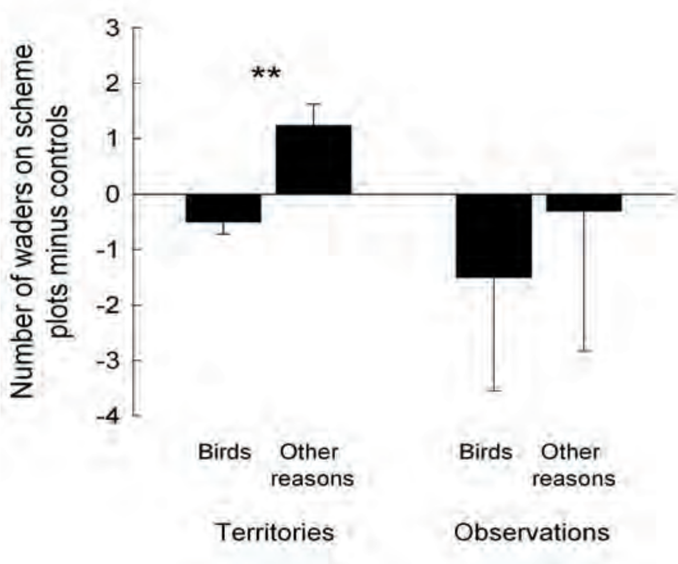

Figure 2.3. Difference in number of wader territories and observations between field pairs (AES – Controls) where farmers allocated the postponed mowing scheme fields based on bird abundance (*n* = 6) and scheme fields where farmers used other reasons for the allocation (*n* = 13). ** *P < 0.01*

Discussion

Plots with a combination of the postponed mowing and per-clutch payment scheme hosted more bird territories and higher numbers of redshank than conventionally managed plots. This result was largely caused by the effects of the per-clutch payment scheme (Figs 2.1 & 2.2) as on fields with postponed mowing, we found more territories of waders but observed fewer lapwings than on control fields (Figs 2.1 & 2.2). Both positive and negative effects of postponed mowing were probably caused by small differences in soil moisture and groundwater level between the two field types, as inclusion of these factors in the statistical model rendered all scheme effects insignificant (Table 2.2). Additional analyses also identified groundwater depth as the main factor determining wader density, along with penetration resistance and prey density.

Effects of the per-clutch payment scheme and combined scheme effects.
On plots with agri-environment schemes, all wader species had more territories but this effect was only (marginally) significant for redshank on plots with a combination of the per-clutch payment and the postponed mowing scheme. There was also a trend towards higher numbers of territories of the four wader species summed, which also existed at the plots with per-clutch payment. While we did not find significant differences in the pooled number of observations of the four wader species, redshanks were observed more frequently both on the combined AES plots and on the per-clutch payment plots. Lapwings and black-tailed godwits breeding on fields with the per-clutch payment scheme reportedly had higher hatching rates (Musters *et al.* 2001) but our results indicate that this does not necessarily result in higher breeding densities.

The number of territories of all bird species was significantly higher on both the plots with combined schemes and plots with only the per-clutch payment scheme. This was partly due to common species like mallard *Anas platyrhynchos* but was also caused by higher breeding densities of species with conservation interest, such as the meadow pipit *Anthus pratensis* (data not shown). This is surprising since volunteers participating in the per-clutch payment scheme do not mark nor protect the nests of these species during their incubation period. Because agricultural practices on fields with the per-clutch payment scheme are comparable to those on control fields, nest losses should be similar on the two field types. Our results correspond to those of Teunissen (2000), who evaluated the effects of nest protection by volunteers on breeding densities of a range of birds breeding in wet grasslands. Breeding densities of skylarks *Alauda arvensis* and tufted ducks *Aythya fuligula* were found to increase in fields with nest protection. At the same time, breeding densities of wader species did not increase during the four years of the study although their hatching rate was found to be 25% higher in areas with nest protection. Most waders show natal philopatry (e.g. Gratto *et al.* 1985; Thompson & Hale 1989; Groen, 1993; Thompson *et al.* 1994) suggesting that the positive effect of nest protection might have been negated by a high chick mortality in intensively managed grasslands.

Willems *et al*. (2004) found increasing differences in breeding densities with increasing distances between control and managed fields for black-tailed godwit, lapwing and redshank. In our study, the within-pair distances between fields mostly fell within the potential range of adult feeding trips and brood movements. However, we did not find a significant relationship between within-pair distance between fields and the effect size (difference between scheme and control fields) for observations. (Spearman's correlation 0.056; $P = 0.826$) or territories (0.017; $P = 0.948$). Thus, it seems that the distance between the AES plot and its control plot did not play a role in our study.

Separate effects of the postponed mowing scheme

The size of fields with the postponed mowing scheme and their control fields was rather small, averaging 1.6 ha. This measure can be implemented on areas as small as 0.5 ha and is usually implemented on contiguous areas of only a few hectares. In this study, the surface of the postponed mowing scheme was often reduced because the paired control field was even smaller. Further, we only considered one field with the postponed mowing scheme (because of comparability) while in some cases a second field with this scheme was present. Nevertheless, results should be interpreted with some caution especially as the two separate schemes were always adjacent.

In contrast to the findings of Kleijn *et al*. (2001), higher numbers of wader territories were found on fields with the postponed mowing scheme than on conventionally managed fields. Since we did not know breeding densities on the study sites prior to scheme implementation, the observed differences may have been due to the selection effect, that is, the preferential location of schemes on fields with high bird densities (see Willems *et al*. 2004). Scheme performance was poorer on those fields selected on the basis of bird abundance than on those fields where farmers had not used birds as a criterion for field selection (Fig. 2.3). This suggests that motivation of farmers with respect to bird conservation did not explain the observed results. In agreement with the findings of Kleijn *et al*. (2001), we observed fewer lapwings and oystercatchers on fields operating the postponed mowing scheme but only in parts of the region. For lapwing, differences mainly occurred in June when conventional fields had been mown. These differences can probably be attributed to the preference shown by this species for short swards (Redfern 1982; Galbraith 1988; Butler & Gillings 2004). Our results indicate, however, that both these species respond even to small differences in soil moisture or groundwater depth. They apparently prefer foraging in the drier parts of their habitat, as indicated by Table 2.2, which might explain the lower densities of lapwings on fields with the postponed mowing scheme.

The negative effect of the scheme on the number of observed lapwings and the positive effect on the number of wader territories were no longer significant when soil moisture and groundwater depth were included in the model. In line with Kleijn & van Zuijlen (2004), this strongly suggests that any observed differences in wader abundance were caused by soil moisture rather than by changes in farm management. Most farmers operating postponed mowing schemes did not consider birds when they entered the scheme and selected fields that were located far from the farm, that were poorly drained or on marginal soils (see also Kleijn *et al*. (2004)). It is possible that waders prefer these types of fields.

When scheme implementation was not considered, groundwater depth was the environmental factor that best explained differences in wader abundance between fields within pairs. Both the number of wader observations and territories were best explained by simple models containing groundwater depth and one additional environmental factor relating to the efficiency with which prey can be obtained from the soil. Several other publications have stressed the importance of groundwater level for breeding waders (e.g. Beintema *et al.* 1997; Schekkerman 1997; Brandsma 1999; Milsom *et al*. 2000). A reduction in soil penetration resistance is known to be beneficial to soil probing birds such as waders (Green 1988) and is generally positively affected by low groundwater depths or high soil moisture. However, we did not find significant correlations between these factors (Table 2.3). Prey density was measured as the abundance of leatherjackets and earthworms; while leatherjackets are mainly affected by field management in the previous year (McCracken *et al*. 1995; Vickery *et al*. 2001), earthworms are positively related to pH (Standen 1984) or fertilization rate with farmyard manure (Vickery *et al*. 2001), anorganic and organic fertilizers (Edwards & Lofty 1977) and therefore overall nitrogen content of the soil (e.g. Edwards & Lofty 1977). Surprisingly, we did not find differences in prey densities between scheme and control fields despite the large differences in the type and amount of fertilizers applied to the two field types and thus in the available nitrogen (Table 2.1). The organic fertilizer application was very similar between the two field types, which might explain the lack of difference in pH and prey density.

Implications for meadow bird management

Our results show that a combination of the two most widely applied Dutch meadow bird schemes, implemented by agri-environment collectives, do not raise wader abundance significantly. The number of wader territories tended to be higher on plots operating the schemes. Although we tried to establish whether a selection effect influenced the results, we cannot exclude the possibility that differences were already present at the onset of the schemes, as was found by Kleijn & van Zuijlen (2004) and Willems *et al*. (2004). In that case, we conclude that simple changes in farm management that can be integrated into existing farming systems relatively easily do not substantially increase densities of breeding waders. However, the implementation of schemes by agri-environment collectives are more effective than postponed mowing implemented by individual farmers (Kleijn *et al*. 2001; Kleijn & van Zuijlen 2004; Willems *et al*. 2004).

This study focused on (breeding) densities and did not take breeding success into account. It remains unclear why higher reproduction rates on scheme fields as found by Schekkerman & Müskens (2000) do not translate in higher breeding densities. On several occasions in this study, we noted that the grass had grown so high and heavy that it had fallen down, rendering it unattractive to birds. Further, most Dutch grasslands have been agriculturally improved making them less suitable as nesting sites and providing less food (Atkinson *et al*. 2005; Vickery *et al*. 2001; Wilson *et al*. 2005). Wilson *et al*. 2005 suggest that reversing the recent trend towards dense, simplified and homogeneous grassland swards may improve agri-environment scheme options designed to assist the recovery of farmland bird populations.

Groundwater depth, soil penetration resistance and prey density play important roles in determining the abundance of foraging and nesting waders. Penetration resistance of the soil is negatively related to groundwater depth as prey can be caught more efficiently if high groundwater levels keep them near the softer surface. This suggests that raising groundwater levels may improve the effectiveness of agri-environment schemes. Even though these measures are currently being implemented in the UK (Ausden & Hirons 2002), the introduction of such measures is not considered a serious option in the Netherlands at present.

Our results suggest that increasing prey density would enhance the abundance of waders on meadows. Unfortunately, this cannot always be achieved simply by high applications of farmyard manure but, rather, emphasis should be placed on maintaining a high pH. However, high rates of fertilizer application and the associated increased vegetation growth on fields with postponed mowing may be problematic to both farmers and birds. A possible solution may be to vary the exact location of a proportion of the fields with the postponed mowing scheme within a wider area based on the number of observed birds at the onset of the growing season. This would ensure that conservation efforts were concentrated on fields where the highest densities of the target species. At the same time it would allow farmers to maintain high productivity levels on all fields, which should result in high densities of prey.

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3

RELATIONSHIP BETWEEN LAND-USE INTENSITY AND SPECIES RICHNESS AND ADUNDANCE OF BIRDS IN HUNGARY

Jort Verhulst, András Báldi & David Kleijn (2004)
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When Hungary, together with nine other central and eastern European countries, enters the European Union in 2004 two major threats will arise to the birds inhabiting agricultural landscapes. Marginal agricultural land may be abandoned, while the remaining area may suffer from intensification. To assess the effects of these threats breeding birds were monitored in abandoned, extensively and intensively used vineyards and grasslands in Hungary using point counts to determine species richness and density. Species numbers and bird density were highest in extensively used vineyards, while bird diversity was highest in abandoned vineyards. Abandoned vineyards were rich in species and individuals, mainly woodland species, whereas intensively used vineyards had both fewer species and individuals than the other two vineyard types. In grassland, four management types were distinguished, abandoned, extensively, intensively grazed and both intensively grazed and fertilised grasslands. Extensive grassland harboured most species, bird density and diversity being highest at the abandoned site which was covered by bushes and contained many non-grassland species. Intensively grazed fields had lower species numbers, lower density and diversity than extensively grazed grassland but were still much more species rich and diverse than the fertilised fields. Our results suggest that extensively used farmland holds the highest diversity and abundance of farmland birds. Conservation efforts aimed at farmland birds should therefore focus on maintaining extensive farming systems.

Introduction

The decline of western European farmland birds in recent decades has been well-documented (Tucker & Heath 1994; Tucker 1997) and was linked primarily to the intensification and industrialisation of agriculture (Tucker & Heath 1994; Tucker 1997; Siriwardena *et al.* 1998; Chamberlain *et al.* 2000; Benton *et al.* 2003). In the European Union, intensification was to a large extent steered by the Common Agricultural Policy (CAP; Donald *et al.* 2002). The CAP was initiated in 1957 with the aim to increase agricultural production, to ensure sufficient food for all inhabitants and a fair standard of living for people engaged in agriculture. The CAP resulted in a polarisation of production areas and a loss of mixed farming. Although it has prevented some low-intensity systems with high biodiversity from being abandoned, the CAP has also lead many marginally economic areas to be abandoned (Bignal 1998). The CAP has also encouraged homogenisation of the farmland and many non-agricultural features such as hedgerows and woodlands have been removed (Lefranc 1997).

In Central and Eastern European Countries (CEEC) the rate of increase in agricultural productivity between 1960 and 1980 was similar to that of the EU Member States. After the collapse of the state support in the former communist countries in the 1990s, agricultural output dropped sharply (Donald *et al.* 2001). However, even before the fall of communism, state support in the CEEC's was generally lower than it was in the EU resulting in a less intensive agriculture. Low-intensity farmland habitats are far more widespread in eastern than in western Europe (Tucker & Evans 1997) and farmland birds have suffered smaller declines in Central and Eastern Europe than in the EU (Donald *et al.* 2001). Now that the CEEC's are about to enter the EU, their farmland birds may face the same hazards as in the EU: intensification and abandonment (Tucker & Heath 1994; Lefranc 1997; Tucker 1997; Heath & Evans 2000; Suárez-Seoane *et al.* 2002).

This paper aims to assess the potential effects of the CAP in the CEEC's. The relationship between land-use intensity and species richness and abundance of breeding farmland birds is therefore studied in Hungary. The country is dominated by agriculture, with 50% arable land, 25% other agricultural activities, including vineyards, grassland and forestry (Ángyán *et al.* 2001). Many of Hungary's characteristic birds depend on farmland (Márkus 1993; Tucker & Evans 1997). The study focuses on vineyards and grassland which are important from a conservation point of view and threatened by both intensification and abandonment (Molnár & Vajda 2000; Roudna 2002).

In 2000 vineyards covered 1.1% (104.000 ha) and grassland 11% (1.048.000 ha) of the Utilised Agricultural Area (Hungarian Central Statistical Office 2002). Vineyards are important from a landscape point of view. The Tokaj region has been marked as an UNESCO World Heritage Site, yet little is known about their bird abundance and diversity. Grassland (*puszta*) is likely to expand in Hungary (Ángyán *et al.* 2001) and contains a rich and unique avian life (Faragó 1995; IUCN 2002).

This paper tries to determine the effects both of intensification and abandonment on bird species richness and abundance in grasslands and vineyards.

Methods

Vineyards

The vineyards studied were situated in the Tokaj region (north-eastern Hungary) on the slopes of the lower Zemplén mountains (48°16’N; 21°20’E). The area has been used as vineyards for centuries. Some of the vineyards have been abandoned, while recently the management of others has been intensified after foreign investment. Abandoned areas were rather homogenous and covered with grasses and bushes (mainly *Rosa* spp.) other parts being more heterogeneous with some small managed parts. The extensive vineyards were very heterogeneous. Many of the parcels were small and contained a lot of different landscape elements like fruit trees, hedgerows, forested slopes, houses, grasslands and vegetables. Intensive vineyards were very homogenous, and contained few landscape elements. Average field size was large (c. 20 ha) and the surface levelled to make it accessible for large machines.

The three differently managed vineyard types were selected all randomly through the area. A total of 22 observations were made in intensively used vineyards at five different locations. Another 22 observations were made at ten locations in extensively used vineyards of 10-30 ha. Only 12 observations were made at 10 different abandoned vineyards of less than 5 ha.

Grassland

The second part of this research was conducted on the Peszéradacs meadows, part of the Kiskunság National Park (47°03’N; 19°18'E), and on farmland in the direct vicinity. It is a sandy, rather dry area (annual rainfall of 525 mm) situated on the plain between the Danube and Tisza rivers. Birds were surveyed on grassland with four different land-use intensities: abandoned; extensively grazed; intensively grazed; and intensively grazed and fertilised (henceforth called fertilised).

Abandoned and extensive grassland were located in the National Park, intensive and fertilised categories on private farms, within 25 km of the Peszéradacs meadows. All sites were under the same climatic and geological conditions and management for at least the last five years.

A small part of the meadows, on the edge of a forest, had not been grazed or mown for 20 years. This part is covered with bushes, mainly *Crataegus* spp.

and *Rosa* spp. Due to its small size, only four observations were made, a number too small to be compared with the other grassland types. It nevertheless is an indication of the changes in avifauna following abandonment.

In extensively grazed grassland 23 observations were carried out on 1200 ha meadow that ranged from dry to wet and contained scattered bushes, trees and reed beds. Cattle grazed it intensively up to 1996, when it became part of the National Park. Parts of the grassland were mainly grazed (0.4 cow/ha), some were mown and there was no clear distinction between these two.

Intensively grazed grassland (1 cow/ha) was located on two farms, one of 100 ha about two km east of the extensive grassland, the other (600 ha) 25 km south of it. On each farm twelve observations were carried out. Anorganic fertilisers were not applied, and the 100 ha grassland has more trees, hedgerows, ditches and flowering herbs than the 600 ha grassland.

Nine observations were made in a fertilised grassland situated 10 km northwest of the Peszéradacs meadow. The site receives 50 - 100 kg anorganic fertilisers per ha per year. Some 85 ha were mown each year in June, while some 15 ha were grazed with a density of (2 cows/ha). The vegetation cover was dense, high and dominated by grass species with some scattered trees and bushes on the edge.

Point count method

As for the Hungarian National Common Bird Census (Szép & Nagy 2002), the point count method (Bibby *et al.* 1992) was used to survey breeding birds. All individual birds within points with a radius of 100m were counted. The distance to observed birds was estimated with a range finder (Bushnell; Overland Park, USA). All points were visited twice in 2002, once in April for early breeders, once in May for species that arrived later. The ten-minute counts were conducted under good weather conditions. Observations began at sunrise and lasted 4-5 hours. Disturbances were avoided as much as possible.

Moskát (1987) found that twenty points would be sufficient to find most species (over 90%) in Central European deciduous forests. Since visibility is far better in grassland and vineyards than in forests, twenty points were considered to be largely satisfactory.

Analysis

The highest number of individuals of each species of either the April and May count was used to estimate densities per 10 ha and species diversity and evenness (Shannon H and J indices). Conservation status of the birds in Europe was derived from Tucker & Heath (1994), with “SPEC 1” for species that are globally threatened, conservation dependent or data deficient; “SPEC 2” for species with unfavourable conservation status in Europe whose global populations are concentrated in Europe; “SPEC 3” for: species with unfavourable conservation status in Europe whose global populations are not concentrated in Europe and “SPEC 4” for species with a favourable conservation status in Europe whose global populations are concentrated in Europe.

The danger of pseudo-replication existed for grassland because observation sites were located in just one or two fields. However, these fields were all at least 100 ha whereas individual point counts were about 3 ha in size. Therefore, the point counts were considered to be independent. Selecting fields further apart would have resulted in marked differences in environmental conditions and management which would have hampered interpretation of what caused observed differences.

Data were analysed by analysis of variance. When significant effects of land-use type were found, t-tests were used to test for significance of differences between pairs of means. To keep type I errors within bound a probability of 0.99 ($\alpha = 0.01$) was used when performing the various pair-wise comparisons. If variables were not distributed normally or if variance of the errors was not constant data were subjected to ln-transformation prior to analysis.

Results

Vineyards

The number of bird species sighted hardly increased beyond seven observations in abandoned vineyards and beyond 14 observations in extensively and intensively used vineyards (Fig. 3.1), suggesting that the sample size was sufficient. Extensively used vineyards have significantly more bird species than abandoned and intensively used ones (Table 3.1). Abandonment did not result in significant bird declines, whereas intensification resulted in significantly lower abundance and diversity compared to extensive vineyards.

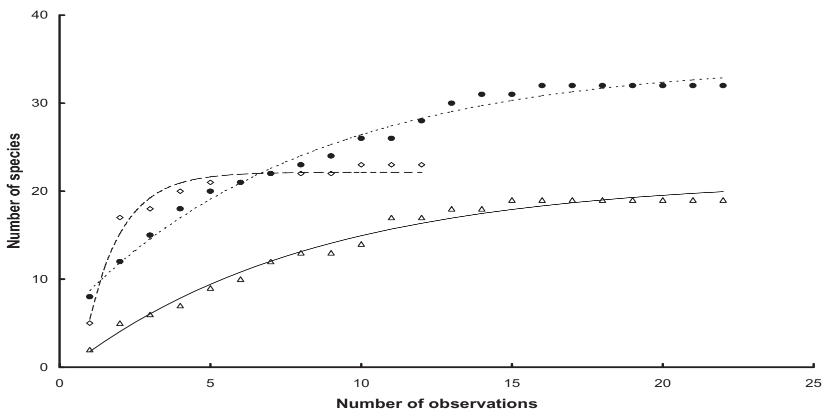

Figure 3.1. Relationship between number of observations and number of bird species in vineyards of different land-use intensity. Diamonds: abandoned; circles: extensive; triangles: intensive vineyards.

