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BIRD POPULATIONS IN LATVIAN FARMLAND: PATTERNS AND TRENDS

PUTNU POPULĀCIJAS LAUKSAIMNIECĪBAS ZEMĒS LATVIJĀ: IZVIETOJUMS UN IZMAIŅU TENDENCES

Thesis for Doctor's Degree in Biology, Zoology

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Bird Populations in Latvian Farmland: patterns and trends

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This thesis is based on the following articles:

I Aunins A., Petersen B. S., Priednieks J., Prins E. 2001. Relationships between birds and habitats in Latvian farmland. *Acta Ornithologica* 36/1: 55–64.

II Aunins A., Priednieks J. 2003. Bird population changes in Latvian farmland 1995 – 2000: responses to different scenarios of rural development. *Ornis Hungarica* 12-13: 41–50.

III Prins E., Petersen B. S., Aunins A., Priednieks J. 2005. Using Landsat TM and field data to produce maps of predicted bird densities in Latvian farmland. *International Journal of Remote Sensing* 26/9: 1881–1891.

IV Aunins A., Priednieks J. 2008. Ten years of farmland bird monitoring in Latvia: population changes 1995 – 2004. *Revista Catalana d'Ornitologia* 24: 53–64.

V Herzon I., Aunins A., Elts J., Preikša Z. 2008. Intensity of agricultural land-use and farmland birds in the Baltic States. *Agriculture, Ecosystems & Environment* 125: 93–100.

VI Aunins A., Priednieks J. (in press). Recent changes in agricultural landscape and bird populations in Latvia: current impacts of EU agricultural policy and future prospects. In: Proceedings of the 17th International Conference of the EBCC: Bird Numbers 2007 Monitoring for Conservation and Management. *Avocetta* (accepted, final proof available).

Contributions

	I	**II**	**III**	**IV**	**V**	**VI**
Original idea	AA	AA	EP, AA	AA	IH	AA
Logic of reasoning	AA, BSP	AA	EP, BSP, AA	AA	IH, AA	AA
Data collection and preparation	AA, JP, AAv, others[3]	AA, JP, AAv, others[3]	AA, EP, JP, AAv, others[3]	AA, JP, AAv, others[3]	IH, AA, JE[1], ZP[2], JP, AAv others[3]	AA, JP, AAv, others[3]
Analyses	AA	AA	EP, AA, BSP	AA	IH	AA
Manuscript	AA, BSP, JP, EP	AA, JP	EP, BSP, AA, JP	AA, JP	IH, AA, JE, ZP	AA, JP

AA – Ainārs Auniņš, JP – Jānis Priednieks, AAv – Andris Avotiņš, EP – Erik Prins, BSP – Bo Svenning Petersen, IH – Irina Herzon, JE – Jaanus Elts ([1] and Estonian fieldworkers), ZP – Žydrunas Preikša ([2] and Lithuanian fieldworkers)

[3] others (Ivars Kabucis, Elga Strazdiņa, Oskars Keišs, Valdis Cīrulis, Vija Kreile, Baiba Bambe, Inga Avotiņa, Otars Opermanis) participated in one or several (up to 5) field seasons in the period 1995 - 2006

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Annotation

The complex relationships existing in Latvian farmland between birds, their habitats and farming practices are explored in this Thesis using quantitative analysis methods. Main ecological gradients affecting bird distribution have been identified as well as the main factors affecting species richness. Species-habitats models have been built for 30 bird species and role of different habitats and landscape features in Latvian farmland assessed as well as impact of farming intensity on bird abundance and species richness proven. Application capabilities of the species-habitats models in building maps of predicted species densities and using habitat variables derived form remote sensing data are demonstrated. Trends of bird population changes in Latvian farmland from 1995 to 2006 are analysed in context of ongoing changes in the agricultural sector.

Considering plight of farmland bird populations in Europe, the results of this study are important for planning and justifying conservation measures in Latvian farmland.

Anotācija

Šajā promocijas darbā ar kvantitatīvām metodēm analizēta kompleksā saistība starp putnu sugām un biotopiem to mijiedarbība ar lauksaimniecību Latvijā. Darba ietvaros identificēti galvenie sugu izplatību noteicošie vides gradienti, kā arī galvenie faktori, kas ietekmē sugu daudzveidību. Izstrādāti sugu-biotopu attiecību matemātiskie modeļi 30 putnu sugām un novērtēta dažādu biotopu un ainavas elementu nozīme Latvijas lauku ainavā, kā arī pierādīta lauksaimniecības intensitātes ietekme uz sugu daudzveidību un īpatņu skaitu. Demonstrēta sugu-biotopu attiecību modeļu pielietošana sugu izplatības prognozēšanā, aprēķinot to prognozētā blīvuma kartes un kā biotopu mainīgos izmantojot attālās izpētes ceļā iegūtus datus. Darbā analizētas putnu populāciju izmaiņu tendences Latvijas agroainavā no 1995. līdz 2006. gadam saistībā ar lauksaimniecības sektorā notikušajām izmaiņām.

Ņemot vērā lauku putnu populāciju katastrofālo stāvokli Eiropā kopumā, pētījuma rezultātiem ir būtiska loma, plānojot un pamatojot vides saglabāšanas un uzlabošanas pasākumus Latvijas laukos.

Contents

1. Introduction

Agriculture and biodiversity

It has been recognized that the current rate of global biodiversity loss more than ten times exceeds Earth's planetary boundaries which may result in disastrous consequences for humanity (Rockström et al. 2009). Global indicators do not show any significant reductions in the rates of biodiversity declines despite international commitment to achieve it (Butchart et al. 2010). Loss of biodiversity has been observed in all types of ecosystems in the world where studies have been carried out and human activities have been recognized as a main driver behind it (Vitousek et al. 1997, Sala et al. 2000, Gaston et al. 2003, Ibisch, Bertzky 2006 and many others). Expansion of agricultural land has been recognised as one of the most significant human induced change to Earth's environment (Tilman 1999). As this expansion results in decreased areas of natural habitats it causes declines and extinctions of species associated with them. Being an ecosystem with lower biological capacity compared to natural ecosystems, increase of agricultural areas result in lower numbers of living individuals (Teyssedre, Couvet 2007). On the other hand, significant amount of biodiversity is associated with farmland and farmland has proven its capability to maintain relatively high biodiversity (Baldock et al. 1993, Beaufoy et al 1994). Moreover, many species have become farmland dependant and their survival is not possible without farmland (Kristensen 2003). The fate of biodiversity is closely linked to agricultural development and as the demands on agricultural lands continue to expand, effective strategies are urgently needed to balance biodiversity conservation and agricultural production (Fischer et al. 2008). Thus interactions of farmland management with biodiversity have become one of the key topics in ecological literature during the last decades (Matson et al. 1997, Ormerod, Watkinson 2000, Butler et al. 2007).