Table 3.1. Mean (± s.e.) bird species richness, abundance, diversity (Shannon's H) and evenness (Shannon's J) per point in abandoned, extensively and intensively used vineyards. Per column, different superscripts indicate differences significant at P < 0.01.

Vineyard type	N	Species richness	Abundance	Diversity	Evenness
Abandoned	12	5.7^{b} (0.91)	9.6^{ab} (1.42)	1.47^{a} (0.153)	0.68^{a} (0.043)
Extensive	22	7.0^{a} (0.58)	13.3^{a} (1.45)	1.63^{a} (0.105)	0.68^{a} (0.042)
Intensive	22	3.2^{c} (0.38)	6.4^{b} (0.55)	0.96^{b} (0.087)	0.54^{a} (0.044)

Table 3.2. Numbers of individuals per 10 ha and SPEC conservation status of the most abundant species and species with a high conservation status in abandoned, extensively and intensively used vineyards.

Bird species	Abandoned *n* = 12	Extensive *n* = 22	Intensive *n* = 22	SPEC conservation status
Skylark *Alauda arvensis*	1.59	0.14	0.87	3
Linnet *Carduelis cannabina*	3.71	4.63	8.10	4
Goldfinch *Carduelis carduelis*	0.00	0.14	0.87	4
Greenfinch *Carduelis chloris*	1.06	2.75	0.87	4
Yellowhammer *Emberiza citrinella*	1.59	0.58	0.14	4
Robin *Erithacus rubecula*	0.80	0.43	0.00	4
Chaffinch *Fringilla coelebs*	0.27	2.03*	0.00	4
Red-backed shrike *Lanius collurio*	2.92	3.18	1.16	3
Woodlark *Lullula arborea*	0.00	0.00	0.29	2
Corn bunting *Miliaria calandra*	3.98	0.29	0.14	4
Tree sparrow *Passer montanus*	0.53	10.71	2.46	-
Black redstart *Phoenicurus ochruros*	0.27	1.59	0.29	-
Stonechat *Saxicola torquata*	1.86	0.43	0.43	3
European serin *Serinus serinus*	1.86	5.79*	3.18	4
Turtle dove *Streptopelia turtur*	0.27	0.87	0.00	3
Whitethroat *Sylvia communis*	0.80	0.29	0.00	4
Barred warbler *Sylvia nisoria*	3.45	0.43	0.00	4
Blackbird *Turdus merula*	2.12	2.03	0.29	4
Song thrush *Turdus philomelos*	1.06	2.17	0.29	4

* Including foraging flocks.

Tree sparrow *Passer montanus,* black redstart *Phoenicurus ochruros* and song thrush *Turdus philomelos* (Table 3.2) were observed most frequent in extensive vineyards. Abandoned vineyards have higher densities of corn bunting *Miliaria calandra*, barred warbler *Sylvia nisoria* and stonechat *Saxicola torquata* but lower densities of greenfinches *Carduelis chloris* and European serins *Serinus serinus* than extensive vineyards. Intensively used vineyards have almost six times the number of skylarks *Alauda arvensis* and twice the number of linnets *Carduelis cannabina* than extensively used vineyards (Table 3.2). Some rare woodlarks *Lullula arborea* were observed in the intensively used vineyards only. The densities of song thrush, blackbird *Turdus merula*, black redstart and tree sparrow were >75 % lower in intensive compared to extensive vineyards (Table 3.2).

Grassland
The number of bird species sighted hardly increased beyond 13 observations in extensively and intensively used grassland (Fig. 3.2) indicating that sample size was sufficient. The sample sizes of abandoned and, to a lesser extent, fertilised grasslands were not sufficient to give a representative account of their bird communities. Care must be taken with the interpretation of the results for these two grassland types.

Extensively grazed grassland were significantly more diverse and supported significantly higher numbers of species and individuals than both intensively grazed and fertilised grassland (Table 3.3). However, abandoned contained more species and individuals than extensively grazed grassland. Skylark, yellow wagtail *Motacilla flava* and winchat *Saxicola rubetra* occurred in high densities on extensively grazed grassland (Table 3.4), wader species black-tailed godwit *Limosa limosa*, curlew *Numenius arquata* and redshank *Tringa totanus* being observed exclusively on extensive grassland albeit in low densities.

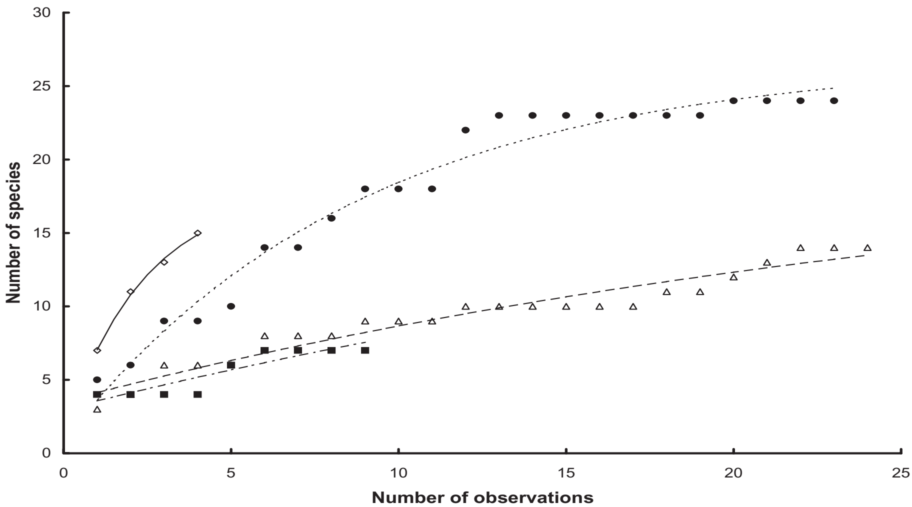

Figure 3.2. Relationship between number of observations and number of bird species in grassland of different land-use intensity. Diamonds: abandoned; circles: extensive; triangles: intensive; squares: fertilised grassland.

Table 3.3. Mean (± se) bird species richness, abundance, diversity (Shannon's H) and evenness (Shannon's J) per point in abandoned, extensively, intensively grazed and fertilised grassland. Per column, different superscripts indicate differences significant at P < 0.01. One asterisk is placed by means calculated from two points less, two asterisks by mean calculated from three points less.

Grassland type	N	Species richness	Abundance	Diversity	Evenness
Abandoned	4	8.3^{b} (0.75)	15.8^{b} (1.93)	1.92^{a} (0.072)	0.70^{a} (0.032)
Extensive	23	4.7^{a} (0.40)	10.2^{a} (0.69)	1.29^{a} (0.097)	0.56^{a} (0.041)
Intensive	24	2.5^{c} (0.29)	5.5^{c} (0.78)	0.78^{b*} (0.104)	0.47^{a} (0.063)
Fertilised	9	1.9^{c} (0.30)	3.1^{c} (0.59)	0.43^{b**} (0.190)	0.44^{a*} (0.174)

Table 3.4. Number of individuals per 10 ha and SPEC conservation status of the most abundant species and species with a high conservation status in abandoned, extensively grazed, intensively grazed and fertilised grassland.

Bird species	Abandoned $n = 4$	Extensive $n = 23$	Intensive $n = 24$	Fertilised $n = 9$	SPEC conservation status
Sedge warbler *Acrocephalus schoenobaenus*	0.00	1.25	0.00	0.00	4
Skylark *Alauda arvensis*	0.80	10.10	7.03	6.72	3
Linnet *Carduelis cannabina*	4.77	0.00	0.00	0.00	4
Greenfinch *Carduelis chloris*	3.98	0.00	0.00	0.00	4
Quail *Coturnix coturnix*	2.39	0.14	0.13	0.35	3
White stork *Ciconia ciconia*	0.00	0.14	0.13	0.00	2
Red-backed shrike *Lanius collurio*	4.77	0.14	0.00	0.00	3
Lesser grey shrike *Lanius minor*	0.00	0.14	0.40	0.00	2
Black-tailed godwit *Limosa limosa*	0.00	0.69	0.00	0.00	2
Corn bunting *Miliaria calandra*	11.94	2.08	0.93	0.71	4
Yellow wagtail *Motacilla flava*	3.98	8.30	0.93	1.06	-
Curlew *Numenius arquata*	0.00	0.69	0.00	0.00	4
Great tit *Parus major*	5.57*	0.00	0.00	0.00	-
Winchat *Saxicola rubetra*	3.18	4.71	1.86	0.00	4
Stonechat *Saxicola torquata*	4.77	0.00	0.00	0.00	3
Starling *Sturnus vulgaris*	0.00	0.14	3.05*	0.00	-
Redshank *Tringa totanus*	0.00	0.14	0.00	0.00	2
Lapwing *Vanellus vanellus*	0.00	0.83	0.40	0.00	-

* Adults with fledglings.

Abandoned grassland were characterised by high densities of corn buntings, stonechats and red-backed shrikes *Lanius collurio*. These species were observed in trees and bushes used for nesting, singing or as a perch and were practically absent in other grassland types. Skylarks were rarely observed in abandoned grassland while they were common in all other grassland types. Intensively grazed grassland contained a subset of the bird community observed in the extensive grasslands, only skylark and winchat being found in considerable densities. Still, these were 30% and 61% lower respectively than in extensive grassland. None of the common species was observed with highest abundance in intensively grazed grassland. Fertilised grassland had a subset of the species present at intensive grassland and their densities were lower. No winchat was observed.

Discussion

Vineyards

Bird species richness and abundance were highest in extensively used vineyards. The high diversity is probably due to the small scale of these vineyards and the variety of landscape elements. Tree sparrow, black redstart and song thrush were common in extensive vineyards. The first two species often nest in buildings, the last species nests in bushes and shrubs. Species common in forests (blackbird, chaffinch *Fringilla coelebs*) or typical of open landscapes (skylark, stonechat) were also observed here. Thus the heterogeneity of extensively used vineyards allows species from a wide range of ecosystems to co-occur. Habitat heterogeneity is generally considered one of the most important determinants of farmland biodiversity (Isenmann & Debout 2000; Benton *et al.* 2003).

The bird community of abandoned differed from extensive vineyards in subtle ways only. On the less accessible slopes abandonment resulted in a vegetational shift towards shrubland which was reflected by the occurrence of species like the barred warbler and red-backed shrike, typical of wood- and shrublands. On the more accessible slopes abandoned vineyards were regularly used for livestock grazing which may explain the relatively high numbers of skylarks. The virtual absence of tree sparrows and black redstarts was probably due to the absence of sheds and buildings.

Most notable in intensive vineyards was the absence (barred warbler, chaffinch) or low abundance (blackbird, song thrush, yellowhammer *Emberiza citrinella*) of species that were relatively common in extensive vineyards. Intensively used vineyards had a more open character than the other vineyards, due to their large field size. Skylarks probably benefited from this. In general, the removal of hedgerows, fruit trees and shrubs has resulted in a loss of feeding, resting and nesting habitats thus in population declines (Lefranc 1997; Suarez *et al.* 1997; Donald *et al.* 2001; Donald *et al.* 2002).

Grassland

The abundance and species richness of birds in extensive grassland was higher than in intensively grazed and fertilised but lower than in abandoned grassland. Ground nesting birds of open landscapes occurred in extensive grassland exclusively (black-tailed godwit, curlew, redshank) or in high densities (skylark, yellow wagtail). The low grazing intensity of the extensive grassland resulted in low rates of nest loss due to trampling (Beintema & Müskens 1987). Unfertilised, structurally diverse and species rich vegetation such as in the National Park generally reduced the risk of nest discovery by predators (Vickery *et al.* 2001) and supported higher numbers of prey items than improved grasslands (Rushton *et al.* 1989; Vickery *et al.* 2001).

The higher species richness and abundance of abandoned grassland may be explained by their greater heterogeneity and structural diversity and were probably underestimated as they were based on only four observations (Fig. 3.2). Abandoned sites consisted of a mosaic of grasslands and bushes suitable for grassland (yellow wagtail), shrubland (red-backed shrike) and woodland (great tit *Parus major*, greenfinch) species.

On both intensively grazed and fertilised grassland, species richness, abundance and diversity were significantly lower than on extensively grazed grassland. The same set of species that was observed in extensively grazed grassland occurred in intensively grazed and fertilised grassland but the densities were an order of magnitude lower. However, the sample size in fertilised grasslands was considerably smaller (Fig. 3.2). The density of yellow wagtail and winchat declined by 89 and 61% respectively from extensively grazed to intensively grazed grassland. Winchat was not observed on fertilised grassland. In western Europe, skylark, yellow wagtail and winchat all suffered 50-90% declines in population size between 1950 and 2000 (Busche 1994; Hagemeijer *et al.* 1996; Chamberlain & Crick 1999; van ’t Hoff 2002) attributed to land-use intensification (Donald *et al.* 2001; 2002). However, for grassland birds, the main cause of the decline may be habitat deterioration after improved drainage, increased levels of fertiliser applications and increased stocking densities. (Beintema *et al.* 1997; Vickery *et al.* 2001).

Conclusions

The productivity of Hungarian agriculture dropped significantly after the fall of the socialist system. Farmers with 100-300 ha farms do not use anorganic fertilisers and pesticides because they are not profitable (Podmaniczky *et al.* 2000), probably preserved a rich bird community. Farmland birds that have recently suffered serious declines in western Europe are still very abundant even on intensively used Hungarian farmland. The Hungarian shift from extensive to somewhat less extensive already resulted in a significant reduction in bird species richness and abundance.

In western Europe, CAP has increased the level of both intensification and land abandonment in agriculture (e.g. Diáz *et al.* 1997; Pain & Pienkowski 1997; Suárez *et al.* 1997; Chamberlain *et al.* 2000; MacDonald *et al.* 2000; Donald *et al.* 2001,; 2002; Suárez-Seoane *et al.* 2002). The introduction of the CAP is likely to speed up the intensification of Hungarian agriculture and to result in significant areas of farmland being abandoned.

The current study provided one of the first examples that intensification in Central and Eastern European countries results in population declines of farmland birds similar to what has occurred in Western Europe in the past decades (Busche

1994; Hagemeijer *et al.* 1996; Chamberlain & Crick 1999).

Although abandonment of extensive farming systems is believed to have negative consequences in terms of biodiversity (Diáz *et al.* 1997; Suárez *et al.* 1997; MacDonald *et al.* 2000; Suárez-Seoane *et al.* 2002), species richness and abundance in abandoned vineyards and grassland of Hungary were generally not lower. There was a shift however from farmland birds in extensive vineyards and grassland to shrub- and woodland species on abandoned sites. This shift can be expected to progress as vegetation succession continues towards forest ending up in farmland species being replaced by woodland species entirely on abandoned farmland. In terms of biodiversity or species richness, abandonment may not necessarily result in losses, but may have adverse effects similar to intensification on the conservation of rare and threatened birds.

A possible way to counteract the adverse effects of the CAP could be the use of agri-environment schemes. Large numbers of farmers have joined the National Agri-Environmental Program introduced in Hungary in 2002 and farmland birds will benefit most from measures aimed at the conservation of existing extensive farming systems.

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4

SPATIAL DISTRIBUTION OF BREEDING MEADOW BIRDS - IMPLICATIONS FOR CONSERVATION AND RESEARCH

Jort Verhulst, Simone de Brock, Frank Jongbloed, Willem Bil, Wim Tijsen & David Kleijn (2007)
Wader Study Group Bulletin 112: 52–56

Although numerous studies have focused on the (pre-post) nest phase of waders, spatially explicit data of their territory use or foraging range are rare. We quantified spatial habitat use relative to the nest site of eleven adult lapwings *Vanellus vanellus* during the nest phase and of eleven adult redshanks *Tringa totanus* mainly during the chick phase. Both species used areas of about 0.6 hectare; 72 to 80% of the bird observations were done within 60 m from the nest site. Further, we found that in both species, about 50% of the nests were located at what seemed to be the border of the territory. Considering the spatial scale breeding waders' use their habitat, our results suggest that the field scale may be too large a spatial scale for the implementation of beneficial measures such as agri-environment schemes.

Introduction
All over western Europe, populations of farmland birds are in decline (Donald *et al*. 2001, Burfield *et al*. 2005). Since 1975, an ever increasing area of agricultural land in the Netherlands has been designated as meadow bird reserve or managed under agri-environment schemes specifically for the benefit of meadow birds. Despite the fact that in 2006 conservation activities were being implemented on about 150,000 ha (van Brederode & Laporte 2006), the decline of meadow birds has never been more rapid with populations dropping almost 5% per year during 2000-2004 (Teunissen & Soldaat 2006).

One of the main causes of these declines is the uniformity of the landscapes produced by modern farming. It is increasingly being recognized that farmland wildlife requires habitat heterogeneity at different spatial scales (Vickery *et al*. 2001, Benton *et al*. 2003). For example, lapwings *Vanellus vanellus* nesting in arable fields have higher breeding success when nests are near pastures, the preferred foraging habitat of chicks, and within fields broods select those parts with a retarded crop growth (Galbraith 1988). Although numerous studies have focused on the nest and chick phases of waders, spatially explicit data on their territory use or foraging range are rare. Thus, the spatial scale at which heterogeneity needs to be present is largely unknown.

We present results of an exploratory study examining the spatial scale of territory use by two wader species in wet grasslands. We focused on lapwing and redshank *Tringa totanus* which in recent years have both suffered moderate declines in the Netherlands (Teunissen & Soldaat 2006) and more severe declines in surrounding western European countries (Burfield *et al*. 2005). We quantified spatial habitat use relative to the nest site of adult lapwings during the nest phase and of adult redshanks mainly during the chick phase. We examined whether common principles emerged in relation to both species despite their characteristic differences and the fact that they were studied at different stages of the breeding cycle. We discuss the potential implications of the results for conservation management and highlight knowledge gaps relating to spatial habitat use and foraging behaviour of meadow birds during the breeding season.

Methods
Lapwing study

Lapwings were studied during the 2004 breeding season in polder "De Dulf" in the province of Friesland in the north of the Netherlands (Table 4.1). This area, which is managed as a meadow bird reserve, has a vegetation with species characteristic of moderate nutrient-enrichment (e.g. Caltha palustris, Carex sp.). In winter, lower fields are flooded but in spring the water level is reduced. Half the fields are mown in mid June and the rest are grazed with cattle. In some fields, grazing starts during the breeding season. The surrounding polders consist mainly of grassland used for dairy farming and some fields have agri-environment schemes aimed at of meadow birds.

Table 4.1. Characteristics of lapwing and redshank study areas.

	Lapwing	Redshank
Coordinates study area	53°03’N; 6°00’E	52°53’N; 4°55’E
Size study area (ha)	30	25
No. breeding pairs*	25	25
No. colour ringed birds present	21	25
No. colour ringed birds in analyses	11	11
Males	0	4
Females	11	7
Length of study (weeks)	9	10

* in 2004

Since 2000, nest traps have been used during the last ten days of the incubation period to catch and individually colour-mark adult lapwings (rings on both legs, on one a ring with a letter and on the other a ring with a number). Because females tend to return to the nest first after disturbance, hardly any males were caught. Hence, only two ringed males were present and the results for these were omitted from the analysis. Birds were observed from a dyke and a road surrounding the polder. Also, two hides were placed in the centre of the study area to enlarge the area that could be overseen (an overview of the lapwing study area is presented in figure 4.1a). Because rings were difficult to read from the observation points, individuals were followed for two consecutive hours once birds had been identified. During this period a time budget was made of its behavioural activities. Only positions of birds that were spatially (e.g. after flying) or temporally (e.g. after incubating) separated were considered independent observation points and used for the analysis of spatial habitat use. Observations were limited to the incubation period because birds had been generally absent in the pre-breeding stage and a low hatching rate precluded observations in the post-breeding stage.

Redshank study

The redshank study was carried out in the “Westerlanderkoog” in the province of Noord-Holland in the northwest of the Netherlands during the 2004 breeding season (Table 4.1). The Westerlanderkoog is a wet grassland polder with long, narrow fields surrounded by ditches. A large part of the polder is managed as a reserve for wintering geese (mainly Brent Geese *Branta bernicla*) and breeding meadow birds. Fields are not mown before 15 June. Two fields in the central part have postponed mowing (8 & 15 June) under an agri-environment scheme. In early spring, farmyard manure is applied but until mid May, swards are kept short by grazing geese. The vegetation has grass species characteristic of nutrient rich conditions. The Westerlanderkoog is surrounded by a high dyke and a road and both were good for making observations. An overview of the redshank study area is presented in figure 4.1b. Tidal flats of the Wadden Sea are within 1 km of the polder.

Since 2000, redshanks have been caught in the Westerlanderkoog using a nest trap or scoop net and individually colour-marked (single ring with a letter and two numbers). The use of a scoop net is possible because in the last week before hatching redshanks tend to stay on the nests even when people approach. Because both males and females incubate, both sexes have been caught and were used in the analysis. Compared with lapwings, individually marked redshanks were easier to identify because of their longer legs and their habit of sitting on fence poles. However, because of the redshank's later breeding season, the vegetation was taller making it impossible to distinguish between different behaviours once they were on the ground. We therefore aimed at maximizing the number of independent observations per individual redshank. Observations were considered independent if they were separated in time (at least four hours) or in space (at least 100m). During incubation, redshanks present in their territories were very inactive. Moreover, in 2004 a number of the birds were only ringed at the end of the incubation period. Therefore, few redshank observations were made during incubation but many during the chick phase. Spatial use of habitat by redshanks did not differ significantly between the incubation phase and the chick phase (see results), so data for both periods were pooled in the analysis.

Analyses

All observations were charted onto maps and distance from the nest was measured for each individual observation point. Only lapwings observed for more than four hours and redshank with more than ten independent observations were included in the analyses. Observations were grouped into 15 m distance classes with observations of incubating birds being excluded. Patterns in the distribution of observations over the distance classes were analysed using nested ANOVA's (GenStat, Release 7.1, VSN International Ltd, UK) with the factor 'distance class' nested within the factor 'bird' and individual birds were considered replicates. For redshank, we used an unpaired t-test to determine whether the mean distance to the nest differed between observations made in the nest phase and the chick phase. Additionally, we estimated territory size per individual using the minimum convex polygon (Harris *et al*. 1990).

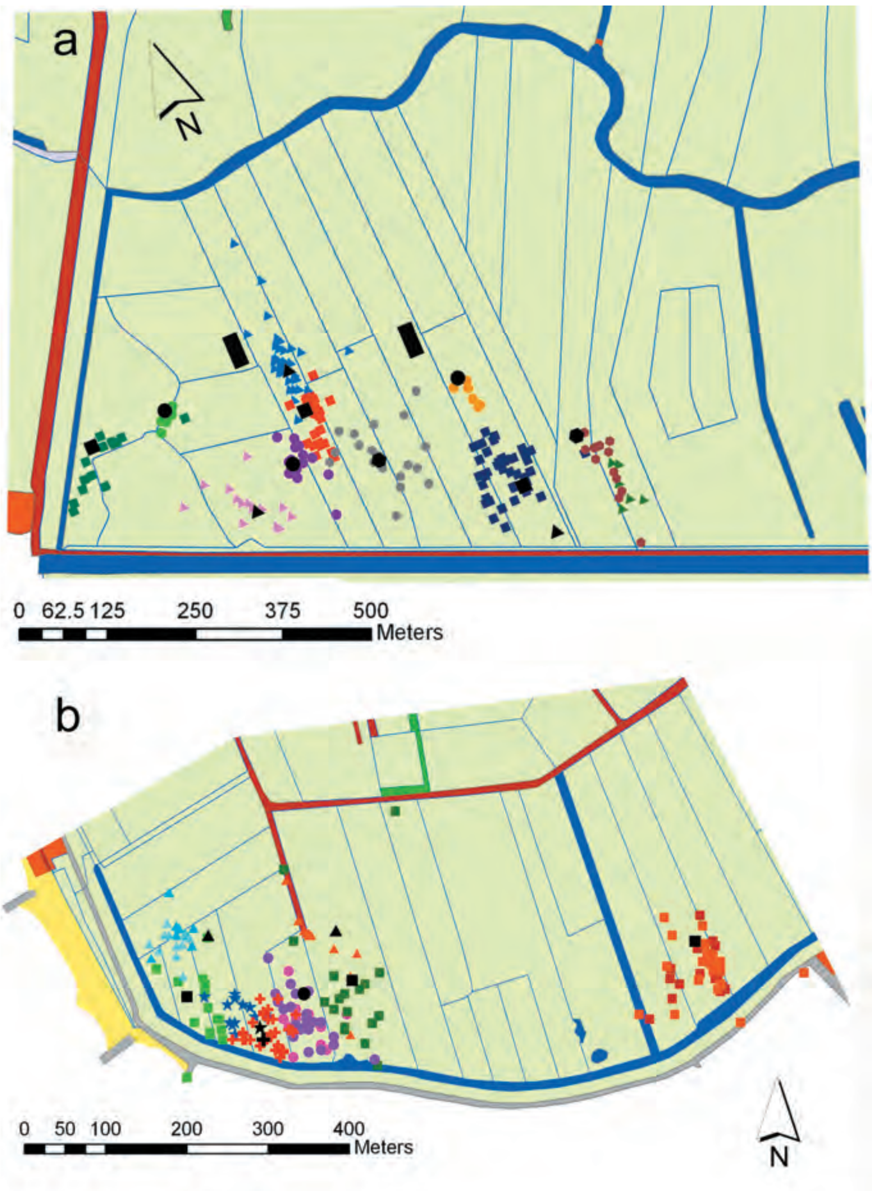

Figure 4.1. Spatial distribution of observations and nests of (a) eleven female lapwings and (b) five individual redshanks and three redshank pairs. Different symbols and colours refer to different individuals. For each individual, the nest site is indicated with the same, larger symbol in black. For redshank, pairs have the same symbol but closely related colours. No distinction has been made between redshanks in the incubation phase and the chick phase. In the lapwing study area, the two black rectangles show the locations to the two observation hides. Background colours represent the following: dark red: roads; dark green: deciduous woodland; light green: meadows; yellow: beach; pale red: buildings; blue: water; grey: dyke.

Results

Lapwing

Eleven females were observed for more than four hours (Table 4.1). In total 38 nests were found, of which 12 were replacement clutches. Eight nests hatched, eight were abandoned, and the remaining 22 nests were probably depredated. Only four broods were observed. Three of them moved to grazed pasture about 200 m from the nest; the fourth female was seen trying to lead her chicks to grazed pasture.

Lapwing females were observed significantly more often within 45m of the nest than further away (Fig. 4.2a) and 72% of observations were within 60m. Birds were incubating during 53% of observation time and feeding during 25%. Birds were out of sight 8% of the time.

Observations of individual lapwings often formed irregular clusters with very skewed distributions relative to their nests Fig. 4.1a. Five of the eleven lapwings observed had their nest sites on the edge of the cluster. Most birds were observed within a relatively small area and the average apparent territory size was only 0.68ha (SE 0.18).

Two colour-marked birds were observed once on conventionally managed agricultural grasslands outside the reserve at 300 and 475m from the nest.

Redshank

Eleven birds (including three pairs) were observed with sufficient frequency to merit analysis of their spatial distribution. During the breeding phase, seven birds were observed 31 times and during the chick phase, eleven birds were observed 187 times. On average, broods were observed for 18.7 days (SE 1.7) and the average time between the last observation in the nesting phase and the first in the chick phase was 6.7 days (SE 1.7).

Redshanks were most often seen 15-60m from the nest or the former nest (Fig. 4.2b); with 84% of observations in this range. Remarkably, the distances to the nest did not differ between the nest and chick phases (nest phase 50.2m, SE 9.1; chick phase 45.8m, SE 3.0; $t_{7.4} = -0.46$, $P = 0.661$).

Redshank observations and nest sites are depicted in Fig. 1b. Even in the chick phase, for which we have most data, most adults stayed very close to the nest site; only one of the eight broods moved as much as 200m from the nest site. Seven nests were found in the south-west part of the area within 200m of each other. Nevertheless, the overlap in spatial distribution of these birds is remarkably low. As for lapwing, four of the eight nests were on or just next to the edge of the cluster of observations. The eleven birds with at least ten independent observations had an average apparent territory size of 0.56ha (SE 0.20).

Three colour-marked redshanks were observed once on the tidal flats of the Wadden Sea >1km from their nests. One of these observations occurred during incubation while the other two were during the chick phase.

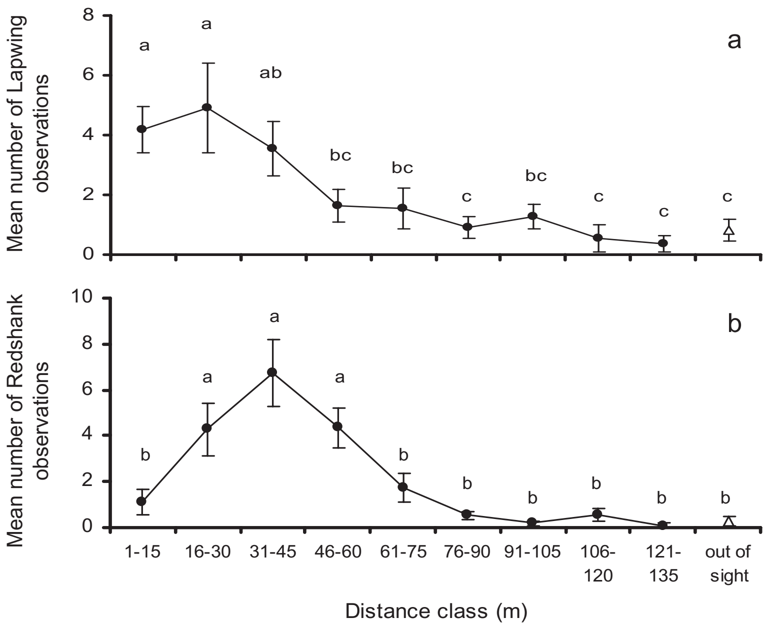

Figure 4.2. Mean number of (a) lapwing and (b) redshank observations at increasing distance from the nest in study areas in the Netherlands during the 2004 breeding season. The letters (a, b, & c) indicate statistically homogenous data groups that are significantly different from each other at the level of α = 0.01 (e.g. there were significantly more observations of lapwings within 30m of the nest (group a) than further than 46m (groups b & c)).

Discussion

Habitat heterogeneity at multiple spatial scales is increasingly being recognized as one of the key-factors determining the success of farmland wildlife (Vickery *et al*. 2001, Benton *et al*. 2003,). Yet, we know hardly anything about the spatial scale with which farmland wildlife perceives the landscape and requires heterogeneity, even for such a relatively well-studied species-group as meadow birds. To our knowledge, this exploratory study is the first spatially-explicit analysis of habitat use by meadow birds. Observations were carried out in just a single year on only two species. Therefore care should be taken in interpreting the results and applying them to other situations. Nevertheless, a number of aspects seem to be significant.

In both species the adults spent most of the time in very small areas of about 0.6ha. For lapwing, this is within the range reported in previous studies (0.3-1.6ha; Berg 1993, Byrkjedal *et al*. 1997, Parish & Coulson 1998). Redshanks do not seem to be territorial during incubation (Hale 1956), but do defend areas of several hectares around their chicks against predators (Hale 1980). 72-80% of our observations of the adults of both species were within 60m of the nest site.

The adult lapwings that were not incubating spent 53% of the time foraging. In this species, prey intake rate is positively correlated with egg-volume (Blomqvist & Johansson 1995) and egg-volume is positively correlated with chick size. Larger chicks have a higher growth rate and survival probability than smaller chicks (Galbraith 1988, Hegyi & Sasvári 1998a). This highlights the importance of the abundance of resources in the immediate vicinity of the nest site.

In this study, redshank broods hardly moved at all over an 18-day period with only one brood dispersing as far as 200m from the nest. The redshank study site was managed specifically for grassland breeding waders and habitat quality was probably uniform in both space and time. This makes extensive moves unnecessary especially since moving broods may decrease chick survival (e.g. Blomqvist & Johansson 1995, Lengyel 2006). Grassland breeding waders are capable of moving considerable distances as illustrated by a pair of redshank traveling 2 km with their one-day-old chicks (Hale 1980). Blomqvist & Johansson (1995) found that lapwing broods moved 9-332m and Schekkerman & Müskens (2000) found a maximum dispersal distance for Black-tailed Godwit *Limosa limosa* broods of 1.6km, but 50% stayed within 250m of the nest. This suggests that broods of meadow birds are also capable of moving over considerable distances, but apparently they tend to stay close to the nest site when conditions are favourable.

In both species, about half the nests were located at what seemed to be the edge of the territory; certainly it was the edge of the area used by the adults. This may have been the result of territorial behaviour by neighbours. Alternatively, preferred foraging sites were not evenly distributed around the nests. We expected nests to be well within the boundary of each territory, and this result may have significant implications for other studies of meadow bird ecology. Many studies aim to explain breeding success by random samples of the environmental characteristics of the immediate vicinity of nests (e.g. Hegyi & Sasvári 1998b, Whittingham *et al*. 2002, Smart *et al*. 2006). Our results suggest that a description of environmental quality at random points around a nest may not correlate with the way that the quality of the habitat is perceived by the birds, because the birds may only use a restricted part of the area.

Implications for conservation management and future research

All our results point towards the importance of the presence of resource-rich patches at a very small scale (within no more than <200m of one another; Fig 4.1). In such conditions, resources will be accessible to both adults and young and chicks will not be forced to move great distances. This should enhance chick survival (Galbraith 1988, Blomqvist & Johansson 1995, Lengyel 2006). Currently, conservation management such as agri-environment schemes is implemented at the field scale. Our results suggest that this may be too large for the creation of the heterogeneity the birds need; especially in areas where fields are large. More attention should be given to intra-field heterogeneity.

Several studies have clearly indicated the importance of territory quality for nest site selection and the breeding success of meadow birds (e.g. Berg 1993, Smart *et al*. 2006). Nevertheless birds may compensate poor territory quality by foraging outside their territory, as observed by Galbraith (1989) and Hegyi & Sasvári (1998b). Hegyi & Sasvári (1998b) found lapwing foraging trips away from nest or chicks generally to be restricted to distances of around 200m. However, occasionally we observed adult lapwing and redshank foraging at high quality feeding areas well over 200m from the nest. Female lapwings might have been foraging outside their territories for at most 8% of the time they were observed. This is close to the 9% reported by Berg (1993). We therefore need to establish the importance of foraging outside the territory, particularly whether this depends on the quality of the territory compared with surrounding areas and whether there are costs associated with these foraging trips, such as an increased risk of predation.

In summary, our results highlight the importance of spatially explicit research. More such studies should be carried out for other farmland bird species or for the same species in other habitats (especially in intensively managed farmland). Insight into these spatially explicit processes is essential for the design of management practices that may further contribute to stable meadow bird populations.

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5

NEST SITE SELECTION OF MEADOW BIRDS IN RELATION TO ENVIRONMENTAL CONDITIONS AND THE PRESENCE OF HETEROSPECIFICS

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Dutch initiatives to preserve farmland breeding wading birds have so far not been able to reverse negative population trends. Effectiveness of these agri-environment schemes might be enhanced if birds could be attracted to fields where specific measures are taken. In this paper we aim to determine how nest site selection of different meadow bird species is influenced by differing environmental conditions and the presence of heterospecifics (i.e. other meadow bird species). We do so by examining the spatial autocorrelation between a range of environmental variables with meadow bird territories in four areas of over 100 ha each. Furthermore, we examine whether territories of the most common meadow bird species are spatially associated at the polder scale, which might either obscure or override the effects of environmental conditions. We found that all combinations consisting of exclusively waders and those consisting of exclusively passerines were significantly positively associated. Of eight wader – passerine combinations, only one was significantly related. Nest sites of black-tailed godwit *Limosa limosa* and redshank *Tringa totanus* were associated with high groundwater levels and those of lapwing *Vanellus vanellus* were marginally negatively associated with soil moisture. Prey abundance was not consistently

associated with either of the wader species. The contrasting preferences for breeding habitat of species that often nest in close association of one another could suggest that the benefits of nesting close to other species outweighs that of selecting optimal habitat in some areas. A second explanation might be that within a breeding cluster, each species must have been able to select its preferred nest site. Nest site preferences of black-tailed godwits, redshanks and lapwings seem to be more closely related to the requirements of chicks than adults. Our results provide additional support for the pivotal role of high groundwater levels in conservation efforts aimed at meadow birds. As raised groundwater levels might increase in-field heterogeneity, other species attracted by high densities of black-tailed godwits and redshanks, are also likely to find suitable habitat in these fields.

Introduction

Similar to the trends in other European countries (BirdLife International 2004), in the Netherlands, meadow birds are declining rapidly, both in range and population size (SOVON Vogelonderzoek Nederland 2002; Teunissen & Soldaat 2006). Agricultural intensification has been identified to be mainly responsible for these declines (Donald *et al.* 2001; Newton 2004). Grassland breeding birds have specifically suffered from increased silage production which replaced hay meadows, increased stocking densities and fertiliser inputs, re-seeding and changes in drainage regimes (Beintema *et al.* 1997; Vickery *et al.* 2001). Because the larger part of populations of important meadow bird species such as black-tailed godwit *Limosa limosa*, lapwing *Vanellus vanellus* and redshank *Tringa totanus* are breeding in agricultural fields, conservation measures on farmland are required to halt the ongoing decline of these species (Beintema *et al.* 1997).

Currently, Dutch meadow bird management is increasingly aimed at the requirements of the black-tailed godwit (e.g. Schekkerman *et al.* 2005), for which the Netherlands have an international responsibility (BirdLife International 2004). These schemes aim to increase clutch survival predominantly through nest protection activities of volunteers and farmers and enhance chick survival through the provision of tall swards in the chick phase (Schekkerman *et al.* 2005, Teunissen *et al.* 2005). Other species are expected to benefit to varying extents from measures developed for the black-tailed godwit. So far meadow bird conservation on Dutch agricultural grasslands has not been very successful for black-tailed godwit or any of the other meadow bird species (Kleijn *et al.* 2001; Schekkerman *et al.* 2005; Verhulst *et al.* 2007b).

In the Netherlands most agricultural areas with high densities of meadow birds are monotonous and consist of uniform wet grasslands. Despite the lack of clear differences to the human eye meadow birds often breed clustered in specific parts of these areas and the location of these clusters may vary with time. The effectiveness of conservation management could be improved if we knew what factors trigger birds to nest on specific sites. Delaying mowing or grazing to facilitate birds to safely hatch their chicks has been found to enhance clutch survival (Beintema & Müskens 1987) but to adversely affect the number of waders nesting on these fields (Kleijn *et al.* 2001). Knowledge of the cues that are used by birds to estimate nest site quality could help to attract meadow birds to sites where measures to enhance nest and chick survival are being implemented.

Meadow birds have a resource defence territorial system (Groen & Hemerik 2002), which implies that nest sites will preferentially be located in resource-rich areas. It is unclear, however, whether meadow birds use resource abundance, or a proximate factor that correlates well with future resource abundance to select their nest sites. Factors that affect settlement densities of meadow birds and that are relatively constant through time are food abundance, penetration resistance of the soil, pH, ground water level and vegetation structure (Green 1988; Milsom *et al*. 2002; Vickery *et al*. 2001; Kleijn & van Zuijlen 2004). Even more of an enigma is whether or how birds selecting a nest site take into account the future habitat quality for their chicks especially when these use different food sources.

A complicating factor is that grassland breeding birds are known to nest in intra- (e.g. Hale 1956; Green *et al.* 1990; Berg *et al.* 1992; Hegyi & Sasvári 1997) and inter-specific colonies (e.g. Hegyi & Sasvári 1997; Valle & Scarton 1999a; Cuervo 2004) in parts of their breeding ranges. In mixed-species colonies, shy wader species benefit from the fierce nest defence demonstrated by more bold species (Dyrcz *et al.* 1981; Beintema *et al.* 1995). For the same reason, passerines are suggested to nest close to lapwings (Eriksson & Gotmark 1982). Nest site choice of one species may therefore be influenced by habitat preferences of a species that starts breeding earlier.

In this paper, we explore what factors may be used by meadow birds to select their nest site. We do this by examining the spatial autocorrelation of a range of environmental variables known to affect meadow birds with meadow bird territories. The environmental variables were sampled just before or at the time of the establishment of the territories in areas of approximately 100 ha. Furthermore, using data from a range of meadow bird inventories carried out in the years 1989-2001 in 24 areas across the Netherlands, we examined whether the territories of the most common species of meadow birds were spatially associated at the polder level. Specific research questions we addressed were (1) what environmental variables are spatially associated with the territories of meadow birds in agricultural wet grasslands, (2) are territories of different meadow bird species spatially associated with one another at the polder scale, (3) can we infer from these associations what cues meadow birds use to select their nest sites in homogeneous agricultural grassland areas.

Methods

Spatial association between territories of different meadow bird species

To examine whether the distribution of territories of different meadow birds is spatially associated, we selected 24 polders where meadow birds had been surveyed. The majority of the polder level surveys were commissioned by the Dutch 'Directie Beheer Landbouwgronden', the organization responsible for the evaluation of the Dutch agri-environment program. All study areas contained only grassland. Some were (partly) managed as a (meadow bird) reserve, others contained parts with agri-environment schemes aimed at meadow birds or with botanical agreements, most were managed by dairy farmers.

Within each polder, a preferentially rectangular area was selected. Borders were located at least 150 meters from disturbing structures like trees, buildings and roads, which are avoided by meadow birds in order to reduce nest predation by avian predators (e.g. Galbraith 1989; Berg 1992; Berg *et al.* 1992; Wallander *et al.* 2006).

Surveys were carried out between 1989 and 2001 using a territory mapping approach (Bibby *et al.* 1992). The approach varied somewhat between studies but in each study, birds were observed during several survey rounds and nests were allocated to the point where the observation most indicative of a territory was done (e.g. singing or displaying male, actual nests; Teunissen & van Kleunen 2000). These points are then considered nest sites in this study. The disadvantage of this approach is that the actual nest site location is unknown. However, nests of grassland breeding passerines and the wader species redshank are notoriously hard to find and thus territory mapping is a more suitable method for estimating meadow bird species density and distribution. The assumed nests sites were depicted on maps of 1:10.000.

For purpose of analysis, fields were subdivided in approximately 1 ha large sub-units which approximates the home-range of breeding waders in Dutch wet grasslands (Verhulst *et al.* 2007a). Sub-units had a grid-point in its centre and nest sites in each sub-unit were allocated to the related grid-point.