Increased demand for food and other goods that are obtained from cultivated lands due to growing human population and its living standards has been and still is the main driver behind further increase of areas used for agriculture as well as intensification of the existing areas (Foley et al. 2005). Intensification of agriculture has proven to have devastating effect on diversity and numbers of individual species in various taxa (Green et al. 2005, Conrad et al. 2006). However, it allows more effective use of existing agricultural lands thus reducing the pressure on natural territories and their conversion rates.

Two dominant strategies to balance biodiversity conservation and agricultural production currently proposed - "land sparing" and "wildlife-friendly farming" (Chappel et al. 2009). In land sparing, homogeneous areas of farmland are managed to maximize yields, while separate reserves target biodiversity conservation. Wildlife-friendly farming, in contrast, integrates conservation and production within more heterogeneous landscapes (Fischer et al. 2008). Both social and biophysical factors influence which approach is feasible or appropriate in a given landscape. It has been suggested that in regions where development of agriculture has started recently and it is connected with converting natural ecosystems to farmland, land sparing is more appropriate. In areas with long farming traditions, where conversion to farmland had taken place for centuries, wildlife-friendly farming is recommended (Green et al. 2005).

Agriculture and farmland birds in Europe

Farmland is the most important type of land use in Europe, with 34% of the European terrestrial area used for crop production and 14% for grassland (Verburg et al., 2006). It has formed thousands of years and many species have adapted to this ecosystem. There are species associations that are unique to European farmland. Europe is very diverse regarding agroecosystems and their quality. The highest biodiversity can be found in Spain and the New EU Member States (Reidsma et al. 2006).

Assessment of the conservation status of European birds shows that 58% of farmland bird species with known trends are currently declining and this is the largest proportion of all habitat associations (BirdLife International 2004). Agricultural intensification and abandonment of farmland are mentioned as the two main threats to European farmland birds currently. Farmland in intensive systems tends to support relatively few species of macrofauna (Benton et al. 2003, Tscharntke et al. 2005) while continuous abandonment of farmland results in overgrowing with trees and bushes thus becoming unsuitable for most of farmland birds. It has been shown that extensive agriculture has the highest biodiversity value (Osterman 1998) and low-intensity farming systems are critical to nature conservation and protection of the rural environment (Bignal, McCracken 1996), while large-scale input-intensive systems can cause major environmental problems in agricultural and surrounding non-agricultural ecosystems (Donald et al. 2001, Benton et al. 2002).

Agricultural development in Europe

During the second half of the 20th century, agriculture and the rural environment diverged in Western and Central and Eastern European countries. The main driver during the last 50 years has been the agricultural policy and it was clearly defined by the political system being different in so called “capitalist” and “socialist” blocs.

Post-war agricultural policies in the “capitalist” bloc focused mainly on increasing agricultural productivity by promoting technical innovations and by ensuring the rational development of agricultural production (Reidsma et al. 2006). It resulted in increased yields due to increased use of agrochemicals, changes in timing and practices of farming works. The process was particularly accelerated with the early CAP (Common Agricultural policy) of the EEC which promoted intensification by linking subsidies to production (Pain, Pienkowski 1997). However, increased agricultural intensity has also resulted in an increasing pressure on biodiversity (Tilman et al. 2001). At the same time marginal areas became abandoned as they could not survive the competition that also resulted in biodiversity loss.

Prior to their transition to market economies, CEE countries supported agriculture through state ownership and planning. Agriculture in these countries was characterized by the extensive use of heavy machinery and by the high rates of fertilizer and pesticide usage (Liira et al. 2008). Although cereal yields (proxy for the farming intensity) were constantly growing during 1970-ties and 1980-ies, they, however, always stayed behind those achieved in the EEC countries (Fig. 1.1). After collapse of the socialist economic bloc and during transition of the economies, the costs of variable inputs, such as fertilizers or pesticides, increased at a higher rate than did wages, causing a decline in agricultural intensity (Donald et al. 2002). Agricultural sector in CEE countries experienced a strong decrease in most of parameters since the late eighties, and in many cases the decrease in production has even been two or threefold (Liira et al. 2008, Anon. 2010a). Next wave of changes in farming practices in Eastern Europe started to take place when these countries started preparation for EU accession. The result was the focus shift from traditional farming methods, small scale farming and the diversity of crops and animals, in favour of more intensive and specialised agriculture.

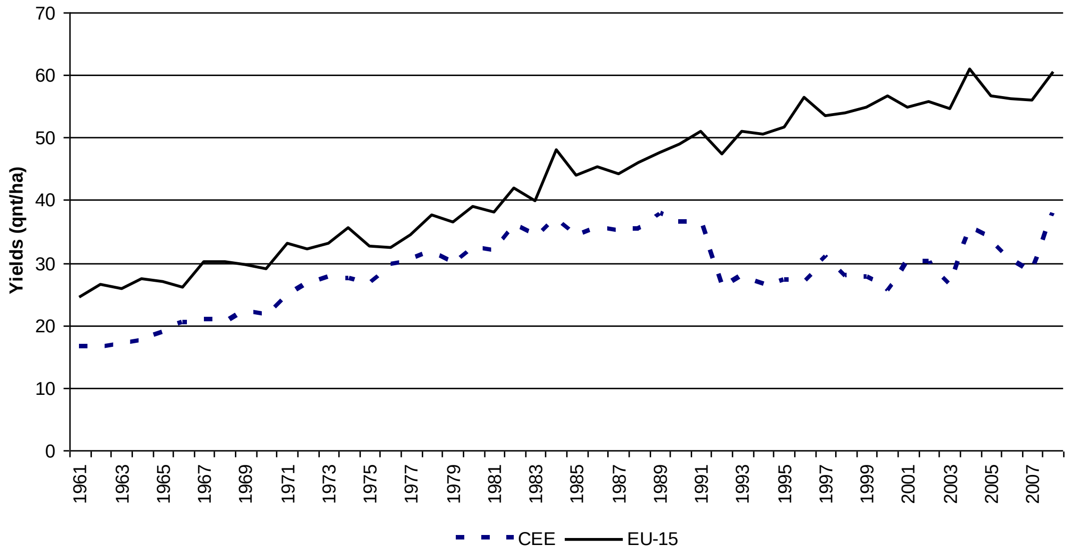


Figure 1.1. Changes in mean cereal yields in central and Eastern European countries (CEE) and the old EU member states (EU-15). Data from Anon 2010a.

Farmland bird population changes in Europe

The European Farmland Bird Indicator (an aggregated index integrating the population trends of 36 common bird species associated with farmland habitats across 22 countries, Gregory et al. 2005) shows that over the last three decades farmland birds have significantly declined in Europe and the trend is not shared by species of the other largest ecosystem – forests. The most rapid decline of the index took place until mid 1980-ies. Although decline is present in both old and new EU countries, the decline in the later has been less pronounced and periods of increase can be observed (PECBMS, 2010).