Traditional methods of analysis, using the relationship between variance and means of counts, relate only to the numerical properties of the underlying frequency distribution and do not use any additional spatial information (Perry *et al.* 1999). It is recognized increasingly that the location of individuals to one another may be critical for the outcome of ecological interactions Hassell *et al*. (1991). We therefore used the SADIE system (Spatial Analysis by Distance Indices; see Winder *et al.* 2001; Perry & Dixon 2002) to examine whether territories of different bird species were spatially associated. The method works through equating the degree of spatial pattern in an observed arrangement of counts to the minimum effort that the individuals in the population would need to expend to move to a completely regular arrangement in which abundance was equal in each sample unit (Perry *et al.* 1999). Cluster indices are calculated for all sample units where sample units with high values surrounded by other sample units with high values receive strong positive values and are indicative of patches. Similarly low-values surrounded by low values receive strong negative values and are indicative of gaps. Cluster indices of two species may then be correlated, delivering a positive value for spatial association and a negative value for dissociation. For a two-tail test with an overall α of 5%, the probability level should be less than 0.025 for significant association, and greater than 0.975 for significant dissociation. Association values were calculated for all combinations of species in each of the 24 study areas that qualified for the criteria that (1) a species should have at least five nests in an area, (2) the number of nests per species should be more than 5% of the number of grid-points in an area and (3) one species should not have more than three times as many nests as the other species. For each species combination, it was tested whether the mean index of association (X) obtained from all qualifying areas differed significantly from zero (indicating no association) using a t-test.

Nest site selection

To examine whether the territories of meadow birds are spatially associated with environmental factors, we surveyed breeding meadow birds as well as a range of soil variables in four sites of approximately 100 ha each. Two sites, Vijfheerenlanden in the province of Zuid-Holland (N51.56, E5.06) and Eempolders in the province of Utrecht (N52.15, E5.17) were sampled in spring 2003. The two other sites, both located in the extensive polder area Zeevang (henceforth referred to as Zeevang East and Zeevang West) in the province of Noord-Holland (N52.36, E5.01), were sampled in spring 2007. All study sites were dominated by grassland but fields with silage maize were present at the Vijfheerenlanden (10% of the area), Zeevang East (18%) and Zeevang West (7%). Except for the Vijfheerenlanden with alluvial clay soils, all other areas had peat soils. Sites were selected to comprise level and homogeneous open areas with upgoing landscape features only present at the edges and to contain moderate to high numbers of meadow birds. The Vijfheerenlanden study area had groundwater tables II and III, the Eempolders I and II and both areas in Zeevang had groundwater table

II (I – mean annual highest groundwater level < 20 cm and mean annual lowest groundwater level < 50 cm below surface level; II < 40 cm and 50-80 cm; III - < 40 cm and 80-120 cm).

Meadow birds were surveyed using territory mapping (Bibby *et al.* 1992) using observations from five survey rounds between the second half of March and the first half of May. In line with the first study, the 'nest site' was allocated to the site where territorial behaviour was observed

Environmental factors were sampled in March and April in as short a period of time as possible. We overlaid all study areas with a grid of sampling points which were regularly distributed. However, we took care to locate at least one sampling point on each field. Similar to the previous study, large fields were subdivided in larger sub-units of approximately 1 ha. Sampling points always were at least 10 m away from ditches or farm tracks. At each sampling point we measured penetration resistance of the soil, pH, amount of available nitrogen, prey density (earthworms and leatherjackets), soil moisture and groundwater level.

Estimation of soil variables varied slightly between years and study sites but never within study sites. Penetration resistance of the upper 10 cm of the soil was measured using a penetrometer with a 1 cm^2 cone (in 2003 Eijkelkamp, Giesbeek; P1.51-1; in 2007 Eijkelkamp, Giesbeek, penetrometer 06.01.14). In Vijfheerenlanden and Eempolders, prey density at each sampling point was estimated by taking three 10 cm deep samples with a 15 cm diameter soil corer. In Zeevang East and West we took respectively four and two 10 cm deep samples with a 20 cm diameter soil corer at each sampling point. Earthworms and leatherjackets were partly extracted in the field and partly in the laboratory, counted, washed, and dry weight in grams per m^2 was determined after 48 hours at 70 ˚C to give a measure of prey density. Because earthworm numbers and dry weights were strongly correlated and leatherjackets only accounted for a small proportion of prey density (4.7% ± 2.9, mean ± se), we only used the total number of prey items in the analyses. Ten soil samples of the upper 10 cm's were taken with a 3 cm (2003) and 1 cm (2007) diameter soil corer and were mixed to comprise one bulk sample used for analysis of pH (KCl) and available nitrogen (NO_3^- + NH_4^+ in mg per kg dry soil) and soil moisture (percentage of dry soil). In Dutch polders, groundwater level is generally kept at a constant level throughout the growing season. However, individual farmers can lower groundwater levels to variable degrees and fields may differ in height above surface water level. Therefore, we also measured groundwater levels in cm below the surface (delivering negative values) by drilling a hole in the field center until we reached the groundwater and measured the water level four hours later.

Again, we used the program SADIE to examine whether different bird species were spatially associated with environmental factors and with each other. Continuous variables can be analyzed using SADIE if they are multiplied by a constant factor to become integer values (Perry *et al*. 1999). The allocation of bird nest sites to grid points was slightly different from the first study. While incubating their eggs, grassland breeding waders spend most of their time foraging within 100 m from their nest site (Verhulst *et al*. 2007a) and may therefore base nest site choice upon the characteristics of this area. A nest site was therefore allocated to all grid points within 100 m from the nest site. The contribution of a nest site to the count of a grid point was inversely proportional to the distance between nest site and grid point, with the sum of all contributions equaling 100. A single grid point within 100 m from an observed nest site thus received a count of 100, whereas two grid points at 25 and 50 m from the nest site received counts of 67 and 33 respectively. Because grid points often received counts from several nest sites the total count per grid point could vary between 0 and several hundred. If a grid point had missing values for any environmental variable it was omitted from all analyses and could not receive counts from nearby nest sites. The grid points surrounding grid points with missing values thus received proportionally larger contributions.

Similar to the first part of this study, we aimed to prevent that effects of upgoing structures confounded the effects of the soil variables of interest on meadow birds. Therefore, we omitted all sampling points within 150 m from upgoing structures from analysis.

To examine whether the spatial association between two variables were consistent over all four areas, in addition to the statistical tests given by the SADIE system for each area, we tested whether the mean index of association (X) over all four areas differed significantly from zero by means of t-tests. Since these tests are based on only four replicates statistical power is low and results should be interpreted bearing this in mind.

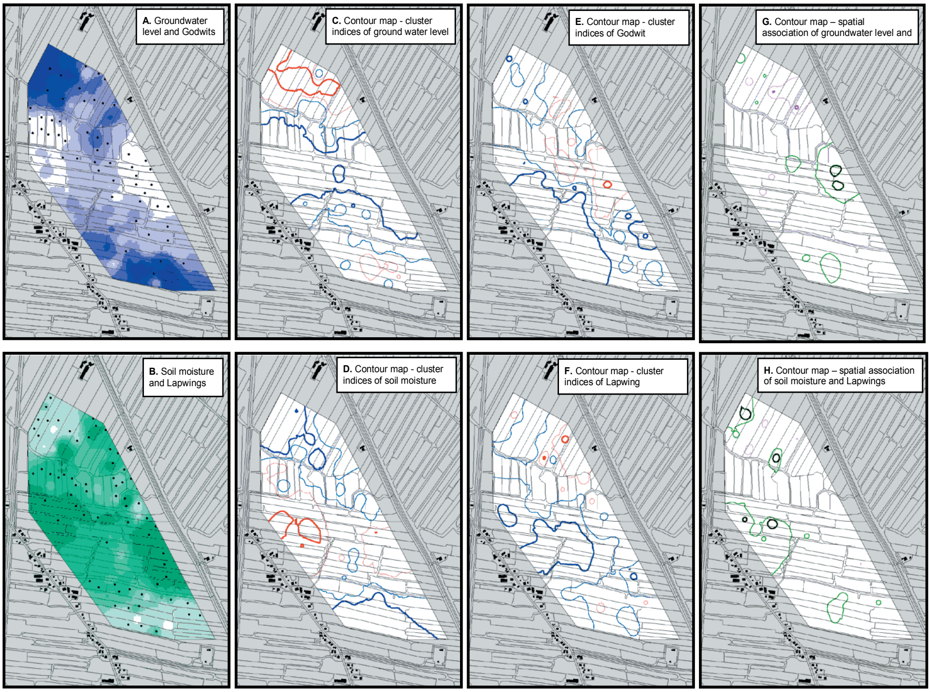

Fig. 5.1. Spatial association between environmental factors measured just prior to the breeding season and meadow bird territories in the study area Zeevang east. (A) Nest sites of black-tailed godwits and interpolated groundwater levels ranging from 11 cm (lightest blue) to 65 cm (darkest blue) below soil surface (B) Nest sites of lapwings and soil moisture ranging from 44 % (lightest green) to 70 % (darkest green) in intervals of c. 3 %. (C-F) Contour maps of the cluster indices (c.i.) of groundwater level, soil moisture, black-tailed godwit and lapwing territories. Areas enclosed by red lines indicate spatial association (light lines, c.i. 1.5-3; solid lines, c.i. > 3;), areas enclosed by blue lines indicate spatial dissociation (light lines, c.i. -1.5--3; solid lines, c.i. < -3;). (G-H) Contour maps of the local association measures (l.s.a.) for black-tailed godwit with groundwater level and for lapwing with soil moisture. Areas enclosed by purple lines indicate spatial association (light lines, l.s.a. 1-2; solid lines, c.i. > 2) areas enclosed by green lines indicate spatial dissociation (light lines, l.s.a. -1--2; solid lines, c.i. < -2;). In panel (G) green areas dominate but not enough to result in significant overall dissociation between black-tailed godwit and groundwater level (X = -0.161, P = 0.905). In panel (H) green areas dominate even stronger resulting in significant overall spatial association (X = -0.246, P = 0.976) indicating that clusters of lapwing territories coincide with patches with low soil moisture. Interpolations and contour maps were created in Arcview 3.2.

Results

Spatial association between territories of different meadow bird species

All species combinations showed positive mean association values, however, not all of these mean values differed significantly from zero (Table 5.1). Sample size (i.e. the number of areas in which spatial association was determined for a particular species combination) ranged from 6 to 24 but did not seem to affect the general outcome considerably (compare the combinations redshank – black-tailed godwit and redshank – skylark). The species combinations with significant positive spatial associations included all wader – wader combinations and the only passerine-passerine combination. In contrast, of the eight wader – passerine combinations only black-tailed godwit and skylark were significantly positively associated. In individual areas species pairs with a significant overall positive spatial association were found to be significantly dissociated or, more often, not associated (Table 5.1), suggesting that in certain areas nest site preferences of these species do not overlap or that the potential benefits of nesting in close proximity of each other are less pronounced.

Table 5.1. Number of study areas that met the selection criteria, number of study areas with either significantly positive or negative associations, mean of all association values per study area (X) and t-values for all species' combinations. T-tests were carried out on the association (X) value for each study area and t-values show whether X-values differ significantly from zero. * *P < 0.05*; ** *P < 0.01*; *** *P < 0.001*.

Species combination	n (study areas)	number of positive associations	number of negative associations	X	t-value
Lapwing – Black-tailed godwit	24	13	0	0.29	8.79 ***
Lapwing - Skylark	17	2	0	0.06	1.55
Redshank - Oystercatcher	14	6	0	0.25	5.36 ***
Skylark - Meadow pipit	14	5	0	0.18	3.13 **
Lapwing - Redshank	13	5	1	0.23	5.39 ***
Lapwing - Oystercatcher	13	10	0	0.31	4.98 ***
Black-tailed godwit - Skylark	13	7	0	0.19	3.30 **
Redshank - Skylark	13	5	1	0.14	1.95
Oystercatcher - Skylark	13	4	1	0.07	0.97
Lapwing – Meadow pipit	11	2	1	0.05	0.75
Black-tailed godwit - Redshank	11	5	1	0.21	3.46 **
Black-tailed godwit - Oystercatcher	11	4	1	0.18	3.01 *
Redshank - Meadow pipit	10	3	1	0.10	1.57
Oystercatcher – Meadow pipit	10	3	0	0.06	0.93
Black-tailed godwit – Meadow pipit	6	2	0	0.11	1.12

Environmental variables associated with nest site selection

The number of meadow bird territories differed substantially between the study areas (Table 5.2, 5.3). The Zeevang East had high numbers (152 pairs), Zeevang West and Vijfheerenlanden (88 and 59 pairs) were intermediate and the Eempolders (19 pairs) contained very low numbers. In the Eempolders, only lapwing occurred in densities high enough to allow the species to be analysed. Of the passerines, only meadow pipit was found in sufficient numbers for analysis in the Eempolders (6 territories) and therefore passerines were not considered any further for the purpose of this study. Similar to the breeding densities of meadow birds, environmental factors also differed considerably between areas (Table 5.2). In the Vijfheerenlanden and the Eempolders, groundwater level, soil moisture and available nitrogen were lower than in Zeevang East and Zeevang West. In part, this may be due to annual variation in rainfall with February and March being very dry in 2003 (total of 44 mm) and wet in 2007 (147 mm; long-term average for this period 112 mm, KNMI 2007). Prey abundance was high in Zeevang West and in the Vijfheerenlanden, and low in the Eempolders.

Few spatial associations between wader species and environmental variables were consistent between areas (Table 5.2). Notable exceptions were the consistent spatial dissociations between black-tailed godwit and redshank with groundwater level suggesting that clusters of territories are located in patches with high groundwater levels (Fig. 5.1). Despite the low power of the test, the measure of spatial association averaged over all areas was significant different from zero. Lapwing tended to be negatively associated with soil moisture (difference mean X and zero marginally significant; t_3=-2.81, P = 0.067, Fig. 5.1). In all four study areas this relation was negative, significantly so in two of them (the two with the higher average soil moisture). Oystercatcher did not seem to be consistently associated with any of the environmental factors, the only significant (negative) association that was observed being that with soil moisture in Zeevang West.

Although the other environmental variables were all significantly associated with at least one wader species in at least one area, associations were generally not consistent between areas. For example, lapwing nest sites were significantly negatively associated with prey abundance in two regions but significantly positively associated with prey abundance in one of the other regions.

Lapwing and oystercatcher prefer to nest on bare soil (Briggs 1984; Galbraith 1988) and although maize fields occupied relatively small proportions in the study areas this preference could have affected the observed association patterns. Comparison of the settlement densities on maize and grass gave 57 and 91 nest sites per 100 ha for lapwing and 15 and 18 nest sites per 100 ha for oystercatcher on grass and maize fields respectively. These differences were not significant ($F_{1,2}$ = 2.70; P = 0.242 and $F_{1,2}$ = 0.05; P = 0.844 for lapwing and oystercatcher respectively) but the power of this test was low (n=3). Black-tailed godwit and redshank had a pronounced preference for grass (black-tailed godwit 55 vs. 7 nest sites per 100 ha, $F_{1,2}$ = 54.33; P = 0.018; redshank 16 vs. 0, $F_{1,2}$ = 18.14; P = 0.050).

Table 5.2. Indices of spatial association (X) between territories of meadow birds and soil variables. Positive values indicate spatial association, negative values spatial dissociation and values around 0 indicate absence of association. Units: groundwater level in cm below surface, soil moisture in %, penetration resistance in N per cm2, prey abundance in numbers per cm2 and available N in mg per kg dry soil. Numbers in brackets behind species names give the number of territories. Two-sided t-tests were used to test whether means of all areas differed significantly from zero (n=3 or 4). * P<0.05, ** P < 0.01, *** P < 0.001

Vijfheerenlanden (n = 60)	mean	Lapwing (29)	Godwit (18)	Oystercatcher (6)	Redshank (6)
Groundwater level	66.9	0.076	-0.273	-0.032	-0.424*
Soil moisture	37.0	-0.104	0.141	-0.041	-0.059
Penetration resistance	128	0.203	-0.056	0.005	-0.346*
Prey abundance	373	0.120	-0.022	0.127	-0.021
pH	5.3	0.133	0.073	-0.183	0.304*
Available N	86.84	0.129	-0.060	-0.085	-0.538**
Eempolders (n = 108)		Lapwing (11)	Godwit (3)	Oystercatcher (2)	Redshank (3)
Groundwater level	69.3	0.446**			
Soil moisture	30.4	-0.049			
Penetration resistance	122	-0.270**			
Prey abundance	176	-0.229*			
pH	5.2	-0.113			
Available N	70.5	0.023			
Zeevang East (n = 78)		Lapwing (69)	Godwit (54)	Oystercatcher (14)	Redshank (15)
Groundwater level	24.5	0.199	-0.161	0.015	-0.199
Soil moisture	58.3	-0.246*	0.102	0.149	0.109
Penetration resistance	100	-0.028	-0.105	-0.056	-0.044
Prey abundance	251	0.303*	0.135	0.178	0.192
pH	5.1	-0.026	0.038	0.271	0.140
Available N	3.76	-0.211	-0.008	-0.099	0.045
Zeevang West (n = 80)		Lapwing (39)	Godwit (26)	Oystercatcher (12)	Redshank (11)
Groundwater level	22.0	-0.125	-0.374***	-0.230	-0.306**
Soil moisture	55.8	-0.335**	-0.318*	-0.297*	-0.238*
Penetration resistance	77	0.121	0.128	-0.149	0.376
Prey abundance	376	-0.234*	-0.055	-0.096	-0.035
pH	4.9	0.058	0.194	0.065	0.020
Available N	3.94	0.266*	0.304**	0.195	0.446
Mean of all areas		Lapwing	Godwit	Oystercatcher	Redshank
Groundwater level		0.149	-0.269*	-0.082	-0.309*
Soil moisture		-0.183(*)	-0.025	-0.063	-0.063
Penetration resistance		0.006	-0.011	-0.067	-0.005
Prey abundance		-0.010	0.019	0.070	0.045
pH		0.013	0.101	0.051	0.155
Available N		0.052	0.079	0.003	-0.016

On average, the measures for spatial association were positive for all wader species combinations, confirming the findings of the first part of this study (Table 5.3). The combinations redshank-black-tailed godwit and redshank-oystercatcher were marginally significant ($t_2 = 3.96$, $P = 0.058$ and $t_2 = 3.01$, $P = 0.095$ respectively). The combination lapwing – black-tailed godwit had the highest overall index of spatial association but the higher variation resulted in the mean not being statistically significantly different from zero ($t_2 = 2.90$, $P = 0.101$).

Table 5.3. Indices of spatial association (X) between territories of meadow birds and soil variables. Positive values indicate spatial association, negative values spatial dissociation and values around 0 indicate lack of association. Units: groundwater level in cm below surface, soil moisture in %, penetration resistance in N per cm2, prey abundance in numbers per cm2 and available N in mg per kg dry soil. Two-sided t-tests were used to test whether means of all areas differed significantly from zero (n=3). Numbers in brackets behind species names give the number of territories. * P<0.05, ** P < 0.01, *** P < 0.001.

Vijfheerenlanden (70 ha)	Godwit	Oystercatcher	Redshank (6)
Lapwing (29)	0.251	-0.107	-0.014
Godwit (18)		0.009	0.201
Oystercatcher (6)			0.126
Redshank (6)			
Zeevang East (81 ha)	Godwit	Oystercatcher	Redshank (15)
Lapwing (69)	0.316*	0.243*	0.266
Godwit (54)		0.447***	0.498***
Oystercatcher (14)			0.344**
Zeevang West (73 ha)	Godwit	Oystercatcher	Redshank (11)
Lapwing (39)	0.726***	0.415**	0.344**
Godwit (26)		0.519**	0.516**
Oystercatcher (12)			0.152
Mean of three areas	Godwit	Oystercatcher	Redshank
Lapwing	0.431	0.184	0.155
Godwit		0.325	0.405(*)
Oystercatcher			0.207(*)

Discussion

This study uses a method of analysis that has little been used in bird studies and that uses the spatial data of the distribution of both birds and environmental conditions optimally. It demonstrates that nest sites of black-tailed godwit and redshank were primarily clustered in patches characterized by high groundwater levels in the pre-laying period. Nest sites of lapwings on the other hand were negatively associated with patches of high soil moisture. Prey density and penetration resistance of the soil were not found to be consistently associated with nest sites. Nest sites of species of the same functional groups of meadow birds were furthermore generally clustered in the same areas, waders with waders, passerines with passerines but not waders with passerines.

Are territories of different meadow bird species spatially associated with one another?

All wader species were significantly spatially associated in the intensively used agricultural meadows (Table 5.1), despite the fact that some species combinations were significantly associated in less than half of the studied polders. Oystercatcher and lapwing were significantly associated in ten out of thirteen studied polders, which might have been caused by their joint preference for sparsely vegetated fields (Cramp & Simmons 1983). Next to an overlap in habitat preferences, the positive associations between waders were likely caused by an improved anti-predator response when nesting with more species (e.g. Goransson *et al.* 1975). Different species differ in the effectiveness in excluding predators and therefore mixed-species colonies might be more effective than single-species ones (Dyrcz *et al.* 1981; Green *et al.* 1990; Hegyi & Sasvári 1997; Valle & Scarton 1999b). As these meadow bird clusters can consist of several fields, all species were apparently able to select suitable sites close to other wader species within a cluster of nesting waders.

Surprisingly, the nest sites of passerines were not found to associate with waders (with the exception of skylark - black-tailed godwit). Eriksson & Gotmark (1982) found a tendency for higher densities of breeding yellow wagtail *Motacilla flava* and meadow pipits within lapwing territories. They suggested that the passerines use the lapwings' anti-predator behaviour as a cue in nest site selection but they could not rule out that associations were based on similar habitat preferences. However, we found few relations between shy passerines and bold waders. The only association we found for meadow pipit is that with skylark. This association therefore is most likely the result of a similarity in habitat preferences.

Nest site selection influenced by environmental variables

Although all environmental factors were found to be significantly spatially associated with one of the meadow bird species in at least one area, few relations were consistent over the different study sites and few were significant when focussing at the overall effects. The distribution of nest sites of both black-tailed godwit and redshank was significantly dissociated with groundwater level (Table 5.2). Even though large differences existed in groundwater levels between the three study areas, both species apparently selected those areas where the groundwater level was closest to the surface. This result confirms previous findings (e.g. Milsom *et al.* 2000; Kleijn & van Zuijlen 2004; Verhulst *et al.* 2007b). Surprisingly, these species did not show a positive relation with soil moisture. Although soil moisture is generally thought to be related to groundwater level (e.g. Milsom *et al.* 2002), they seemed unrelated in our study areas. As different areas had approximately corresponding groundwater levels, differences in drainage, soil compaction or soil type might have been of greater influence in determining soil moisture.

Most interesting is our finding that none of the wader species was consistently spatially associated with prey density over the four study areas. This agrees with findings of Galbraith (1989) and Baines (1990) who similarly found no relationship between lapwing nest sites and soil prey availability. In a growing black-tailed godwit population, Struwe-Juhl (1995a) found the maximum density of earthworms to be 216 individuals per m2. In the current study in areas with declining black-tailed godwit populations the *average* density of earthworms ranged between 176 and 376 per m^2, suggesting that prey density was probably not limiting. The contrasting associations between lapwing and prey density in different areas may have been the result of prey density interacting with other environmental conditions that did affect the distribution of lapwing nests. Further support for the overriding importance of groundwater level over prey density for black-tailed godwits comes from Struwe-Juhl (1995a) who found that black-tailed godwits preferred to nest in very wet areas that, because of long-term flooding in winter, contained hardly any earthworms. Accordingly, in several studies waders were observed to move regularly outside their breeding territory to forage in areas with higher densities of earthworms just prior to and during incubation (Galbraith 1989; Struwe-Juhl 1995a). Apparently, nest site selection is not necessarily based upon density of prey for adults. Rather, other factors such as high groundwater levels, soil moisture or availability of arthropods seem to override their preference for sites with high earthworm densities (Baines 1990; Struwe-Juhl 1995a).

Breeding lapwings were associated with the dryer fields, as indicated by the marginally negative relation between lapwing and soil moisture. This relation is in agreement with Verhulst *et al.* (2007b) who find foraging lapwings (and oystercatchers) to select sites with a lower soil moisture. Consequently, lapwings might have responded negatively to high groundwater levels as the overall association value was high although not significant.

The pH was consistently positively associated with nesting sites of black-tailed godwit and redshank but the association was significant only for redshank in the Vijfheerenlanden, the area with the highest mean pH (5.3). Low pH (<4.0-4.5) is known to constrain the abundance of earthworms (Standen 1984) and may therefore affect nest site selection of meadow birds indirectly. Because pH is less variable in time and less dependant on climatic conditions it might be a

better predictor of earthworm abundance than prey density itself. However, pH was generally not in the range known to adversely affect earthworm numbers (the site with the lowest pH (Zeevang West; 4.9) had the highest abundance of earthworms) and, as indicated before, prey density was probably not limiting in our study areas.
Penetration resistance higher than 125N/cm2 makes the habitat unsuitable for probing by godwits (Ekschmitt 1991 in Struwe-Juhl 1995a). It is unknown whether this threshold value also applies in our sites. Both in Vijfheerenlanden and Eempolders we found values in the range of this threshold. In Eempolders, the virtual absence of black-tailed godwits might have been caused by low penetration values. Lapwings prey upon surface active arthropods as well as soil inhabiting invertebrates and might have shifted to alternative prey here (e.g. Baines 1990). In Vijfheerenlanden, we did find many black-tailed godwits while the penetration resistance was high. However, the prey density was over twice as high as in Eempolders, and black-tailed godwits might have been able to attain sufficient amounts of prey. At the two sites in Zeevang, penetration resistance was lower than the threshold value, which suggests that at the time of investigation prior to the breeding season, the effort needed to probe was probably not a constraint. However, penetration resistance may change rapidly over time with the amount of rainfall (Green 1988).

Implications for management and conservation
We find more territories of both black-tailed godwits and redshanks at sites with high groundwater levels rather than sites with high prey densities. Such sites - with high groundwater levels and low earthworm biomass - have been observed to be good chick rearing habitats (Struwe-Juhl 1995a). Low chick survival is nowadays thought to be the main cause of population declines in many meadow breeding waders (Belting & Belting 1999; Schekkerman & Müskens 2000; Schekkerman *et al.* 2005). Therefore, the creation of suitable chick rearing habitats should be (and partly is) the main focus in meadow bird schemes. Until now, this has been aimed to be achieved by simply postponing mowing until a set date in May or June (Beintema & Müskens 1987) but this measure alone might not be sufficiently effective (e.g. Schekkerman *et al.* 2005). We suggest the postponed mowing scheme should be implemented on fields where in addition groundwater levels are raised and fertilizer applications lowered. These measures will likely attract breeding black-tailed godwits and redshanks and will provide open, structure-rich swards with sufficient prey items for chicks (Belting & Belting 1999, Struwe-Juhl 1995b). Drastic measures that involve raises of groundwater levels are currently implemented in other European countries and have been able to reverse negative population trends (Ausden & Hirons 2002; Kahlert *et al.* 2007; Wilson *et al.* 2007).

Despite partly contradicting preferences for nest sites - lapwings showed a marginally negative preference for soil moisture - lapwings and oystercatchers were observed to nest in close association with both black-tailed godwits and redshanks. Such a contradiction was also found by Verhulst *et al*. (2007b) who found more wader territories in the wetter fields but observe fewer lapwings on those fields. Species probably make a trade-off between selecting the optimal habitat and then nesting solitary or in conspecific colonies on the one hand (as found by Hegyi & Sasvári 1997) and nesting close to another wader species on the other hand. Apparently, sometimes the latter turns out to be decisive. Further, each species might have been able to select nest sites that met their specific criteria within a breeding cluster (or gap) that usually consisted of several adjacent fields (Fig. 5.1). This highlights the importance of in-field heterogeneity in groundwater level and soil moisture, and the threat of reseeding and other sorts of agricultural improvements to meadow breeding waders. In-field heterogeneity has also been suggested to be beneficial for farmland breeding passerines (e.g. Bradbury & Bradter 2004; Wilson *et al.* 2005). Raising groundwater levels and re-wetting in-field gullies might be effective ways of increasing small-scale heterogeneity and therefore likely to benefit a wide range of meadow birds.

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6

SPATIAL DISTRIBUTION OF MEADOW BIRDS TROUGHOUT THE BREEDING SEASON
- RELATIONS TO HETEROGENEITY AND MANAGEMENT

Jort Verhulst, Willem Loonen, David Kleijn & Frank Berendse

Effectiveness of European initiatives to restore populations of meadow breeding wading birds is heavily debated. Suggested causes for disappointing results are changes in water levels and increased sward uniformity. Therefore, we studied field preference of meadow birds throughout the breeding season in four areas of over 100 ha each and related observed patterns of individual birds to field characteristics (sward heterogeneity, sward height and management). We found considerable differences in heterogeneity and management between study areas and also in density of waders. Over the four areas, black-tailed godwit *Limosa limosa*, lapwing *Vanellus vanellus* and redshank *Tringa totanus* reached their highest densities on the most heterogeneous fields at the period of nest site selection. At the incubation stage, all of the four considered wader species (including oystercatcher *Haematopus ostralegus*) were observed in the highest densities on the more heterogeneous fields. Additionally, we found that fields grazed with 'low' cattle densities for longer consecutive periods, generally overlooked in Dutch wader studies, were of high importance for lapwings but also for black-tailed godwits. The densities of black-tailed godwits and lapwings were strongly negatively correlated with the percentages of the study areas being grazed and mowed. However, densities also severely declined throughout the season and therefore we were unable to determine which part of the declines were indeed caused by management (mowing or grazing). Corresponding with large declines in bird densities, we observed only few alarming birds. Black-tailed godwit families did not move towards unmanaged fields (with tall swards) as expected but seemed to be attracted to heterogeneous fields. Lapwing families were observed to avoid unmanaged fields but did not avoid nor prefer heterogeneous fields.. Our results indeed show that in-field heterogeneity is of key importance for meadow breeding waders. Fields with prolonged grazing with relatively low stocking densities were generally heterogeneous and harbour high densities of waders. We therefore suggest that initiatives aimed at meadow breeding waders should incorporate field heterogeneity and that prolonged grazing regimes might be one way to do so.

Introduction

Agricultural intensification over the last 50 years has resulted in substantial changes in farming practices (e.g. Donald *et al*. 2002). For wet grasslands in Europe, this meant increases in stocking levels and fertiliser applications and the frequent re-seeding of the fields (e.g. Beintema *et al*. 1997). Improvements in field drainage allowed farmers to earlier access their fields in spring and thus to advance their activities (Beintema *et al*. 1985) and to replace hay crops with silage crops (Vickery *et al*. 2001). At the field scale, these factors greatly reduced variation in micro-topographical features of grasslands and resulted in more homogeneous and denser swards (Vickery *et al*. 2001; Wilson *et al*. 2005). However, agricultural intensification also reduced farmland heterogeneity at the larger spatial scales (Benton *et al*. 2003). These changes in agricultural practices and reductions in farmland heterogeneity coincided with large declines in European farmland bird populations (e.g. Siriwardena *et al*. 1998; Donald *et al*. 2001). Similarly, grassland breeding wading birds have experienced considerable declines over the last decades (e.g. BirdLife International 2004).

In the Netherlands, agri-environment schemes were designed to halt declines in meadow breeding waders. The Netherlands have an international responsibility for this species group as the country harbours over 40% and 30% of the European breeding populations of black-tailed godwits *Limosa limosa* and oystercatchers *Haematopus ostralegus* (BirdLife International 2004). The key tool was and is to postpone mowing or grazing of grassland to allow birds to safely hatch their eggs (Beintema & Müskens 1987). Additionally, Schekkerman & Müskens (2000) and Schekkerman & Beintema (2007) found black-tailed godwit families to select fields with tall swards. Fields with this scheme however do not have higher settlement densities of waders (e.g. Kleijn *et al*. 2001) and neither did additional schemes implemented at larger scales by individual farmers that were part of agri-environment collectives (Verhulst *et al*. 2007). The most recent initiative designed to maintain especially the black-tailed godwit populations on farmland, the so-called 'mosaic management' aims to provide at least 1 ha with tall swards for food and shelter per black-tailed godwit family and to create a spatial mixture of differently managed fields at the polder scale (200 – 400 ha). However, in a large scale pilot, the breeding success of black-tailed godwits was found not to differ from control areas without these measures and reproductive success was insufficient to maintain stable populations (Schekkerman *et al*. 2005). Consequently, despite the fact that over 15% of all Dutch grassland is managed under some sort of meadow bird scheme, meadow birds are still declining rapidly both in range and in population size (SOVON Vogelonderzoek Nederland 2002; Teunissen & Soldaat 2006).

Kleijn *et al*. (2004) hypothesize that the reductions in farming intensity on postponed mowing scheme fields are not sufficient to deliver benefits to breeding waders. Nearly all fields have been agriculturally improved and temporal reductions in fertiliser inputs stimulated by agri-environment schemes may not deliver the desired heterogeneity in sward structure or micro-topographical features. Schekkerman *et al*. (2005) suggest that the poor variation in vegetation structure of (late mowed) grassland might be responsible for the observed low reproductive success of black-tailed godwits. Preferences of different species of farmland breeding waders concerning sward structure have been determined in several studies but most of these studies were carried out in natural habitats (coastal marshes) or mixed farmland and few have done so in intensively farmed wet meadows (e.g. Galbraith 1989; Berg 1992; Norris *et al*. 1997; Johansson 2001, but see Schekkerman *et al*. 1998).

We present results of a large scale study exploring the effects of field characteristics on meadow breeding wading birds in the Netherlands. We mapped the position of black-tailed godwits, lapwings *Vanellus vanellus*, redshanks *Tringa totanus* and oystercatchers twice per week throughout the breeding season in three intensively farmed areas and one somewhat less intensively farmed area of over 100 ha each. Considered field characteristics were management type, sward height and sward heterogeneity. Each study area had fields that differed in heterogeneity, ranging from uniform fields that were recently reseeded to fields that contained many topographical features such as molehills, flowering forbs or areas with retarded grass growth. We determined the field preference of meadow birds in two periods of the breeding season, 1) in the pre-laying period and 2) in the period when most birds were incubating. Further, we explored whether we could detect a relation between the area of unmanaged fields and the densities of meadow birds. Finally, we determined whether black-tailed godwits and lapwings with chicks were attracted to unmanaged (thus with tall swards) or heterogeneous fields.

Methods

Study areas

In 2005, we surveyed meadow breeding waders in four areas in the Eempolders (N52.15, E5.19) in the centre of the Netherlands. Each study area covered over 100 ha. To make sure that at least some fields with tall swards were present during the entire breeding season, we selected sites that contained several fields under the postponed mowing scheme. Three of the four areas were very similar in agricultural management (conventional intensive dairy farming), soil type (peat) and consequently parcellation (typical long and narrow fields). These areas will be referred to as 'conventionally farmed areas'. The fourth area was a small triangularly shaped polder enclosed by a highway, a dyke and the 'Eemmeer', a large lake. Farming had a divergent character. The study area was bordered by a riding stable and a number of fields was grazed by horses. Other fields were grazed with beef cattle and dairy cattle were absent. The soil type was sea clay and fields missed the typical narrow and long shape of Dutch wet meadows on peat soils. This area will be referred to as 'hobby farming area'.

Surveys

From the end of March until mid June, we mapped the position of the four meadow breeding waders several times per week. We recorded the behaviour of the birds (e.g. foraging, sleeping, displaying, breeding) from roads intersecting the study areas using telescopes and binoculairs. As the breeding season proceeded, we paid special attention to behaviour indicative of the presence of offspring (alarming, pursuing predators, etc.). Flocks of black-tailed godwits and lapwings that occurred from mid May onwards were excluded from analyses. Usually, a study area was mapped twice per day but at the end of the breeding season we were able to complete three surveys per day because of the low number of birds. On average, each area was mapped 54 times on 26 days divided over the breeding season.

On each survey day, we estimated sward height of each field (in cm's) and recorded the management (e.g. no management, grazing or mowing). Sward height was classified into 5 cm classes: 0-5, 6-10, 11-15, 16-20, 21-25, >25 cm. For management, we distinguished between management types in the period itself and in the previous period (referred to as e.g. recently mowed); types of management that took place prior to the previous period were classified as "regrown". Fields were classified as "intensive grazing" when they were subjected to high densities of cattle for a short time (e.g. 80 cows on a field of two hectares for two successive days) or "prolonged grazing" when they had lower densities (but still quite high) of cattle for a longer period (e.g. ten cows on a field of two hectares for twenty successive days). Fields grazed by horses and sheep were classified as "intensively grazed", similarly to those grazed by high densities of cattle.

Additionally, we visually estimated sward heterogeneity four times during the breeding season (end of March, mid April, mid May and beginning of June). Heterogeneity was classified as follows: class I – very heterogeneous; large diversity in sward height over the field, containing inundated patches, tussocks or many (flowering) forbs (such as *Ranunculus*, *Rumex* or *Taraxacum* spp.), class V – very homogenous; recently reseeded, swards generally consisting of *Lolium perenne* monocultures, no flowering forbs present.

Prior to analyses, we divided the breeding season in seven ten-day periods. For each of these periods, we determined the dominant management type and sward height class for each field. Sward heterogeneity classes were also assigned to each period. In the periods sward heterogeneity had not been estimated, we took the values of the date closest to these periods. All meadow bird observations were entered into ArcView 3.2 (Esri, Redlands, USA). Field characteristics were also entered for each ten-day period. Subsequently, bird observations were linked to field characteristics using ArcGIS 9.2 (Esri, Redlands, USA).

Analyses

To determine whether meadow birds showed preferences for fields with specific characteristics we used log-linear models employing the Poisson distribution (McCullagh & Nelder 1989) followed by a likelihood ratio test (or *G*-test; Payne et al. 2002). Models included the random factors study area and field surface and the fixed factors, management type, sward heterogeneity and sward height as explanatory variables and the number of observed birds (per ten-day period per field) as a response variable. Analyses were carried out for each of the four wader species for the first period (25 March–10 April) when most birds were selecting nest sites and for the third period (21–30 April) when most birds were incubating but few chicks were present. Management and heterogeneity categories present on less than five fields over all study areas were omitted from analyses. After these periods, birds were observed to be less territorial, and therefore their distribution became more dependent of good foraging sites for adults; of less interest for our study. When necessary, overdispersion was accounted for by inflating the variance of the Poisson distribution with a constant factor. In this case the deviance ratio, following an approximate *F*-distribution, was used as the test statistic.

The proportion of the area that is covered by unmanaged tall swards is currently considered a key factor constraining chick survival and reproduction of black-tailed godwits in Dutch agricultural grasslands. Because unsuccessful godwit pairs rapidly leave the area, the proportion of unmanaged swards may be correlated with the trend in godwit numbers. Because other factors such as predation may affect reproductive success independent from management which will also result in declining bird numbers with time, we had to account for time effects. We therefore tested whether the proportion of unmanaged grassland explained any additional variation in the dataset after the trend in time had been accounted for. Because a significant interaction was found between the effects of the proportion of unmanaged fields and study area we examined this for each area separately using a General Linear Model with observation day and the arcsine of the percentage unmanaged fields as the explanatory variables.

We used ArcInfo (Esri, Redlands, USA) to determine whether black-tailed godwit and lapwing families selected fields with specific qualities in the periods after mowing, that is from May 11th onwards. Redshank and oystercatcher families were not considered because we observed too few. We determined the distance of all birds and that of birds likely to have chicks (alarming birds and those with chicks; henceforth referred to as alarming birds) to the nearest unmanaged field or field with heterogeneity classes I, II or III for the periods 11 - 20 May, 21 - 31 May and 1 - 15 June. As a control, we calculated the distance of all black-tailed godwits and lapwings in the periods before May 11th relative to the distribution of unmanaged or heterogeneous fields in the selected period after May 11th. For each area, this yielded an average distance to a particular type of field of (1) all observed birds prior to mowing (2) all observed birds after mowing and (3) alarming birds after mowing. Both after-mowing distances were subsequently divided by the average distance of all birds previous to mowing to obtain a proportional distance. A value lower than 1 indicates that birds had concentrated on or around these fields in the periods after mowing relative to the periods before mowing, a value higher than 1 indicates that birds had generally moved away whereas a value of around one indicates no change in distribution. The proportional distances from each of the four study areas were plotted against the proportion of the fields with specific qualities in the periods after mowing. When birds would be distributed randomly over the study areas, the proportional distance to unmanaged or heterogeneous fields would increase with a decrease in the proportion of the study area covered by these fields. Spearman's correlations were used to test the significance of the emerging relations.

Results

Characteristics of the study areas

Throughout the breeding season, the proportion of the study sites that was grazed (both in high – intensive grazing – and in lower – prolonged grazing – densities) was slowly increasing (Fig. 6.1a, b). In the conventionally farmed areas many fields had been mowed from 11 May onwards with nearly 90% of the fields having experienced some form of management in the period of 21-31 May and the last unmanaged fields being mowed in June. In the hobby farming area however, grazing in high or in lower densities were the dominant management forms until the end of May and by then, nearly 50% of all fields were still unmanaged. Consequently, in the latter area nearly 50% of the fields had swards taller than 20 cm in June against about 15% in the conventionally farmed areas (Fig. 6.1c, d). The peak in mowing around mid May in the conventionally managed areas was reflected by the high percentage of fields with short swards from that period onwards. In the last period, short swards (<10 cm) covered over 60% of the conventional study areas. The area of heterogeneous fields (class I, II or III) never exceeded 20 % in the intensive areas (Fig. 6.1e). The increase in homogeneity early April can be attributed to farming practices at the onset of the growing season (such as the leveling of mole hills). Throughout the season we observed a slight increase in the most homogenous class which was probably caused by the fact that mowed fields have a very uniform appearance. In the more extensively managed area, heterogeneous types covered over 60% at the onset of the breeding season and this proportion fell to about 40% during the season (Fig. 6.1f). Many fields had more open swards here and few fields were reseeded with fast growing grass species such as *Lolium*. The decline in the area of heterogeneous fields early May was probably caused by the rapid growth of the vegetation, which caused swards to become increasingly dense.