A number of reasons are given to explain the dynamics in bird populations in European agricultural lands. Two main groups can be distinguished – one is connected with changes in agricultural practices leading to intensification, the other is connected to abandonment. Effects of agricultural intensification on farmland biodiversity have been studied in details in the Western and Northern Europe. The wealth of studies on bird declines have been carried out in UK (Fuller et al. 1995, Siriwardena et al. 1998, Chamberlain et al. 2000 and many others). Declines are reported also from other western European (Flade, Steiof 1990, Saris et al. 1994), Fennoscandian countries (Tiainen, Pakkala 2001, Wretenberg et al. 2006, but see Fox 2004) and Czech Republic (Reif et al. 2008b).

Traditional farming practices were beneficial for certain bird species and contributed to maintenance of their populations. Intensification of agriculture resulted in phasing out of these practices and number of studies have proven its negative impact on farmland bird populations (Matson et al. 1997, Chamberlain et al. 2000, Donald et al. 2001, 2006). Intensification consists of several processes acting both on landscape and field level (Stoate et al. 2001, 2009). Agricultural specialization when farms are specializing in production of certain types of products leads to uniformization of landscape, reduced patchiness and lower proportion of set-aside. Role of ecological heterogeneity in farmland is not disputed (Benton et al. 2003). For example, the abundance of edge and farmyard species is positively correlated with the amount of field variety, combinations of crop and grasslands, presence of structural elements such as field margins, fences, hedges, ditches (Herzon, O'Hara 2007). Mid-field marsh patches in agricultural lands are very important for *Acrocephalus* warblers (Surmacki 2005). However, it has to be noted that the effect of habitat heterogeneity may differ in relation to spatial scale at which it is measured (Tews et al 2004). Nagy et al. (2009) show importance of the areas with small parcels in comparison with large scale fields for several farmland species. Massive switch from spring to winter cereals led to higher and denser vegetation at the beginning of bird breeding season thus reducing suitability and reducing nesting success (Wilson et al. 1997, Chamberlain et al. 1999). Increased use of agrochemicals reduces availability of food items while mechanised cultivation destroys nests (Campbell et al. 1997).

Farmland abandonment is another group of factors causing significant biodiversity loss and declining bird populations. In Czech Republic during the period of farmland abandonment farmland bird populations were highest in years with the most intensive agriculture (Reif et al. 2008b). Positive impact of set-asides and negative impact of long-term abandonment on populations of farmland birds has been shown in a number of studies (e.g. Orłowski 2005, Nagy et al. 2009). The decline of farmed areas in Eastern Europe is the main issue of concern with respect to impacts on biodiversity (European Environment Agency 2004). Abandonment of farmland, particularly where farming conditions are unfavourable and not supported by EU area payments, leads to impoverished ecosystems. Although starting management of such land would be the best solution, most of it will not return to cultivation unless eligibility criteria are changed and this will have negative impact on several farmland species (Nagy et al. 2009).

In addition to ecological conditions in the species breeding areas, the importance of conditions in the wintering sites has been noted. It has been shown that population trends of Afro-Palearctic migrant birds are worse than those of species wintering in Europe and both breeding and over-wintering factors influence population trends (Sanderson et al. 2006, Thaxter et al. 2010).

Regarding restoration of farmland bird populations in Europe it has been suggested that if agricultural practice has reduced the populations, then agricultural practice can also restore the losses. Broad scope of measures has been suggested – from micro (how to modify local land structure to benefit birds) to macroscopic (suggested policy changes; Ormerod, Watkinson 2000). In response to biodiversity loss in the old EU countries and suggested measures to prevent it (Donald et al. 2002), environmental objectives and landscape preservation in recent years have become prominent issues in the EU Common Agricultural Policy and related environmental policies. The CAP reform has taken place and the payments have been decoupled from production. In addition, all EU Member States are currently required to implement agri-environment measures to protect and restore farmland environmental quality. However, measures currently implemented in EU regulations are strongly biased towards conditions existing in the old EU countries and are dealing mostly with problems caused by intensification than abandonment. Concerns on effectiveness and sufficiency of these measures have been raised as they often do not reach their targets (Kleijn, Sutherland 2003). To make agri-environmental schemes and conservation measures applicable to the new EU countries, it is necessary to carry out studies in these countries, to quantify changes in farmland bird species richness and abundance that are likely to result from agricultural change. The differing ecological conditions and lower level of agricultural intensity make extrapolation from similar research in Western Europe unreliable (Sanderson et al. 2009).

Development of agriculture in Latvia (1990 – 2009)

The proportion of agricultural land in Latvia has continuously been declining during the 20th century due to overgrowing and replacement with forests. Currently reported total area of agricultural land in Latvia is 24339 km^2, which is 37.7% of its terrestrial area. However, only ca 18330 km^2 or 75% of it are in active use. The rest is abandoned lands which are in different stages of overgrowing. From the active farmland 64% is arable lands and 36% - grasslands (Anon. 2010b).

Agricultural sector experienced dramatic changes in the late 20th century due to political and economical changes in Latvia. After the period of fairly intensive agriculture during Soviet era, agricultural production index steeply fell down. Compared to 1990, it halved in 1994 and reached its lowest point in 1999. Since then agricultural production is steadily increasing, however, it has not reached the previous level yet (Fig. 1.2A).

These changes resulted in abandonment of large areas of farmland. The proportion of abandoned lands reached 40% in late 1990-ies. The number of cattle declined more than twofold by the mid-1990-ies, and application of mineral fertilizers decreased almost tenfold (Fig. 1.2B, C). Due to land reform structure of land owners changed from large collective farms to small individual farms. Return of the land to the previous owners and their descendants resulted not only in rapid abandonment but also in ploughing of permanent grasslands as the new owners established their crop fields. At this time also invention of new and more intensive farming practices started to take place so the average cereal yields soon reached and surpassed the Soviet time level and is still constantly growing (Fig. 1.2D). Although the intensity level still does not reach the level characteristic for the Western Europe (Anon 2010b), it is not far behind the level present in the old EU countries at the time when collapse of farmland bird populations started (Anon. 2010a).

Although the recovery of the agricultural sector in Latvia started from mid 1990-ies, the most rapid development was after Latvia joined EU in 2004. Since then funding allocated to agricultural sector increased several times due to EU subsidies and direct payments (fig. 1.3A), modernisation of farms and a rapid increase of active farmland, took place. Previously abandoned lands were converted to arable or became managed grassland to become eligible to receive EU payments (Fig. 1.3B). Small scale farming is still characteristic for Latvia – 2/3 of the farms had less then 10 ha active farmland in 2007. However, there is a clear tendency for a number of small farms to decline and the number of large farms to increase (Anon. 2010b).