Bird densities

In the conventionally farmed areas, densities of black-tailed godwits and lapwings were highest at the onset of the breeding season with little over 50 birds per 100 ha (Fig. 6.2a). Redshank and oystercatcher were much less common with about 10 birds per 100 ha. Whereas oystercatcher densities remained more or less constant through the season, the densities of the other species decreased substantially. At the beginning of May, densities of the latter species had about halved. Lapwing and redshank stabilized from that point onwards but the density of black-tailed godwits declined further and dropped under 10 birds per 100 ha per survey in June. In the hobby farming area, densities peaked by mid April (Fig. 6.2b).

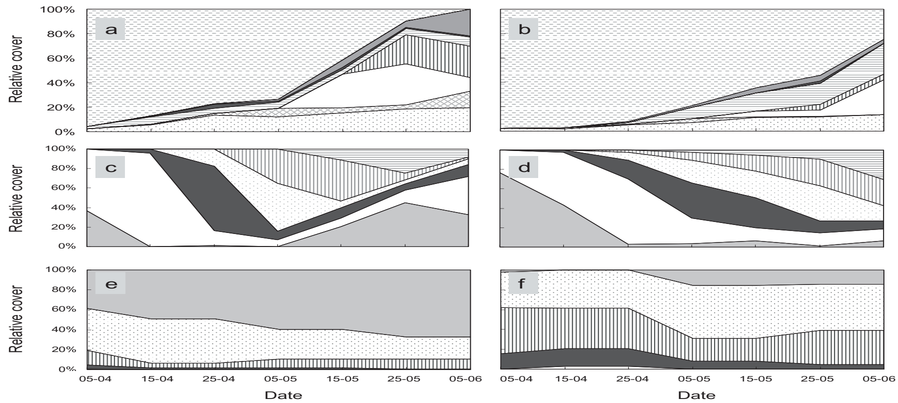

Fig. 6.1a-f. Relative cover of different management types (a, b), different sward heights (c, d) and different sward heterogeneity classes (e, f) in three study areas with conventional dairy farming (a, c, e) and area with hobby farming (b, d, f) throughout the breeding season. Dates on the x-axis are the first days of each ten-day period (i.e. 21-04 stands for 21-30 April). Symbols used for the relative cover of different management types (a, b): dashed area - unmanaged; light grey - regrown (last management two periods ago); dark grey - recent prolonged grazing (i.e. prolonged grazing in previous period); horizontally striped – prolonged grazing; vertically stripped - recently mowed; white - mowed; crosses - recent intensive grazing; spotted – intensive grazing. Symbols used for the relative cover of different sward heights (c, d): horizontally stripped - sward higher than 25 cm; vertically stripped - sward height 21-25 cm; spotted - sward height 16-20 cm; dark grey - sward height 11-15 cm; white - sward height 6-10 cm; light grey - sward height 0-5 cm. Symbols used for the relative cover of different sward heterogeneity classes (e, f): white - class I (very heterogeneous); dark grey - class II; veritcal stripes - class III; spots - class IV; light grey - class V (very homogeneous).

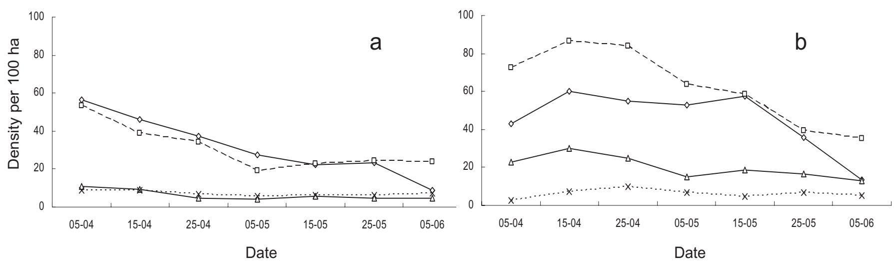

Fig. 6.2a, b. Average number of observations per ten-day period of different wader species throughout the breeding season in the conventionally farmed areas (a) and the hobby farming area. Squares – lapwing; diamonds – black-tailed godwit; triangles – redshank; crosses – oystercatcher.

Lapwing numbers were much higher than in the intensively farmed areas but dropped gradually. Black-tailed godwits remained stable until mid May but declined steeply from then onwards and by June, densities were little higher than in the intensively farmed areas. Redshank density declined rapidly but stabilized from the beginning of May onwards and oystercatcher density remained more or less constant.

At the onset of the breeding season, black-tailed godwits were predominantly found in unmanaged fields and prolonged grazing fields where they occurred in densities of about 90 and 80 birds per 100 ha (Fig. 6.3a). These categories were significantly preferred over intensively grazed fields, as can be derived from the significant management effect in table 1. As hardly any differences in sward height occurred, no differences in black-tailed godwit densities were observed between fields with different sward heights (table 1). Heterogeneity had a significant effect on black-tailed godwit densities, with much higher densities being observed on the most heterogeneous fields compared to fields with the other heterogeneity classes (Fig. 6.3b, Table 6.1). At the end of April when birds started incubating, unmanaged fields still had the highest densities (Fig. 6.3a). However, by this time black-tailed godwits were found in significantly higher densities on the fields with the lower sward heights, i.e. those with swards of 5-15 cm. By then, also fields with intermediate heterogeneity were preferred by black-tailed godwits over the homogeneous ones. In May and June, no heterogeneity type seemed to be preferred over another (Fig. 6.3b). Considering management types, prolonged grazing fields became more important in May and June. In May, black-tailed godwits were also found in high densities on fields that had been managed earlier in the season. In June, hardly any differences occur between any of the management categories.

Management type had a significant effect on lapwings with highest densities observed on prolonged grazing fields in both the nest site selection and the incubation phases (Fig. 6.3c, Table 6.1). Furthermore, during both phases, fields with the shortest swards hosted the highest densities (Table 6.1). Surprisingly, intensively grazed fields with high densities of cattle – which probably had short swards – had the lowest lapwing densities in both of these periods. Similar to black-tailed godwits, most lapwings were found on the more heterogeneous fields both in early as late April (Fig. 6.3d, Table 6.1). By mid May, the intermediate heterogeneity category III had the highest densities of lapwings and the importance of the most heterogeneous category had dropped. Fields with prolonged grazing remained the management type with the highest densities throughout the season but the importance of intensive grazing fields increased gradually.

Table 6.1. Test statistics of the effects of management type, sward heterogeneity and height on the distribution of meadow birds at the onset of the breeding season (25th March – 10th April) and when most species were incubating (21st – 30th April). Analyses were carried out on the density per period (thus not divided by field areas). Models included field size, study area, management type, sward heterogeneity and sward height. Shown is the deviance ratio. The directions of the effects for sward height and heterogeneity are in brackets. * $P < 0.05$; ** $P < 0.01$, *** $P < 0.001$.

		Black-tailed godwit	Lapwing	Redshank	Oystercatcher
Period		Dev ratio	Dev ratio	Dev ratio	Dev ratio
25-03 - 10-04	Management	**4.21***	**7.22*****	1.9	0.29
25-03 - 10-04	Heterogeneity	**7.4***** (-)	**4.27**** (-)	**6.21***** (-)	2.3
25-03 - 10-04	Sward height	1.0	**8.98**** (-)	1.8	1.72
21-04 - 01-05	Management	**6.37****	**13.05*****	1.58	1.87
21-04 - 01-05	Heterogeneity	**9.17***** (¶)	**18.31***** (¶)	**4.48**** (¶)	**3.61*** (¶)
21-04 - 01-05	Sward height	**5.5***** (§)	**7.79***** (-)	0.91	0.65

(¶) Intermediate heterogeneity (class III) preferred.

(§) Lower sward height (6-10 cm) preferred.

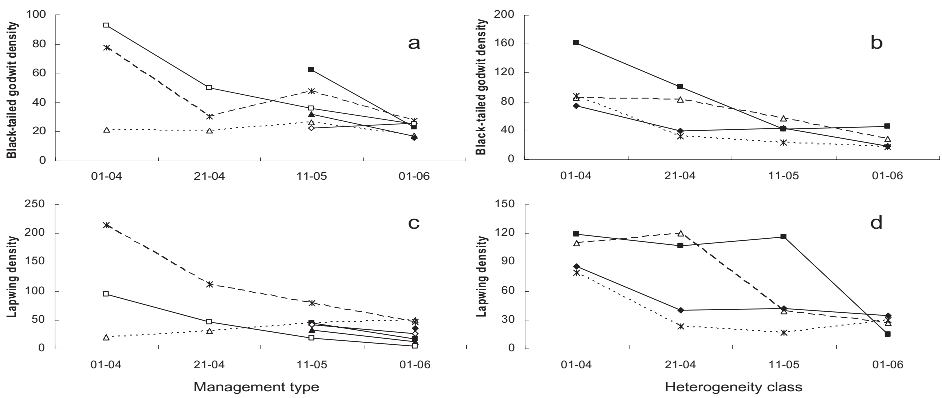

Fig. 6.3a-d. Average densities of black-tailed godwits (a, b) and lapwings (c, d) on fields with different management types (a, c) and heterogeneity classes (b, d) over the four different study areas throughout the breeding season in number of individuals per 100 ha. Management or heterogeneity types that covered less than five fields were not depicted. Values represent averages of two time periods (e.g. date 21-04 represents the average of periods 11-04 and 21-04). Symbols used for the different management types (a, c): open triangles – intensive grazing; filled triangles - recently intensive grazing; asterisks - prolonged grazing; open squares - unmanaged; filled squares - regrown; open diamonds - mowed; filled diamonds - recently mowed. Symbols used for the different sward heterogeneity classes (b, d): squares – class II (very heterogeneous); triangles - class III; diamonds - class IV; asterisks - class V (very homogeneous).

Densities of redshank and oystercatcher were much lower and remained more or less constant with an average density of redshanks of 10 birds per 100 ha (range 0-30) and density of oystercatchers of 7 birds per 100 ha (range 2-11). Neither of these species showed a significant preference for any of the management types or the sward heights (Table 6.1). However, redshanks (and oystercatchers marginally so; $P = 0.075$) show a significant preference for the most heterogeneous fields at the onset of the breeding season (Table 6.1). By the end of April, both were found in the significantly highest densities at fields with intermediate heterogeneity.

Mass mowing responsible for decline in bird densities?

Densities of black-tailed godwits and lapwings dropped substantially over the breeding season. Spearman's correlation analyses between the relative density of birds and the relative area of unmanaged fields revealed significant positive relations over the four study areas for both black-tailed godwit ($R^2 = 0.71$; $P < 0.01$) and lapwing ($R^2 = 0.68$; $P < 0.01$). For both species the inclusion of time however explained practically all of the variance. As Spearman's correlation between time and the percentage of unmanaged fields was strongly negative ($R^2 = 0.93$; $P < 0.01$), we were unable to determine which part of the declines could be attributed to the proceeding of the season and which to the area of unmanaged fields.

Alarming birds

A total of 285 alarming black-tailed godwits were observed in the three periods after mowing. The hobby farming area alone had 195 of these 285 birds, which left only 30 observations per conventionally farmed study area. The proportional distance of alarming black-tailed godwits in the periods after mowing did not differ from that of all black-tailed godwits after mowing (Fig. 6.4a), indicating that alarming black-tailed godwits were not observed closer to unmanaged fields than all black-tailed godwits. Neither did black-tailed godwits move closer to unmanaged fields when the proportion of unmanaged fields decreased ($R^2 = 0.18$; $P = 0.64$). The relation of alarming black-tailed godwits to fields with sward height of over 15 cm was similar to that of unmanaged fields and is therefore not shown. Alarming black-tailed godwits did seem to be attracted to the more heterogeneous fields, as their proportional distance to these fields was lower than the proportional distance of all black-tailed godwits in the periods after mowing (Fig. 6.4b). Further, their proportional distance was consistently lower than 1 and no relation was observed with the proportion of the study area covered by heterogeneous fields ($R^2 = 0.10$; $P = 0.77$).

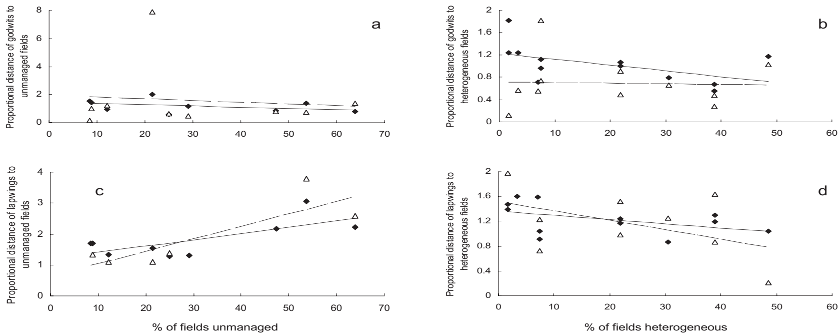

Fig. 6.4a-d. The proportional distances of all and alarming black-tailed godwits (a, b) and lapwings (c, d) to unmanaged (thus with tall swards; a, c) and heterogeneous fields (b, d) after mowing (periods 11 - 20 May, 21 - 31 May, 1 - 15 June). Proportional distances were plotted against the percentages of unmanaged or heterogeneous fields in the four study areas. Distances are proportional to the distance of all black-tailed godwits or lapwings to the configuration of unmanaged or heterogeneous fields after mowing in the periods before mowing (01 April – 10 May). Heterogeneous fields were fields with heterogeneity classes I, II and III. Diamonds and solid lines – average distance of all birds in the periods after mowing divided by the average distance of all birds in periods before mowing. Triangles and dashed lines - average distance of alarming birds to unmanaged fields after mowing divided by the average distance of all birds before mowing. Lines are generally indicative and do not represent significant relations.

In the periods after mowing we observed a total of 200 alarming lapwings, 162 of which were found in the hobby farming area. When a high proportion of the study areas was unmanaged, alarming lapwings and to a lesser extent all lapwings were further from unmanaged fields in the periods after mowing than all lapwings in the periods before mowing (Fig. 6.4c). However, as the area of unmanaged fields decreased, alarming lapwings reduced their distance to unmanaged fields relative to the distances of all lapwings prior to mowing ($R^2 = 0.71$; $P = 0.11$) and thus were increasingly similarly distributed as lapwings before mowing. Alarming lapwings were relatively close to the more heterogeneous fields when these fields were abundantly present (fig. 4d). However, with the proportion of heterogeneous fields decreasing, alarming birds seemed to increase their distance to these fields ($R^2 = -0.36$; $P = 0.34$).

Discussion

In each of the study areas, black-tailed godwits selected the more heterogeneous fields in both the nest site selection and the incubation stages (Fig. 6.3b, Table

6.1). These heterogeneous fields were predominantly unmanaged (data not shown). However, prolonged grazing fields - with lower densities of grazers - in general also were intermediately heterogeneous and contained high densities of black-tailed godwits. Johansson (2001) found that black-tailed godwits preferably nest in tussocks with low surrounding vegetations. Several Dutch studies (e.g. Buker & Groen 1989) found nesting black-tailed godwits to prefer mowed fields over grazed fields while the latter are generally more heterogeneous. Probably, also fields that were predominantly mowed in the previous season contain a sufficient amount of structural differences at the micro-scale. High densities of black-tailed godwits on fields with prolonged grazing seem to contradict with previous studies on habitat use (e.g. Buker & Groen 1989; Beintema *et al*. 1995) but stocking densities of grazers are rarely distinguished in recent Dutch meadow bird studies.

Similar to black-tailed godwits, we observed the highest densities of lapwings at the nest site selection and the incubation stages on the more heterogeneous fields (Fig. 6.3d, Table 6.1). Lapwings are known to nest in a wide variety of field types, from homogeneous dry to wet tilled fields and to heterogeneous rough grazing grasslands (e.g. Galbraith 1988; Berg 1993). Galbraith (1988) and Baines (1990) both found the highest grassland densities in unimproved pasture, and these were probably most closely resembled by our heterogeneous fields. Further, we found high densities in fields with prolonged grazing with lower cattle densities. In early season, the grazers probably kept swards short and created some small-scale heterogeneity which might have contributed to their attractiveness to lapwings. Fields with intensive grazing however, similarly had reduced sward heights but were avoided. These fields tended to be more homogeneous which suggests that these grazing regimes with extremely high stocking densities might be too intensive for lapwings. Second, trampling of nests might be a huge threat in these intensively grazed fields (e.g. Beintema & Müskens 1987).

Finally, we observed redshanks to significantly select heterogeneous fields over the more homogeneous fields by early and late April (Table 6.1). Norris *et al*. (1997) found this species to preferably nest in structure-rich swards in coastal grazing marshes. Our findings in intensively farmed wet meadows are in accordance to those results, although we do not have data on the actual nest sites. Even though oystercatchers occurred in very low densities throughout the breeding season (Fig. 6.2), by the end of April their density in the heterogeneous fields significantly exceeded those in the homogeneous fields (Table 6.1). Oystercatchers usually start nesting later than the other wader species (Beintema *et al*. 1995), so the end of April might have coincided with their nest site selection phase. However, as with redshanks, we were not able to determine whether these fields were also preferred for nesting.

Over all study areas, densities of meadow birds declined sharply throughout the breeding season (Fig. 6.2). Consequently, we observed few alarming birds so reproductive success was probably low. At the start of the breeding season declines could be explained by the fact that birds were becoming less visible because they were incubating. However, these birds should have become visible again in May when nests would have hatched (Kruk *et al*. 1996; Schekkerman & Beintema 2007) but densities dropped further over May into June. The declines in the number of observations of meadow birds strongly correlated with the proportion of the study areas being managed (mowed or grazed). However, declining meadow bird densities were also correlated with time, and the 'proportion managed' was also correlated with time. Therefore, we were not able to determine which parts of the declines in waders could be attributed to the increasing area that was mowed or grazed.

We found extremely low numbers of alarming meadow birds. We might have missed some broods as we did not enter the fields themselves. However, breeding success in these areas must have been very low, a trend that is generally observed in farmland wader studies recently (e.g. Kruk *et al*. 1997; Ottvall 2005; Schekkerman *et al*. 2005; Teunissen *et al*. 2005). Teunissen *et al*. (2005) find that chick survival drops rapidly after the beginning of May and becomes very low in June. This might have been partly responsible for the declines we observed and for the low numbers of alarming birds (fig. 4). Similarly, with the percentage of fields being managed increasing rapidly from mid May onwards, birds that were still incubating (fi. replacement clutches) also had higher chances of loosing clutches (Teunissen & Willems 2004; Teunissen *et al*. 2005).

Opposite to several studies, e.g. Schekkerman & Beintema (2007), we did not observe alarming black-tailed godwits to move towards unmanaged fields with taller swards (Fig. 6.4a). Often, fertiliser applications in fields with postponed mowing are not reduced sufficiently to prevent swards from becoming very dense or even lying down (Schekkerman *et al*. 2005; Verhulst *et al*. 2007). In our study, several fields had swards lying down already by mid May. This might have played a role in the fact that we did not observe more alarming black-tailed godwits at unmanaged fields. Also, the number of families we observed was not too high but we did find them to move closer to the more heterogeneous fields (Fig. 6.4b). The latter result seems to confirm findings of Kruk *et al*. (1997) who found black-tailed godwit broods predominantly in 'herb-rich' fields with either tall or short swards.

Alarming lapwings were found far away from unmanaged fields, as might expected based on their preference for fields with short swards (Cramp & Simons 1983). Several studies have found lapwing broods to move to areas with short swards where chicks obtain higher intake rates (e.g. Galbraith 1988; Johansson

& Blomqvist 1996; Devereux *et al*. 2004). Fields with short swards in our study were generally regrown either after mowing or intensive grazing and the greater part of these fields were rather homogeneous. Consequently, lapwing broods were not found to be attracted to the more heterogeneous fields. Extensively fields grazed - with low stocking densities - are also known to be attractive to lapwing broods (e.g. Galbraith 1988; Johansson & Blomqvist 1996) but such fields in our study were generally intermediately heterogeneous and most had sward heights of 10 – 20 cm's.

We found substantial differences in management between the study areas with conventional dairy farming and the one with hobby farming (Fig. 6.1). In the latter area, we observed higher densities of meadow birds (Fig. 6.2) and much more alarming black-tailed godwits and lapwings. Farming practices started much later in the season in the hobby farming area and this area still contained fields with tall swards. The absence of sufficient fields with tall swards at the end of May and in June is generally thought to be the factor responsible for the low reproductive success of black-tailed godwit (e.g. Schekkerman & Müskens 2000; Schekkerman *et al*. 2005). Second, the proportion of heterogeneous fields was much higher in the hobby farming area, which might have been responsible for the observed higher densities (e.g. Vickery *et al*. 2001; Schekkerman *et al*. 2005).

Implications for management

Several recent publications have stressed the importance of in-field heterogeneity for farmland birds (e.g. Vickery *et al*. 2001; Benton *et al*. 2003; McCracken & Tallowin 2004; Wilson *et al*. 2005). Our study is one of the first to show that meadow breeding waders significantly prefer heterogeneous fields over more homogeneous ones. Also, we observed black-tailed godwit families to move to heterogeneous fields rather than fields with tall swards, which confirms findings of Kruk *et al*. (1997). Heterogeneous fields are likely to provide optimal foraging opportunities for meadow birds (chicks), because the variation in vegetation structures both increase the range of potential prey species in these swards and ensure their availability (e.g. Morris 2000; Vickery *et al*. 2001; McCracken & Tallowin 2004). Additionally, we found fields that were grazed for longer consecutive periods with lower cattle densities were much more heterogeneous that those with conventional grazing regimes (with 80 cattle in fields of 2 ha for or two days). Consequently, fields with prolonged grazing contained high densities of lapwings but also black-tailed godwits.

Our results suggest that initiatives aimed at breeding waders should incorporate field heterogeneity. Prolonged grazing with lower cattle densities might be an effective way to achieve this objective. An alternative way might be reseeding fields with slowly growing grass species that create more open swards attractive to both adult and juvenile meadow birds. Other European countries have schemes that include rewetting whole fields (Ausden & Hirons 2002; Vickery *et al*. 2004; Kahlert *et al*. 2007), which seriously conflict with intensive farming, and found these to be cost-effective (Ausden & Hirons 2002; Wilson *et al*. 2007). Therefore, we suggest the inclusion of a grasslands "unimprovement" scheme. Including such a scheme in the agri-environmental program would require high compensations for farmers and it would not be popular. However, agri-environment schemes more feasible for farmers that conflicted less with intensive farming practices have not proven to be successful (e.g. Klein *et al*. 2001; Wilson *et al*. 2007; Verhulst *et al*. 2007).

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MEADOW BIRD ECOLOGY AT DIFFERENT SPATIAL SCALES

RESPONSES TO ENVIRONMENTAL CONDITIONS AND IMPLICATIONS FOR MANAGEMENT

Dutch wet grasslands host high densities of meadow birds. Especially striking are the huge numbers of breeding wading birds. Half of Europe's black-tailed godwits *Limosa limosa* and on third of the oystercatchers *Haematopus ostralegus* breed in the Netherlands. Meadow birds originally benefited from the cultivation of vast areas of forest and marshland. Due to the extensive character of farming, many species were able to adapt to these new habitats. However, since the second half of the 20th century, changes in farming intensity, stimulated by the Common Agricultural Policy (CAP) of the European Economic Community, have occurred at a very high rate. Many species have not been able to adapt to the new circumstances and farmland birds – and other taxa - have been experiencing severe declines ever since.

In the 1970s, it became clear in the Netherlands that the establishment of nature reserves, the traditional way of protecting nature, could not maintain the large populations of birds breeding in wet grasslands. Therefore, a new Dutch policy was started that aimed to establish reserves where optimal conditions for farmland birds could be realized on the one hand, and the limited area of reserves was aimed to be complemented by management agreements with farmers on the other hand. Farmers were to be compensated for income loss if they agreed to postpone mowing and grazing, reduce drainage and lower levels of fertilizer application and stocking rates. Although the policy became operative in 1975, the area under agreement became substantial (>20.000 ha) only after 1990. Postponed mowing was the dominant agreement, and farmers were not allowed to carry out any agricultural activities from April 1st until a set date in June or July.

In 1992, the European Economic Community introduced a regulation that required all member states to apply agri-environment measures according to environmental needs and potential. Agri-environment schemes still vary markedly between countries within the European Union (EU). Schemes in the Netherlands were and are mainly focussed on meadow birds but programmes in other member states have objectives such as reducing the use of agro-chemicals, protecting biodiversity, restoring landscapes and preventing rural depopulation. As a large part of the costs are co-funded by the EU this regulation is a financially attractive form of environmental protection for member states. By 2001, 20% of the agricultural land in the EU was covered by agri-environmental measures but uptake of programmes is generally low in highly productive and intensive agricultural areas such as the Netherlands. Annual spending on agri-environment schemes was less than 5% of the total CAP budget (about €55 billion) in 2004.

The effectiveness of the Dutch postponed mowing scheme was monitored in the 80ies and 90ies and in general results were positive. However, in the majority of studies, the research design was inadequate to reliably assess the effectiveness. In 2001, the results of a study were published that showed that the postponed mowing scheme, the agri-environment scheme with the highest uptake in the Netherlands, adversely affected two wader species and had no effect on the other two considered. Additional analyses of meadow bird trends confirmed the lack of effectiveness of the postponed mowing scheme. However, in other parts of the EU, agri-environment schemes do deliver clear biodiversity benefits. Despite the uncertainty about their effectiveness, agri-environment schemes at present do represent the only available mechanism to reverse the declines in farmland biodiversity in the EU. Therefore, they are of key interest if the 2010 targets to reduce or halt biodiversity loss, agreed in the EU at the 2001 Gothenburg Summit, are to be met.

This thesis focuses at the effectiveness of the Dutch agri-environment scheme aimed at meadow birds and mechanisms that influence the effectiveness. I evaluated recently introduced types of meadow bird schemes. Further, I have studied the relation between farmland birds and management intensity in Hungary. This study places agri-environment schemes in perspective as that it shows the potential of reducing agricultural intensity on biodiversity. Back in the Netherlands, I have aimed to enlarge our basic ecological understanding of spatial habitat use and nest-site selection in meadow birds. These topics have clear management implications which are being discussed in each chapter.

Chapter 2 focuses at the effectiveness of the most widely applied Dutch meadow bird policies. From 1995, agri-environmental collectives have become involved in coordination of scheme applications, while additional measures have been introduced. One of them is per-clutch payment (PCP): farmers are paid per wader clutch, without being restricted in their farming practices. We evaluated the effectiveness of the combination of the PCP and the postponed mowing (PM) scheme by determining the number of birds and territories on 12.5 ha plots where the two measures (on average 1.6 ha PM and 10.9 ha PCP) were being implemented. Conventionally managed grasslands served as controls. Additionally, we focussed on the fields with postponed mowing by sampling a number of environmental factors that might influence the distribution of waders and compared these with values obtained at control fields.

On plots with a combination of postponed mowing and per-clutch payment, the total number of territories of all bird species were higher and more redshanks *Tringa totanus* individuals were observed. We found no differences in wader territories for individual species but the breeding density of the four wader species summed was found to be marginally higher compared to conventional farms. On fields with postponed mowing, we found more territories of the most abundant wader species summed but we observed fewer lapwings *Vanellus vanellus* than on conventional fields. The positive effects of postponed mowing on wader territories were found to be correlated to small differences in soil moisture and groundwater level between the two field types, as inclusion of these factors in the statistical analyses rendered all scheme effects insignificant. Postponed mowing affected the form and amount of fertilizer applied to the fields as well as available nitrogen, but none of the other environmental factors that were measured. Additional analyses identified groundwater depth, penetration resistance and prey density (earthworms and leatherjackets) as main factors determining wader density.

Our results suggest that the effectiveness of agri-environment schemes directed towards conservation of waders might be enhanced by including raised groundwater levels into scheme prescriptions.

In **Chapter 3**, I describe results of a study determining the effects of agricultural intensification and abandonment on farmland birds in Hungary. These two processes are the main threats to farmland birds in central and eastern European countries that recently joined the European Union. Marginal agricultural lands were threatened by abandonment, while the remaining area came under pressure of intensification as stimulated by the Common Agricultural Policy of the EU. To assess the effects of these threats to breeding birds, we monitored birds in abandoned, extensively and intensively used vineyards and grasslands in Hungary.

Species numbers and bird density were highest in extensively used vineyards. Abandoned vineyards were rich in species and individuals, mainly woodland species, whereas intensively used vineyards had both fewer species and individuals than the other two vineyard types. In grasslands, four management types were distinguished, abandoned, extensively, intensively grazed and both intensively grazed and fertilised grasslands. Extensive grasslands harboured most species but bird density was highest at the abandoned site which was covered by bushes and contained many non-grassland species. Intensively grazed fields had lower species numbers and lower densities than extensively grazed grasslands but were still much more species rich than the fertilised fields.

Our results suggest that extensively used farmland holds the highest diversity and abundance of farmland birds. Conservation efforts aimed at farmland birds should therefore focus on maintaining extensive farming systems.

Chapter 4 focuses on Dutch meadow breeding waders again. Numerous studies have focused on the nest phase of waders but spatial data of their territory use or foraging range are rare. We quantified spatial habitat use relative to the nest site of eleven adult lapwings during the nest phase and of eleven adult redshank mainly during the chick phase.

Both species used areas of about 0.6 hectare; 72 to 80% of the bird observations were done within 60 m from the nest site. Further, we found that in both species, about 50% of the nests were located at what seemed to be the border of the territory.

Considering the spatial scale at which breeding waders' use their habitat, our results suggest that rather than present (Dutch) postponed mowing schemes that are implemented to whole fields and create large, uniform units, conservation measures might be increasingly effective when they create heterogeneity within fields.

In **Chapter 5**, I describe results of a study aiming to determine how nest site selection of different meadow bird species is influenced by differing environmental conditions and the presence of heterospecifics (i.e. other meadow bird species). Effectiveness of agri-environment schemes might be enhanced if birds could be attracted to fields where specific measures are taken. We therefore examined the spatial autocorrelation between a range of environmental variables, similar to those described in Chapter 2, with meadow bird territories in four areas of over 100 ha each. Furthermore, we examined whether territories of the most common meadow bird species are spatially associated with each other at the polder scale, which might either obscure or override the effects of environmental conditions.

We found that all combinations consisting of exclusively waders and those consisting of exclusively passerines were significantly positively associated. Of eight wader – passerine combinations, only one was significantly related. Nest sites of black-tailed godwit and redshank were associated with high groundwater levels and those of lapwing were marginally negatively associated with soil moisture. Both of these effects were also found in Chapter 2. Prey abundance was not consistently associated with either of the wader species.

The contrasting preferences for breeding habitat of species that often nest in close association of one another could suggest that the benefits of nesting close to other species outweighs that of selecting optimal habitat in some areas. A second explanation might be that within a breeding cluster, each species must have been able to select its preferred nest site.

Our results provide additional support for the pivotal role of high groundwater levels in conservation efforts aimed at meadow birds, like we suggested in Chapter 2. As raised groundwater levels might increase in-field heterogeneity, other species attracted by high densities of black-tailed godwits and redshanks, are also likely to find suitable habitat in these fields (which was also suggested in Chapter 4).

Chapter 6 focuses at the role of heterogeneity in determining wader densities. Reductions in sward heterogeneity have been suggested (amongst others in Chapter 3 and 4) to be responsible for disappointing results of agri-environment schemes. Therefore, we studied field preference of meadow birds throughout the breeding season in four areas of over 100 ha each and related observed patterns of individual birds to field characteristics (sward heterogeneity, sward height and management).

We found considerable differences in heterogeneity and management between study areas and also in density of waders. Over the four areas, black-tailed godwit, lapwing and redshank reached their highest densities on the most heterogeneous fields at the period of nest site selection. At the incubation stage, all of the four considered wader species (including oystercatcher) were observed in the highest densities on the more heterogeneous fields. Additionally, we found that fields grazed with prolonged grazing (with lower cattle densities), generally overlooked in Dutch wader studies, were had high densities of lapwings but also of black-tailed godwits. The densities of black-tailed godwits and lapwings were strongly negatively correlated with the percentages of the study areas being grazed and mowed. However, densities also severely declined throughout the season and therefore we were unable to determine which part of the declines were indeed caused by management (mowing or grazing). Corresponding with large declines in bird densities, we observed few alarming birds. Black-tailed godwit families did not move towards unmanaged fields (with tall swards) as expected but seemed to be attracted to heterogeneous fields. Lapwing families were observed to avoid unmanaged fields but did not avoid nor prefer heterogeneous fields.

As suggested in previous chapters, our results indeed show that in-field heterogeneity is of key importance for meadow breeding waders at the nest site selection and incubation stages. Additionally, we find that fields with prolonged grazing harbour high densities of waders. We therefore suggest initiatives aimed at meadow breeding waders should be targeted at increasing in-field heterogeneity and that alternative grazing regimes might be one way to do so.

In conclusion, we found that extensively managed Hungarian fields, with large variation in micro-topographical features, contained high densities of threatened farmland birds. In western Europe however, almost all grasslands have been agriculturally improved and drained. We did not find relatively simple agri-environment schemes that are feasible for farmers to be effective in the preservation of breeding meadow birds. We did find higher densities of meadow birds in fields with a high groundwater level and in heterogeneous fields. Therefore, we argue that more radical forms of agri-environment schemes, incorporating both water levels and in-field heterogeneity, are required to maintain the high densities of meadow birds in the Netherlands.

S

WEIDEVOGELECOLOGIE OP VERSCHILLENDE RUIMTELIJKE SCHAALNIVEAUS

EFFECTEN VAN OMGEVINGSFACTOREN EN CONSEQUENTIES VOOR HET BEHEER

De Nederlandse veenweidegebieden (en graslanden op kleigrond in het noorden van het land) herbergen hoge aantallen broedende weidevogels. In het oog springend is dat grofweg de helft van de wereldpopulatie van de grutto *Limosa limosa* en een derde van die van de scholekster *Haematopus ostralegus* in Nederland broedt. Weidevogels profiteerden oorspronkelijk van de cultivatie van grote oppervlakken bos en moeras. Het boerengebruik van de gecultiveerde gronden was dermate extensief dat veel (vogel)soorten deze nieuwe habitats konden bevolken, deels gedwongen omdat hun originele leefgebieden verloren waren gegaan. Vanaf de jaren 50 van de 20ste eeuw veranderde het boerenland in een erg hoog tempo, onder invloed van het gemeenschappelijk landbouwbeleid van de Europese Economische Gemeenschap. De intensiteit van het landgebruik nam zo snel toe dat veel soorten zich niet konden aanpassen en sindsdien nemen veel (vogel)soorten van het boerenland sterk in aantal af.

Rond 1970 werd het in Nederland duidelijk dat alleen het oprichten van natuurreservaten niet genoeg zou zijn om de hoge aantallen weidevogels te behouden. De ‘Relatienota’, een nieuw beleidsinstrument uit 1975, richtte zich daarom enerzijds op het aankopen van natuurreservaten waar de omstandigheden voor (kritische) weidevogel soorten (zoals watersnip *Gallinago gallinago* en kemphaan *Philomachus pugnax*) optimaal konden worden gemaakt. Daarnaast moest het beperkte oppervlak aan reservaten aangevuld worden met 'beheersovereenkomsten' met boeren. Boeren werden gecompenseerd voor gederfde inkomsten als ze later zouden maaien of beweiden, of als ze de hoeveelheid mest of vee reduceerden op een perceel. In eerste instantie waren de beheersovereenkomsten niet populair en het duurde tot na 1990 voordat een substantieel oppervlak landbouwgrond (> 20.000 ha) onder de beheersovereenkomsten viel. 'Uitgesteld maaien', waarbij boeren van 1 april tot een bepaalde datum in juni of juli geen enkele landbouwkundige handelingen mochten uitvoeren, werd de belangrijkste overeenkomst.

In 1992 kwam de Europese Economische Gemeenschap met een richtlijn die elke lidstaat verplicht om '*agri-environment schemes*' te implementeren. Deze overeenkomsten met boeren waren erop gericht de negatieve effecten van de moderne landbouw op natuur en milieu een halt toe te roepen. Er zijn altijd grote verschillen geweest in de overeenkomsten die boeren in verschillende landen konden afsluiten. In Nederland is ervoor gekozen het weidevogelbeheer te versterken en op te schalen, terwijl andere landen van de Europese Unie (EU) programma's hebben die gericht zijn op het milieu, landschap of het tegengaan van ontvolking van het platteland. Een groot deel van de nationale '*agri-environment schemes*' wordt gefinancierd door de EU en zijn daardoor erg aantrekkelijk voor de lidstaten. In 2001 viel 20% van alle landbouwgrond van de EU onder een bepaalde vorm van '*agri-environment scheme*', maar de bedekking is over het algemeen laag in hoogproductieve agrarische regio's. De jaarlijkse uitgaven waren in 2004 minder dan 5% van het totale landbouw budget van € 55 miljard.

De effectiviteit van het uitgesteld maaibeheer in Nederland werd gedurende de jaren 80 en 90 regelmatig geëvalueerd en over het algemeen waren de uitkomsten redelijk positief. Achteraf bleek echter dat veel van deze evaluaties niet zorgvuldig genoeg opgezet waren om de effectiviteit werkelijk te kunnen bepalen. En in 2001 bleek dat uitgesteld maaibeheer een negatieve invloed had op twee van de belangrijkste weidevogels en geen (positief) effect op de andere twee. Uit vervolg onderzoek kwam hetzelfde beeld naar voren. In veel andere EU landen worden de '*schemes*' überhaupt niet geëvalueerd en daar waar het wel gebeurt (vooral in het Verenigd Koninkrijk) lopen de resultaten sterk uiteen. Ondanks het feit dat dus niet duidelijk is of de programma's goed werken, vormt agrarisch natuurbeheer de belangrijkste optie om de negatieve effecten van landbouw op de natuur een halt toe te roepen. Dus speelt agrarisch natuurbeheer een centrale rol in de 'Countdown 2010', een afspraak van de EU, Europa en de hele wereld om te zorgen dat de continue afname van biodiversiteit gestopt wordt.

Dit proefschrift gaat over de effectiviteit van agrarisch natuurbeheer gericht op weidevogels in Nederland en de processen die de effectiviteit beïnvloeden. In de meeste hoofdstukken bestuderen we de vier meest algemene weidevogelsoorten. Op deze steltlopers (grutto, kievit *Vanellus vanellus*, tureluur *Tringa totanus* en scholekster) is het Nederlandse weidevogelbeheer vooral gericht. We evalueren de meest wijdverspreide vormen van agrarisch natuurbeheer waaronder een recent geïntroduceerde vorm. Vervolgens bekijken we waarom we in NL überhaupt agrarisch natuurbeheer nodig hebben door de avifauna van extensieve en intensieve Oost-Europese landbouwsystemen te vergelijken. Terug in Nederland proberen we de basale ecologische kennis van weidevogels te vergroten, met name op het gebied van het ruimtelijk habitatgebruik van weidevogels op verschillende schaalniveaus en door welke omgevingsfactoren dit beïnvloed wordt. De verschillende onderzoeken hebben allemaal duidelijke implicaties voor weidevogelbeheer en die worden in elk hoofdstuk ook besproken.

In **hoofdstuk 2** wordt de effectiviteit van agrarisch weidevogelbeheer in Nederland geëvalueerd. Vanaf 1995 zijn agrarisch natuurverenigingen betrokken geraakt bij het aanvragen en regelen van beheersovereenkomsten voor boeren. Verder is het pakket met mogelijkheden voor agrarisch weidevogelbeheer vanaf 2000 uitgebreid. Eén van de nieuwe mogelijkheden is betaalde nestbescherming. In veel gevallen wordt deze vergoeding aan boeren uitgekeerd aan de hand van het aantal aanwezige weidevogelnesten (resultaatbeloning). Behalve het beschermen van nesten bij agrarische activiteiten (zoals een nestbeschermer over het nest als er vee in het perceel komt) worden boeren niet beperkt in hun bedrijfsvoering.

In deze studie hebben we de effectiviteit van combinaties van resultaatbeloning en uitgesteld maaien bekeken. Dit hebben we gedaan door aantallen weidevogels en hun territoria te tellen op boerenbedrijven met agrarisch natuurbeheer (in totaal 12.5 ha, bestaande uit gemiddeld 1.6 ha uitgesteld maaien en 10.9 ha resultaatbeloning). Vervolgens werden deze aantallen vergeleken met boerenbedrijven zonder enige vorm van agrarisch natuurbeheer (ook 12.5 ha). Ook hebben we op de percelen met uitgesteld maaien een aantal omgevingsfactoren gemeten die waarschijnlijk van invloed zijn op broedende weidevogels en deze vergeleken met een vergelijkbaar perceel zonder agrarisch natuurbeheer.

Op boerenbedrijven met een combinatie van uitgesteld maaien en resultaatbeloning vonden we meer territoria van alle vogelsoorten en werden meer tureluurs geobserveerd ten opzichte van gangbare bedrijven. Voor de vier steltlopers konden we individueel geen verschillen in de aantallen territoria vaststellen maar opgeteld waren er marginaal meer territoria bij beheersboeren. Op percelen met uitgesteld maaien waren er meer territoria van de vier steltlopers opgeteld maar zagen we minder kieviten in vergelijking met de controlebedrijven.

Het positieve effect van uitgesteld maaien op het aantal steltloper territoria bleek bij nader inzien echter vooral veroorzaakt door kleine verschillen in bodemvocht en grondwaterstand. Het uitgesteld maaibeheer had een duidelijke invloed op de hoeveelheid en vorm van bemesting en ook op de hoeveelheid beschikbaar stikstof in de bodem, maar op geen van de andere gemeten factoren. Verdere analyses wezen grondwaterstand, indringingsweerstand van de bodem en de hoeveelheid wormen en emelten aan als factoren die de meeste invloed hadden op het voorkomen van steltlopers.

Onze resultaten suggereren dat de effectiviteit van het agrarische weidevogelbeheer zou kunnen worden verhoogd door verhoging van de grondwaterstand op te nemen als beheerspakket.

Hoofdstuk 3 gaat over de effecten van agrarische beheersintensiteit op vogels van het boerenland in een Oost-Europees land. Toetreding tot de EU en de invoering van het ‘Gemeenschappelijk Landbouwbeleid’ van de EU leveren twee belangrijke gevaren op voor vogels van de, over het algemeen extensieve, landbouwgronden. Enerzijds zal de landbouw intensiveren en anderzijds zullen marginale gronden verlaten worden. Om de gevolgen daarvan in te schatten hebben we in Hongarije de vogelgemeenschappen van extensieve graslanden en wijngaarden geïnventariseerd en deze vergeleken met die van intensieve en verlaten graslanden en wijngaarden.