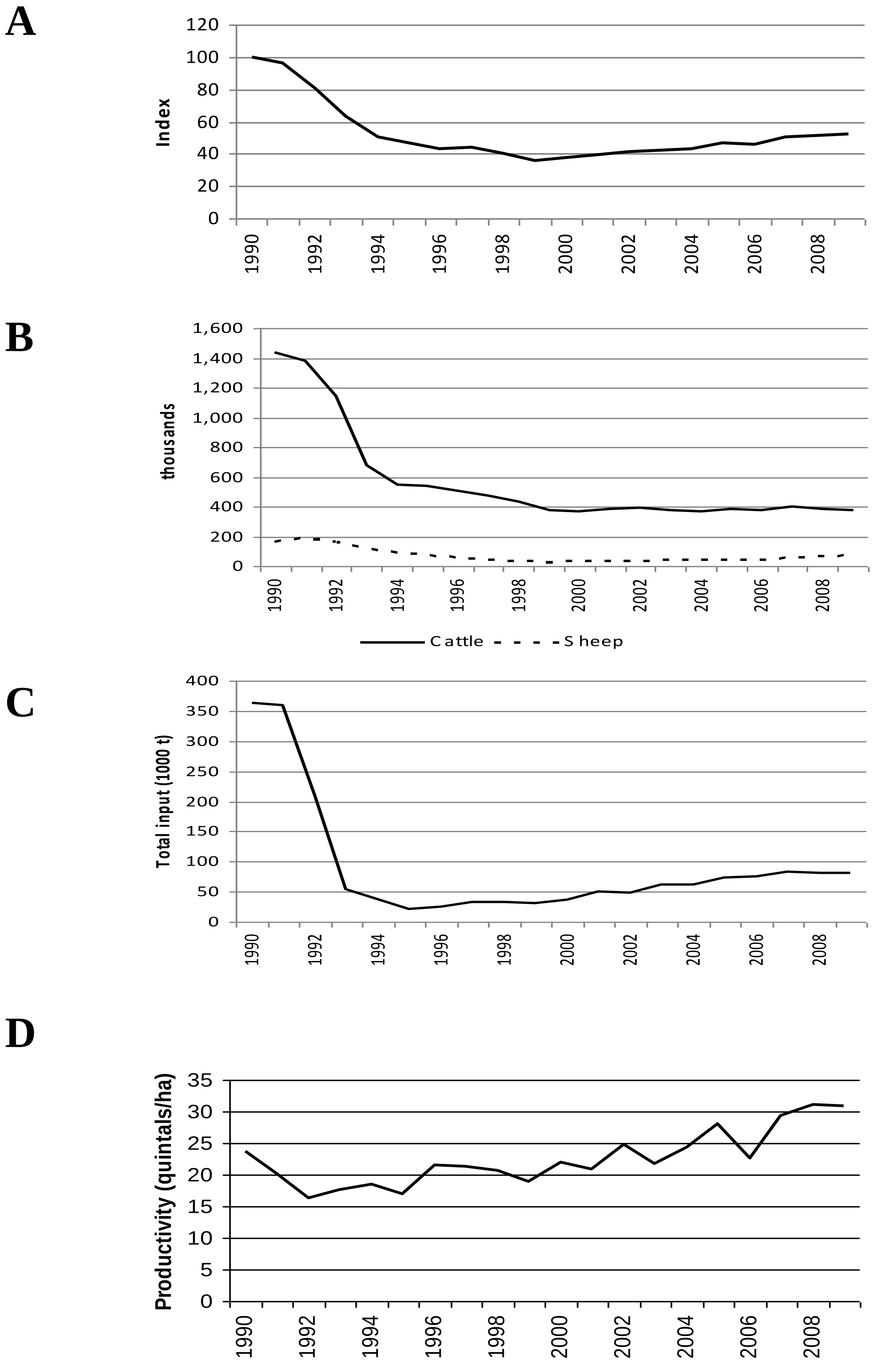
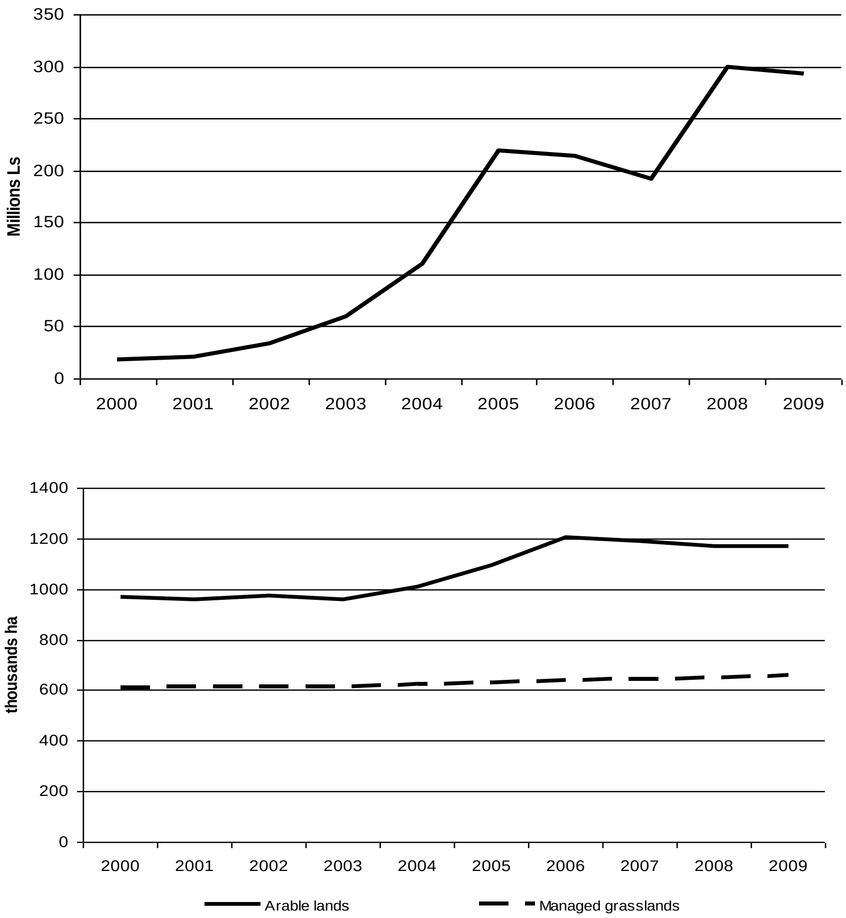


Figure 1.2. Changes of important agricultural measures in Latvia (1990 – 2009). A – agricultural production index , B – livestock, C – application of mineral fertilizers, D – cereal yields (Anon 2010b).

A



B

Figure 1.3. Changes in investments into agriculture (A) and areas of the main categories of agricultural lands (B) (2000 – 2009; Anon 2010b)

Previous studies of farmland birds in Latvia

Farmland birds were practically neglected during Soviet era and early 1990-ies, as ornithological studies in Latvia focused mostly on wetlands and forests. Baseline distribution data for most of the farmland bird species were collected during the first Latvian Breeding Bird Atlas (19080 – 1984) along with other species (Priednieks et al. 1989). Although the common bird monitoring scheme covering also farmland existed from 1983 to 1994 (see details in chapter about bird monitoring), its data has not been analysed in the context of changes in Latvian agriculture. Two species specific monitoring programmes (Corncrake *Crex crex* and White Stork *Ciconia ciconia*) were launched in 1989 and are the only studies providing information on changes in densities or breeding success in this transition period (Janaus 2000, Keišs 2005). Additionally large scale surveys were carried out for these two flagship species: countrywide counting of White Stork nests in 1984 and 1994 – 1995 (Janaus, Stīpniece 1989, 2000) as a part of an international survey and special countrywide Corncrake survey (Keišs 1997).