In de wijngaarden bleek het aantal soorten en de dichtheid het hoogst in het extensieve type. Verlaten wijngaarden herbergden ook veel soorten en individuen, maar dat waren veelal bossoorten. In intensief gebruikte wijngaarden kwamen minder soorten in een lagere dichtheid voor dan in de andere twee typen. Voor de graslanden hebben we vier typen onderscheiden. De intensief gebruikte graslanden hebben we in twee typen verdeeld aangezien één deel bemest werd met kunstmest (intensief & bemest) terwijl dat over het algemeen niet gebeurde (intensief). In de extensieve graslanden vonden we het meeste soorten maar in de verlaten graslanden was de dichtheid het hoogst. Omdat het verlaten grasland begroeid was met struiken, kwamen daar veel niet-graslandsoorten voor. De intensieve graslanden waren minder soortenrijk en vogels kwamen voor in lagere dichtheden dan in de extensieve en verlaten graslanden, maar intensieve graslanden waren nog een stuk rijker dan de intensieve en bemeste weilanden.

Deze resultaten laten zien dat extensief beboerde landbouwgronden de meeste soorten van boerenland herbergen en dat deze soorten er in de hoogste dichtheden voorkomen. Op verlaten landbouwgronden kwamen ook veel bossoorten voor die minder bedreigd zijn in Europa. Daarom zou voor de bescherming van vogels van landbouwgronden vooral ingezet moeten worden op het behoud van extensief beboerde landbouwgronden.

In de volgende hoofdstukken komen de Nederlandse weidevogels weer aan de orde. Veel eerder uitgevoerde studies hebben de broedbiologie van weidevogels bekeken, maar weinigen daarvan hebben zich gericht op het ruimtelijk habitatgebruik. In **hoofdstuk 4** beschrijven we een studie waarbij we hebben gekeken naar het ruimtelijk habitatgebruik en de afstand waarop vogels zich bevinden ten opzichte van de nestplaats. We hebben dit gedaan voor elf gekleurringde kieviten (alleen vrouwtjes) tijdens het broeden en voor elf tureluurs (beide geslachten) die vooral tijdens de opgroeifase van de kuikens bekeken werden.

Beide soorten gebruikten gebieden met een oppervlak van ongeveer 0.6 ha en 72 tot 80% van de waarnemingen werd binnen 60 meter van de nestplaats gedaan. Ook vonden we voor beide soorten dat de nestplaats in de helft van de gevallen op de rand van het gebruikte gebied lag (in plaats van in het midden).

Huidige beheersmaatregelen (zoals uitgesteld maaien) worden toegepast op hele percelen en creëren zo heterogeniteit op landschapsschaal. Onze resultaten over de grootte van het gebied dat door broedende weidevogels gebruikt wordt, geven aan dat weidevogels echter behoefte hebben aan heterogeniteit op perceelsniveau. Daarom suggereren we dat agrarisch natuurbeheer zou moeten voorzien in het creëren van heterogeniteit binnen percelen.

In **hoofdstuk 5** beschrijf ik hoe we hebben geprobeerd te bepalen welke factoren van invloed zijn op de nestplaatskeuze van weidevogels. De effectiviteit van (agrarisch) weidevogelbeheer zou namelijk vergroot kunnen worden als vogels naar bepaalde percelen met speciale maatregelen gelokt kunnen worden. We hebben gekeken naar de ruimtelijke (cor)relatie tussen een aantal omgevingsfactoren (dezelfde als in hoofdstuk 2) en de hoeveelheid weidevogelterritoria in vier gebieden van minstens 100 ha elk. Ook hebben we bepaald of territoria van weidevogels met elkaar geassocieerd zijn, met andere woorden of de verschillende weidevogelsoorten elkaar opzoeken. Als dat zo is dan zou dat de relatie met omgevingsfactoren kunnen beïnvloeden.

Alle steltloper-steltloper combinaties waren positief geassocieerd, dus alle steltlopersoorten broeden dicht bij elkaar. De enige combinatie tussen zangvogels was ook positief geassocieerd. Van de acht steltloper-zangvogel combinaties was er maar één significant gerelateerd. Verder waren de territoria van grutto en tureluur geassocieerd met een hoge grondwaterstand. Territoria van kieviten waren marginaal significant negatief gerelateerd met bodemvocht. Beide resultaten komen overeen met bevindingen uit hoofdstuk 2. Geen enkele steltloper was eenduidig gerelateerd met prooiaanbod (wormen en emelten).

De tegenovergestelde preferenties van steltlopers die over het algemeen wel geassocieerd broeden zou erop kunnen duiden dat de voordelen van dichtbij elkaar broeden die van het broeden op de ideale plek overstemmen. Een andere verklaring zou kunnen zijn dat binnen een cluster van broedende weidevogels, elke soort zijn eigen optimale nestplaats heeft kunnen vinden.

Onze resultaten wijzen wederom op de essentiële rol van grondwaterstand voor broedende weidevogels, net zoals we in hoofdstuk 2 vonden. Daarom denken we dat (agrarisch) weidevogelbeheer zich hierop zou moeten richten. De hogere dichtheden aan grutto's en tureluurs op percelen met een hogere grondwaterstand zullen een aanlokkende functie hebben op andere weidevogelsoorten. Aangezien een hogere grondwaterstand waarschijnlijk ook leidt tot meer heterogeniteit binnen percelen, zullen de andere soorten binnen deze percelen ook een geschikte nestplaats kunnen vinden (en dit komt overeen met bevindingen uit hoofdstuk 4).

Hoofdstuk 6 richt zich expliciet op de relatie tussen weidevogels en de heterogeniteit van de percelen. De afname van heterogeniteit van percelen/grasmatten wordt herhaaldelijk genoemd als één van de oorzaken voor de achteruitgang van vogels van het boerenland (zie ook hoofdstuk 3, 4 en 5) en zou een reden kunnen zijn voor de tegenvallende resultaten van agrarisch natuurbeheer. Om het belang van heterogeniteit voor weidevogels te kwantificeren hebben we gedurende het gehele broedseizoen van 2005 in vier gebieden van minstens 100 ha het terreingebruik van weidevogels bepaald en dit gerelateerd aan een aantal perceelskenmerken (heterogeniteit, beheer en grashoogte).

Er bleken behoorlijke verschillen in heterogeniteit en beheer te bestaan tussen de verschillende gebieden en ook in de dichtheid van weidevogels. Aan het begin van het seizoen, toen de vogels bezig waren met de nestplaatskeuze, kwamen grutto, kievit en tureluur in de hoogste dichtheden voor op de meest heterogene percelen. Eind april, toen de meeste vogels op het nest zaten, haalden alle vier de steltlopers hun hoogste dichtheid op de heterogene percelen. Verder bleken standweides (met relatief lage veedichtheden voor langere tijd op een perceel) geliefd bij kieviten maar ook bij grutto's. De dichtheden van grutto en kievit waren sterk negatief gecorreleerd met het percentage van de percelen dat begraasd of gemaaid was. De dichtheden namen echter ook sterk af naarmate het seizoen vorderde, dus we waren niet in staat te bepalen of de factor beheer of tijd verantwoordelijk was voor de afnamen van vogels gedurende het seizoen. Overeenkomstig de sterke afnamen door het seizoen, zagen we erg weinig alarmerende vogels (een indicatie dat oudervogels kuikens hebben). De gruttofamilies die we wel zagen bleken niet naar de percelen met lang gras te trekken maar wel naar de heterogene percelen. Ouderparen met jongen van de kievit bleken een afkeer te hebben van percelen met lang gras, maar vertoonden geen reactie ten opzichte van heterogene percelen.

Zoals we al gesuggereerd hebben in vorige hoofdstukken, blijkt uit deze studie inderdaad dat de heterogeniteit van percelen van groot belang is voor individuele weidevogels ten tijde van de nestplaatskeuze, als ze aan het broeden zijn en ook voor gruttofamilies. Verder bleken standweides hoge dichtheden van verschillende soorten te herbergen. Daarom zou agrarisch weidevogelbeheer zich moeten richten op het verhogen van de heterogeniteit binnen percelen. Alternatieve beweidingsregimes zoals standweides zouden een manier kunnen zijn om dat te bereiken.

Concluderend kunnen we stellen dat op extensief beheerde Hongaarse landbouwgronden, met veel variatie binnen percelen, hoge dichtheden van bedreigde vogelsoorten aanwezig zijn. In West-Europa zijn praktisch alle percelen landbouwkundig verbeterd, dat wil zeggen geëgaliseerd, gedraineerd en regelmatig opnieuw ingezaaid. Wij hebben vastgesteld dat de huidige, relatief simpele vormen van agrarisch natuurbeheer die weinig ingrijpend zijn in de bedrijfsvoering van boeren weinig effectief zijn in het behoud van weidevogels. Wel vonden we in meerdere studies (in verschillende gebieden en met verschillende analysemethodes) hogere weidevogeldichtheden op percelen met een hogere grondwaterstand. Ook hebben we het belang van heterogeniteit binnen percelen aangetoond. Daarom stellen we dat meer ingrijpende vormen van agrarisch weidevogelbeheer, gericht op een verhoging van de grondwaterstand en een toename van heterogeniteit binnen percelen, nodig zijn voor het behoud van de hoge dichtheden van weidevogels in Nederland.

Dankwoord

Ik had mezelf nooit als aio gezien. Maar toen deze plek vrijkwam, heb ik niet lang getwijfeld. De toegepaste aard en de duidelijke link met de praktijk maakten het voor mij interessant. En nu ruim viereneenhalf jaar later, kijk ik terug op een periode waarin ik me met veel plezier heb verdiept in de weidevogels. Een aantal mensen hebben in meer of minder belangrijke mate bijgedragen aan de totstandkoming van dit proefschrift en die wil ik hier bedanken.

Ik begin met mijn begeleiders David Kleijn en Frank Berendse. David, als dagelijks begeleider liep ik in het begin van mijn project ook bijna dagelijks bij je binnen wat erg plezierig was. Naarmate het project vorderde nam je meer afstand, deels daartoe gedwongen omdat je aanstelling bij de vakgroep afliep en je uit Wageningen vertrok. Toen ik vlak voor het verstrijken van de deadline (van het inleveren van m'n proefschrift) nog steeds met twee hoofdstukken bezig was, heb je steeds op erg korte termijn commentaar geleverd. Dat waardeer ik heel erg. Daarnaast was je ook de initiator van het EU-project waarop ik aangesteld ben. De twee jaarlijkse bijeenkomsten met het EASY-team in verschillende EU-landen vormden hoogtepunten van mijn aio-tijd. Dus dat had je goed geregeld.

Frank, als promotor hield jij je naast de strakke begeleiding van David redelijk afzijdig. Wel dwong je me in de winter van 2004-2005 om mijn eerste artikel te schrijven over mijn aio-onderzoek. Dat had ik tot die tijd vakkundig voor me uitgeschoven maar jij accepteerde geen uitvluchten. Uiteindelijk ben ik erg blij dat je me over die drempel hebt geholpen. Verder heb ook jij in de stressvolle periode voor de deadline heel snel commentaar geleverd op de verschillende hoofdstukken zodat ik alles toch op tijd klaar had.

András Báldi, you were my supervisor during my practical period in Hungary. To you it was obvious that we would publish the results of our study somewhere. Because we found striking differences between categories, we were able to publish in an international scientific journal. That has certainly contributed to me realizing that research and thus doing a PhD could be fun and to the fact that I finally was employed in the EASY project.

In de eerste drie jaren heb ik veel veldwerk gedaan. Allereerst wil ik de eigenaren van de grond noemen die ons toestemming verleenden om percelen te betreden. Dit waren veelal boeren, maar ook natuurbeheerders en waterschappen. Tijdens het eerste jaar hielpen mensen van de agrarische natuurverenigingen Den Hâneker, De Utrechtse Venen, De Hollandse Venen en Ark-en Eemland ons met de selectie van de beheerspercelen. De uitvoering van de vergelijking tussen percelen met agrarisch natuurbeheer en gangbaar beheerde percelen voerde ik uit met een aantal studenten en onderzoeksassistenten van de vakgroep. Collega's Frans Möller, Henk van Roekel en Jan van Walsem hielpen mee met de bemonstering van de omgevingsfactoren, evenals de studenten Yvonne de Boer en Philip van Dijk. Merijn Salverda werd tijdelijk aangenomen op mijn project en samen met Philip hielp hij ook mee met het inventariseren van vogels. Philip, Yvonne en Merijn zochten verder de vangsten uit. Dat betekende wormen tellen en drooggewicht bepalen. Uit de (vaak stinkende) bodemvallen haalden jullie meer dan 17.000 loopkevers die vervolgens gewogen werden. De spinnen werden in andere potjes gestopt en die zijn gedetermineerd in Hongarije door Tamas Szuts. Foppe Bijleveld verzorgde samen met Yvonne de vegetatieopnamen. Johan Romelingh van de werkplaats van de WUR bleef het hele seizoen bezig met het maken van dakjes voor de bodemvallen omdat de koeien het liefst bovenop de deksels gingen staan. Willem Loonen voerde de kwantificering van de verschillende landschapstypen rond de bemonsterde percelen uit, iets dat mij weken gekost zou hebben.

In het tweede jaar deden we onderzoek aan gekleurringde weidevogels. Wim Tijsen bleek een flinke aantal tureluurs gekleurringd te hebben op Wieringen. In Friesland waren Willem Bil en Jack Schuurs van Vogelringstation Menork bezig met het volgen van een populatie gekleurringde kieviten. Wij konden aanhaken bij beide projecten en zodoende gebruik maken van elkaars ervaringen en inspanningen. Frank Jongbloed en Simone de Brock kwamen allebei een afstudeervak doen binnen dit project. Zij vertrokken naar Friesland en kregen onderdak bij Franks ouders. Vanuit daar bekeken ze eerst negen weken lang kieviten in midden-Friesland en staken vervolgens tien weken lang de afsluitdijk over om de tureluurs op Wieringen te bestuderen. Simone breidde de lengte van haar afstudeervak zelfs uit zodat ze de hele periode mee kon draaien. Doordat jullie heel erg zelfstandig te werk gingen, kon ik mijn tijd besteden aan de voorbereiding van een tweede project aan de afstand die bloembezoekende insecten afleggen. Bij een aantal boeren in de Gelderse Vallei mochten we 100 m^2 weiland inzaaien met bloeiende planten. Collega's Frans en Maurits Gleichman hielpen mee met het planten, omheinen en wieden van de perken. Johan Romelingh van de werkplaats van de WUR maakte ruim 100 raamvallen van 2.50 m bij 1 m. Met Frans en student Bjorn de Bakker plaatsten we de raamvallen. Vervolgens vingen we insecten in toenemende afstand van die bloemperken. Die vallen stonden over het algemeen langs of in beken. De waterschappen Vallei & Eem en Veluwe verleenden ons toestemming om de vallen daar te plaatsen. Frans en Marien Verhulst hielpen me aan het eind van het seizoen mee de vallen weer terug naar Wagenigen te brengen.

In 2005 deden we voor de tweede keer onderzoek in de Eempolders. Rob Kole van agrarisch natuurvereniging Ark-en Eemland was ons wederom van dienst met de selectie van de studiegebieden. Ook maakten we gebruik van de gegevens van de vrijwillige weidevogelbeschermers in de regio. Henk van Twillert, Yvonne Welner en Gert Bieshaar gaven ons inzicht in de locatie van de weidevogelnesten. Voor de uitvoering van dit project waren we in staat om Bas van de Meulengraaf en Idde Lijnse voor een paar maanden in te huren.

Mark Kuiper tenslotte (www.natuurbeleven.nl) stelde zijn foto's beschikbaar voor het opleuken van mijn proefschrift.

Alle collega's van de NCP en de REG groep in het TON gebouw aan de Bornsesteeg zorgden voor een goede werksfeer. Op de valreep verhuisden we naar Lumen en verruilden we de houtwal met houtsnip voor de pingpongtafel.

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Geert de Snoo streek in 2004 als bijzonder hoogleraar agrarisch natuur- en landschapsbeheer neer in onze groep. Geert, voor mij was het een erg welkome aanvulling dat er iemand bij kwam met interesse in het platteland. De samenwerking met jou, vooral via het begeleiden van studenten was erg leerzaam. Bovendien was je dit voorjaar in staat om financiering te regelen voor het vervolg op een succesvol studentenproject uit 2006. Hierdoor kon ik afgelopen voorjaar toen mijn contract bij de universiteit net afgelopen was, weer lekker het veld in. Via Dick Melman was ik tot 1 september 2007 bij Alterra in dienst. Dick, ook jou wil ik bedanken voor de flexibiliteit die je me hebt gegevens om mijn werkzaamheden uit te voeren. Door de drukte van het afronden van m'n proefschrift ben ik pas net met de verwerking van de gegevens van afgelopen voorjaar bezig, maar daar heb jij geen moment moeilijk over gedaan.

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Allen, heel hartelijk bedankt
Thanks to you all

Jort, Wageningen, augustus 2007.

CV

Curriculum vitae

Jort Verhulst werd op 20 mei 1977 geboren te Nagele in de Noordoostpolder. Vanaf 1989 tot 1995 bezocht hij het Zuyderzee College. Na het behalen van zijn diploma begon hij in 1995 met de studie Bosbouw aan de Landbouwuniversiteit Wageningen. Deze opleiding vond hij beter aansluiten bij zijn interesse in natuur in het algemeen en vogels in het bijzonder dan biologie en hij was dus ook aangenaam verrast toen de opleiding al tijdens zijn eerste jaar werd omgedoopt in Bos-en Natuurbeheer. Hij koos voor de richting natuurontwikkeling in de gematigde zone, want die bevatte veel ecologische/natuurbeheer vakken. In 1999 werkte hij tijdens zijn eerste afstudeervak bij Alterra aan de calibratie van een computermodel dat duurzaamheid van metapopulaties beoordeelt. Dit afstudeervak leidde niet tot een hechte band met computermodellen. Daarom ging hij in de winter van 1999-2000 voor zijn volgende afstudeervak lekker naar buiten, vogels kijken bij Alterra op Texel. Hij draaide mee in de evaluatie van de effecten van kokkelvisserij op wadvogels. Binnen dit onderzoek bekeek hij de ruimtelijke verdeling van scholeksters op kokkelbanken. Na deze afstudeervakken groeide het besef dat hij vooral geïnteresseerd was in de vogels van agrarische systemen. Dr. David Kleijn van de vakgroep Natuurbeheer en plantenecologie (die toevallig net een onderzoeksvoorstel had ingediend bij de Europese Unie over de effectiviteit van agrarisch natuurbeheer) had contact met Dr. András Baldi van de Animal Ecology Research Group, Hungarian Academy of Sciences. Dus vertrok Jort in het voorjaar van 2002 naar Hongarije en deed tijdens zijn stage onderzoek naar de relatie tussen agrarische beheersintensiteit en vogels. De resultaten leidden tot een publicatie en dat zal er zeker toe bijgedragen hebben dat hij in januari 2003 als promovendus aangesteld werd op een project over de effectiviteit van agrarisch natuurbeheer bij de leerstoelgroep Natuurbeheer en Plantenecologie van Wageningen Universiteit. De resultaten van dat onderzoek zijn vastgelegd in dit proefschrift.

List of publications

- Kohler, F., **Verhulst, J.**, van Klink, R. & Kleijn, D. *At what spatial scale do high-quality habitats enhance the diversity of forbs and pollinators in intensively farmed landscapes?* Journal of Applied Ecology xx: xx-xx.
- **Verhulst, J.**, de Brock, S., Jongbloed, F., Bil, W., Tijsen, W. & Kleijn, D. 2007. *Spatial distribution of breeding meadow birds - implications for conservation and research.* Wader Study Group Bulletin 112: 52-56.
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The SENSE Research School declares that Mr. Jort Verhulst has successfully fulfilled all requirements of the Educational PhD Programme of SENSE with a work load of 36 ECTS, including the following activities:

SENSE PhD courses:

- Research Context Activity:
  Organizing End symposium EU-project EASY, January 2006, Wageningen, The Netherlands.
  Organizing session "Farmland birds in a changing environment" at the SENSE SUMMER SYMPOSIUM 2006, 23 June 2006, VU Amsterdam.

Other PhD and MSc courses:

- Applied Statistics
- Estuarine Ecology
- Scientific writing
- Scientific publishing
- Media skills for scientific researchers
- Teaching and supervising Thesis students
- MSc course: Nature and landscape conservation by farmers

Oral Presentations:

- SENSE Summer symposium 2006, 23 June 2006, Amsterdam, The Netherlands
- IX International Congress of Ecology (Intecol), 7 - 12 August 2005, Montreal, Canada
- Annual meeting of the British Ecological Society (BES), 4 - 7 September 2005, Hatfield, UK
- 1st European Congress of Conservation Biology, 22 - 26 August 2006, Eger, Hungary

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Picture of JV (page 126) by Yvonne de Boer

Cover picture: Extensively managed grasslands in the Oostermeent (Eempolders, Noord-Holland), by JV.