It was shown that densities of Corncrake rapidly increased during 1990-ies (Keišs 2005). Although the highest densities Corncrake reached in natural wet (floodplain) grasslands (Keišs 2004) due to limited distribution of this habitat it cannot play an important role countrywide. Study on Corncrake habitat preferences in Latvia showed that majority of the species population occurs in different kinds of grasslands including abandoned lands before bush encroachment (Keišs 1997). Importance of them was shown on later studies thus it is feasible to conclude that the population increase has taken place on expense of increased areas of abandoned lands. However, as a temporary habitat it cannot provide suitable breeding areas on a long run – encroachment of bushes and subsequent overgrowing renders it unsuitable for the species (Keišs 2005). Importance of extensive farmland, especially grassland and abandoned lands has been shown also for Lesser Spotted Eagle *Aquila pomorina* as a feeding habitat (Bergmanis 1999).

Similarly, population of the White Stork increased between the two countrywide nest counts by 30% (Janaus, Stipniece 2000). The increase was confirmed also by the annual monitoring data (Janaus 2000). Extensification of agriculture (decreased drainage, decrease in application of fertilizers and pesticides, etc.) has been mentioned as the main reasons behind the observed population increase (Janaus, Stīpniece 2000).

Another farmland species studied was Great Snipe *Gallinago media*. Countrywide inventory of the species (1999 – 2001) showed that in contrary to the previous reports (Страздс 1983, Lipsbergs et al. 1990) it has not gone extinct as a breeder in Latvia and leks of the species still occur in large, wet floodplain grasslands (Auniņš 2001). However, farmland abandonment and lack of grassland management was found as a threat to the species and almost all leks found during the inventory were located in unmanaged grasslands. It was concluded that the species tolerates lack of management very well until encroachment of shrubs significantly decreases open grassland area (Aunins 2000, Auniņš 2001). Great Snipe monitoring started in 1999 confirmed the negative role of overgrowing with bushes as size of species leks continuously declined. Special management measures in the Great Snipe breeding areas since 2004 allowed reversing population trend of the species (Aunins 2010).

The only study on impact of farming practices on survival of nests of ground nesting birds was the study of breeding biology of Lapwing *Vanellus vanellus* in arable lands and semi natural habitats (cf. grasslands) in study plots located in central Latvia. The study showed that hatching success in arable lands is significantly lower than in more natural habitats (Opermanis, Auniņš 1995). Most of the nests and eggs laid early in the season were destroyed by mechanized cultivation and the percentage of surviving nests in this period was negligible. The survival of second clutches was significantly higher, however, egg size in the replacement clutches were significantly lower than in first clutches thus reducing probability of survival of the hatched young. The highest breeding success was recorded in grasslands and was on the same level as in other studies in similar habitats in Europe (Opermanis, Auniņš 1995).

Before starting this study no representative information on farmland bird populations and their changes in Latvia was available except those few mentioned above. No quantified information on importance of specific farmland habitats and features in landscape as well as their role for specific species were available. The farmland related bird species of European conservation concern were underrepresented in the system of protected nature territories before accession to EU (Opermanis et al. 2008). As major changes in agriculture were expected after accession to EU, it was very important to establish baseline and follow bird populations to allow timely reaction to negative changes.

Monitoring bird populations

The complexity of interactions and the high number of species in most ecosystems makes it extremely difficult to measure biodiversity as a whole. However, birds can be a useful indicator of biodiversity in agricultural land (Gregory 2006).

Large-scale monitoring of bird populations, through generic programmes in the sense of census schemes that cover a wide range of bird species, arose largely independently in a number of European countries. The first annual monitoring scheme for breeding birds was the Common Birds Census in the UK, which started in 1962 and used a mapping survey method (Marchant 1983). It was soon followed by Sweden, Denmark and Finland. Currently monitoring schemes exist in majority of European countries. Monitoring data is used not only for describing the ongoing changes in bird populations but also in more detailed ecological studies (e.g. Fuller at al. 1997, Wretenberg et al. 2007, Reif et al. 2008 and many other studies).

The first standardised counts in Latvia are dated back to 1963 when Aivars Mednis established bird count routes in Kurzeme (A. Mednis, pers. comm.). However, the first long-term scheme involving many routes and bird counters started in 1983 when Jānis Priednieks and Elmārs Pēterhofs organised the First Latvian common bird census. The scheme covered different habitats, including farmland. The scheme was active until 1994. Data from this monitoring scheme has been used for discussing methodological aspects of the line transect method (Peterhofs, Priednieks 1989) and developing new data analysis methods (van Strien et al. 2001)., However, full analysis of this dataset unfortunately is yet to be carried out. A point count based farmland bird monitoring scheme that provided data for this study was started in 1995 (Priednieks et al. 1999) and was active until 2006 when it was replaced with the new Latvian breeding bird monitoring scheme started a year earlier (Aunins 2009).

Common bird Census in Estonia was started at the same time as in Latvia (1983) and a year later in Lithuania. Unfortunately the latest published results from these schemes are for the periods until 1998 for Estonia (Kuresoo, Ader 2000) and 1995 for Lithuania (Kurlavicius 2004).

2. The Aim and Tasks of the Thesis

The Aim of the Thesis

The main aim of this work is to explore bird-habitat relationships existing in Latvian farmland and to analyse changes in bird populations to identify the main factors behind them.

Tasks of the Thesis

1. Identify main environmental gradients and factors influencing bird species richness and abundance in Latvian farmland (Article **I** and **V**).
2. Provide Latvian farmland specific statistical models describing the relationship between the abundance of bird species and various landscape and habitat features (Article **I** and **III**).
3. Demonstrate potential of remote sensing to predict bird distribution and densities applying species-habitat models to unknown locations (Article **III**).
4. Investigate changes in bird species richness and abundance in Latvian farmland in connection with changes in agricultural land use and intensity (Article **II, IV** and **VI**).

Scientific novelty of the study

This study is the first that explores the complex relationships between birds, their habitats and agricultural practices in Latvian farmland using quantitative methods. The obtained multi-factorial species-habitats models mathematically describe ecological niches for 30 farmland bird species which are the first of this kind developed for Latvian birds. This was the first study in Latvia demonstrating potential of these models in prediction of density distribution of wildlife species using GIS methods and remote sensing data. This is the first study in Latvia quantitatively analysing population trends of the common farmland bird species in the context of changing environment.

Approbation of the results

The results of the thesis are published in the 6 articles forming the thesis. The results have been presented in 5 international conferences. The author has 10 other publications related to farmland birds and farmland management.

International conferences

Aunins A., Petersen B. S., Priednieks J., Prins E. 1999. (poster) Relationships between birds and habitats in Latvian farmland. The 2nd Conference of the EOU, Gdansk, Poland, 15–18 September 1999.

Aunins A., Priednieks J. 2001. (oral) Bird population changes in Latvian farmland 1995 – 2000: responses to different scenarios of rural development. The 15th International Conference of the EBCC: Bird Numbers 2001. Monitoring for Nature Conservation, Nyiregyhaza, Hungary, March 26–31, 2001

Aunins A., Priednieks J. 2004. (oral) Ten years of farmland bird monitoring in Latvia: population changes 1995 – 2004. The 16th International Conference of the EBCC:

Bird Numbers 2004. Monitoring in a Changing Europe, Kayseri, Turkey, September 6–11, 2004

Aunins A., Racinska I. 2006. (oral) Restoration of Latvian floodplains for EU priority species and habitats. International Conference "Farming practices and the conservation of humid grasslands/meadows in the European Union", Jūrmala, Latvia, November 9–10, 2006

Aunins A., Priednieks J. 2007. (oral) Recent changes in agricultural landscape and bird populations in Latvia: current impacts of EU agricultural policy and future prospects. The 17th International Conference of the EBCC: Bird Numbers 2007 Monitoring for Conservation and Management. Chiavenna, Italy, April 17–22, 2007.

Additional scientific publications by author related to farmland birds or farmland management

Aunins A. 2000. Results of Great Snipe survey in Latvia in 1999. *OMPO Newsletter* 21: 39–45.

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3. Material and methods

All material presented in this thesis has been collected as a part of the Farmland Bird monitoring programme from 1995 to 2006. Both bird data and habitat/landscape feature data were recorded during the fieldwork.

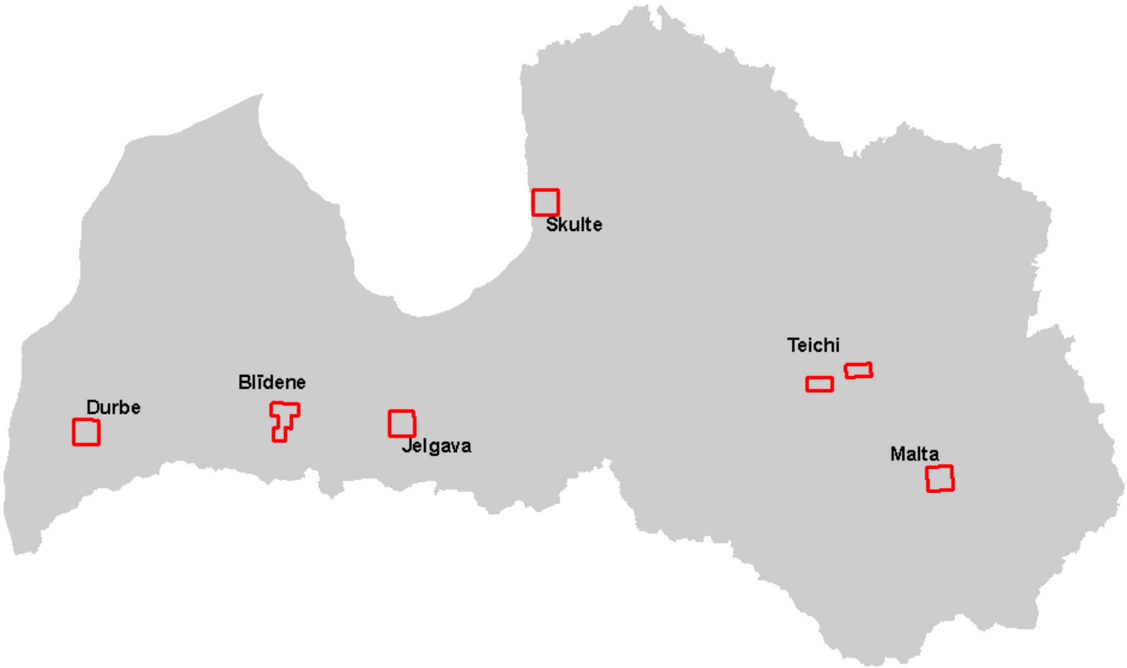


Figure 3.1. The location of the six study sites.

Study sites

The fieldwork was carried out in 6 study sites with a size of 100 km^2 each, located in different regions of the country (Figure 3.1), each representing different habitat composition, landscape structure and dominating farmland practices (Table 3.1). Together they create a gradient of farming intensity that is representative for Latvian farmland as a whole. Four of the study sites (Blīdene, Jelgava, Skulte and Teichi) were established and monitoring started in 1995 while the other two (Durbe and Malta) were established in 2003 to cover wider range of habitats, both geographically and in terms of landscape.

Table 3.1. Main characteristics of the study sites in landscape level obtained from CORINE Landcover 2000 (habitat composition and landscape structure) and official agricultural statistics (yields).

	Blīdene	**Jelgava**	**Skulte**	**Teichi**	**Malta**	**Durbe**
Habitat composition						
Farmland (%)	54.6	93.7	56.6	69.0	76.9	80.3
Forests and shrubs (%)	43.5	6.0	41.9	29.0	23.0	19.2
Wetlands (%)	0.4	0.0	0.4	0.7	0.0	0.2
Streams and waterbodies (%)	1.4	0.0	0.0	0.4	0.2	0.0
Residential/Urban (%)	0.0	0.4	1.1	0.9	0.0	0.3
Landscape structure						
Mean Patch Size (ha)	76.0	169.5	75.1	75.7	90.1	85.5
Edge density (m/ha)	74.2	39.4	77.5	70.5	67.1	68.3
Shannon's Diversity index	4.48	3.19	4.45	4.42	4.34	4.36
Mean farming intensity 1995-2003						
Winter cereal yields (qnt/ha)	31.9	32.7	20.4	17.4	16.5	22.9
Summer cereal yields (qnt/ha)	23.0	24.3	15.0	13.2	15.1	18.3
Grass yields (qnt/ha)	39.8	35.8	30.5	26.0	25.1	30.9

Bird counts

Point counts were chosen are the standard survey method as it has been recognised as the least time consuming per sample unit. Compared to territory mapping, it is 7 times less time consuming, however, it requires 4 times larger sample sizes to reach equal level of data precision (Gregory et al. 1994).

40 bird count points were chosen using combination of random and systematic approaches as described in Article **I** in each study site. This ensured a high degree of objectivity, making it feasible to carry out subsequent statistical data analyses. Statistically, this approach also ensures a representation of habitats, which reflects the actual habitat distribution in the study sites, and that the census points constituted a representative sample of Latvian farmland. The probability of recording an individual bird at more than one point was negligible.

Five minute long standardised bird counts (Bibby et al. 2000) were performed in each point twice per season (mid May and mid June). Initially birds were counted without any distance limitation. Since 1998 division line was introduced at 200m, still keeping full compatibility with the earlier data.

Breeders and non-breeders were separated. Breeders were interpreted in pairs while non-breeders were recorded as individuals (see details in Article **I**). Maximum of the two counts was used in the analyses. The total number of species recoded per point was used as a measure of species richness.

Table 3.2. Habitat variables recorded and the transformations used prior to analysis.

Variable	Explanation	Transformation
WINTER	Winter cereals (% of area)	arcsin √x
SPRING	Spring cereals (% of area)	arcsin √x
ROOTS	Root (furrow) crops (% of area)	arcsin √x
FALLOW	1st year fallow (% of area)	arcsin √x
ABANDON	Abandoned fields (% of area)	arcsin √x
SOWNGR	Sown grass fields (% of area)	arcsin √x
CULTM	Improved meadows and pastures (% of area)	arcsin √x
DRYM	Dry meadows and pastures (% of area)	arcsin √x
WETM	Wet meadows and pastures (% of area)	arcsin √x
PONDVEG	Ponds or pools with water fringe vegetation (% of area)[1]	arcsin √x
PONDCL	Ponds or pools without water fringe vegetation (% of area) [1]	arcsin √x
WOOD	Forests (% of area)	arcsin √x
ORCHARD	Orchards (% of area)	arcsin √x
SHRUB	Scrub (% of area)[1]	arcsin √x
FARM	Farmsteads (% of area)[1]	arcsin √x
BUILD	Isolated farm buildings outside of farmsteads (% of area)[1]	arcsin √x
RUDERAL	Waste (ruderal) areas (% of area)	arcsin √x
DITCH	Length (m) of ditches and regulated watercourses	not transformed
RIVER	Length (m) of natural rivers	In (x+1)
ALLEY	Length (m) of tree lines	In (x+1)
SHRUBLIN	Length (m) of shrub belts and hedges	not transformed
ROAD	Length (m) of roads	not transformed
ETL	Length(m) of electricity and telegraph lines	not transformed
FENCE	Length(m) of fences(including cattle enclosures)	In (x+1)
TREE	Number of single trees	√(x+0.5)
HEAP	Number of stone or brushwood heaps (remains after melioration works)	√(x+0.5)

[1] Coded as 0.5% if present, but occupying less than 1% of area

Habitat descriptions

Habitat description was done annually (late June – early July) for the zone around each bird count point with a radius of 200m (area 12.56 ha). Hierarchical classification of habitats and landscape elements was used and each point was described by means of 33 original habitat variables, which were later merged into 26 variables to avoid classes with too scarce data (Table 3.2, see details in Articles **I** and **II**). For some analyses several of the variables were merged. Proportions of main agricultural and other habitat groups within the description zones varied between the areas (Figure 3.2) according to general landscape structure, farming intensity and other regional factors, although taking into account that the points were located in agricultural lands only.

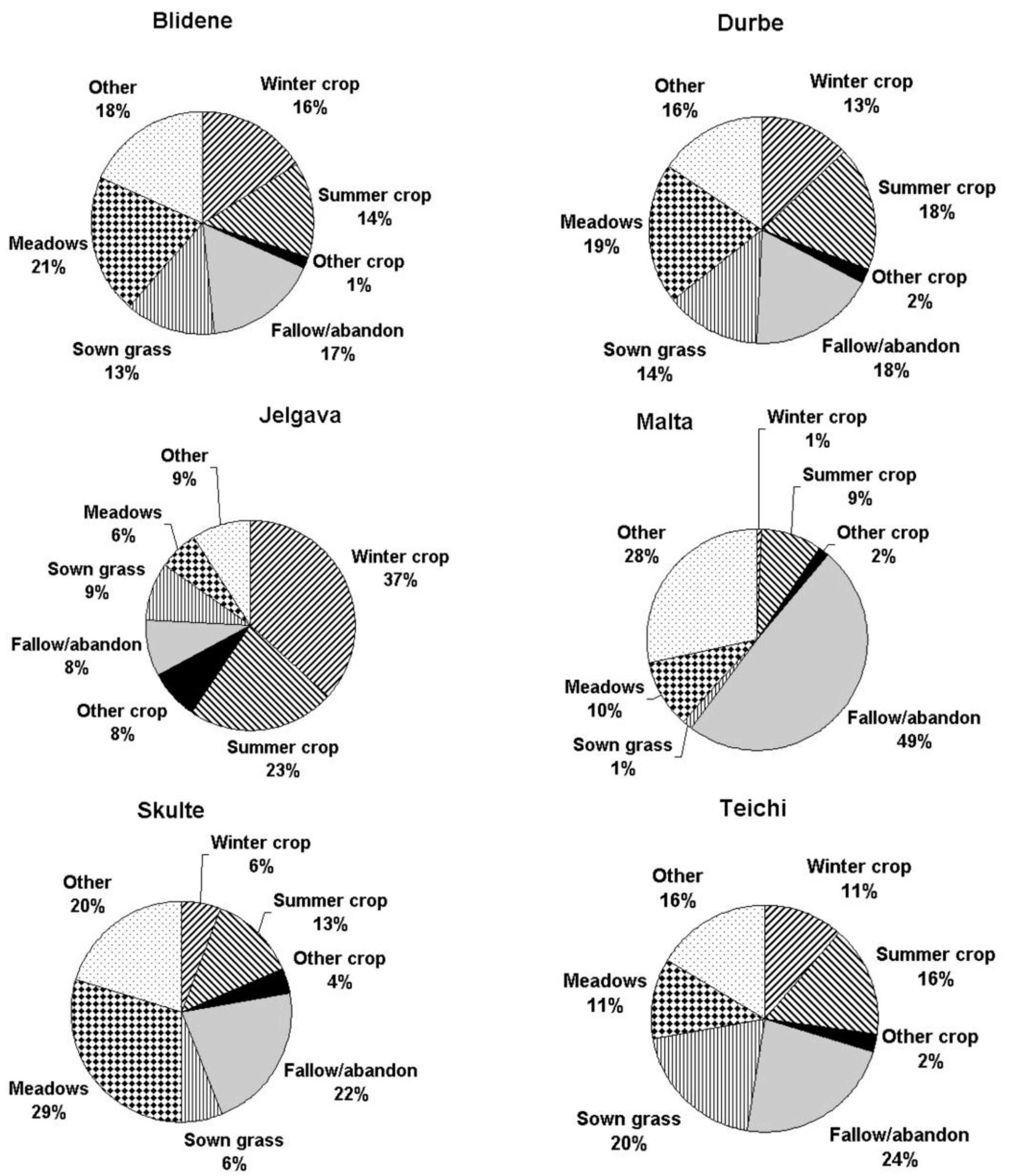


Figure 3.2. Proportions of the main agricultural and other habitat groups in the 200m description zones in 2004.

Changes in crop habitats and landscape features in study sites

Significant changes in crop types, habitats and landscape features took place in the study sites during the study period and they well represented the changes taking place in the country (Auniņš 2006). Area of arable lands slightly increased between 1995 and 1998, was relatively stable or slightly decreased between 1998 and 2003 and steeply increased between 2003 and 2006. Area of abandoned lands was rapidly growing between 1995 and 1997, then it fluctuated until 2002 and started rapidly decrease afterwards. Both sown and semi-natural grasslands experienced decline that was less pronounced by the end of the study period (Auniņš 2006).

Although general trends were shared between the study sites there were also pronounced regional differences, especially until 2004. In this period (1995 – 2004) the increase in arable lands was more pronounced in Jelgava than in other areas. Blīdene experienced significant increase in summer cereals while their area decreased in Teichi study site. Skulte was the only study site where area of fallows and abandoned lands did not increase. Sown grasslands declined in Jelgava and Skulte while they increased in Blīdene study site. Encroachment of shrubs was recorded in all study sites, however, dimensions of the process differed as did the length of linear shrub belts that fluctuated between areas and years.

Cereal yields increased in the related districts of all study sites in the whole study period. However, until 2004 it was significant only for winter cereals in Jelgava (Spearman rank correlation: $r_s = 0.783$, $n=9$, $p<0.05$). After 2003, the increase in yields was significant in all study sites (Anon. 2010b).

Species selection and grouping

Species whose occurrence is very dependent on meteorological conditions (Swifts *Apus apus* and swallows *Hirundidae*) as well as corvids *Corvus spp*. were omitted from calculation of the species richness and single species analyses in the study of bird species – habitats relationship in Latvian farmland (Articles **I** and **V**).

Following the approach of Tiainen and Pakkala (2001) the species were divided into four to seven ecological groups (depending on study) according to their preferred habitat structures and these were analysed separately (Articles **II**, **IV**, **V** and **VI**). Generally the species grouping was based on previously established birds - habitats associations (Article **I**), as additional information sources were used other studies from the Baltic countries or Finland (e.g. Tiainen and Pakkala 2001, Herzon et al. 2006). We made separate groupings also according to wintering areas and feeding preferences (Table 2 in Article **VI**). Details and justification of the groupings are described in the methods section of the corresponding articles. A species could be assigned only to one group in each of the three main grouping categories.

For modelling the bird abundance and species diversity analyses we built several species sets according to their relationship to farmland (Articles **V** and **VI**). Details and justification of the groupings are described in the methods section of the corresponding articles. A species could be assigned to several species sets.

Remote sensing data and GIS layers

Four full Landsat ETM+ scenes from July–August 1999 were used to produce a digital land cover/use map with 15m resolution covering more than 70% of Latvia. The multispectral data from the original Landsat TM scenes were resolution merged with the pan-chromatic channel to obtain 15m spatial resolution by means of a principal component approach (ERDAS 1997). Images were geo-registered to the LKS-92 coordinate system using a cubic convolution resampling algorithm.

The image classification was carried out in several steps. For all study sites the land cover was interpreted in detail. Initially the Landsat TM data were interpreted on the screen (bands 4, 5, 3), together with the field plots to which had been applied a 200m buffer. Gaps in knowledge of cover were identified and a field survey was conducted within the study sites to identify spectral properties that could not be explained by the information gathered from field plots, 1:10 000 maps and aerial photos. In addition, field sampling was carried out in areas outside the study sites to cover habitats not represented in them. Considering the well established knowledge on image classes, use of a supervised classification procedure with maximum likelihood decision rule was selected. A fuzzy convolution 3×3 matrix (ERDAS 1997) was used for cleaning up the post-classification noise by only selecting the involved classes to be used in the convolution of the classified image. In order to obtain a consistent base map, the 50 land cover/use classes derived from the four classified Landsat ETM+ images were merged into seven classes: arable crops, grass, abandoned fields, wetlands, water bodies, forest and shrub. All digital satellite sensor data processing was carried out using ERDAS Imagine software.

Wetland areas were extracted from the CORINE Land Cover dataset for Latvia, converted to raster and added to the classified image data. This was done in order to improve the Landsat ETM+ data classification, where class separability problems were present between wetland/bog areas and grassland in the agricultural areas. Furthermore, since watercourses could not be satisfactorily classified from the satellite image, watercourse data were applied from a digital national watercourse layer, digitised from 1 : 100 000 maps. This information was converted into a 15m resolution raster, merged into the classified data and coded as water.

The final image with seven classes was used as habitat information for spatial modelling of breeding bird densities (Article **III**).

Data analyses

Species-habitat ordinations in Article **I** were performed for each year separately, using Canonical Correspondence Analysis (ter Braak 1986, 1994) with PC-ORD (Multivariate Analysis of Ecological Data) 4.0 software. The method seeks structure in the species matrix in such a way as to maximize the strength of the relationship with the habitats/landscape elements matrix. The relationships between species and habitat data matrices were tested using Monte-Carlo test with 100 permutations. In all cases the hypothesis that there might be no relationship between the matrices was rejected ($p<0.01$).

Models quantifying relationships between bird species richness and the habitat features as well as abundance of particular species and the habitat features were derived for each year separately using stepwise multiple regressions (Sokal, Rohlf 1995; Article **I**). As predictor variables selected by the above procedure were fairly consistent between years form most of the species, the single species models in Article **III** were calculated from data where all five years were combined and a model selection procedure was run with only predictor variables selected in at least one year being entered. SPSS (Article **I**) and SAS (Article **III**) software was used with $p<0.05$ as entry criterion.

The regression models were implemented in the modeller module in ERDAS Imagine software (ERDAS 1997; Article **III**). For integration with spatial data, the model premises were calculated within a circular moving window filter (radius 200 m). To produce the predicted species maps, the seven-class land cover map was re-coded. For each species modelled, percent cover of each image class within the moving window was multiplied by its coefficient in the regression model, and the intercept was added. If appropriate, a back-transformation function (e^y–1) was finally applied. The resulting value was the predicted number of territories of a certain species within each 200m radius.

Species richness and abundance of two species subsets and five ecological groups in pairs of intensive and extensive farmland plots in the three Baltic countries (Article **V**) were modelled using generalised linear models with Poisson error distribution and logarithmic link function in S-Plus 6.1 software. Variables were selected in a stepwise selection procedure based on Akaike's information criteria corrected (AICc) for a small sample size (Burnham, Anderson, 2002). The effect of the intensity type (two-level factor) was first assessed together with a country affinity (three-level factor reflecting possible regional differences). Then five PCA components extracted from habitat variables (PCA with varimax rotation) were added into the models as covariates, to assess whether the difference between the area pairs remain as significant as in the first model set. For the dataset from arable fields, the respective GLMs included the PCA component based on the field management, and three PCA components for the habitat composition.

Population changes were assessed using population indices relating each study year to base year (1995). Trend slopes were estimated using log-linear regression models (often referred to as TRIM models). TRIM software (Pannekoek, van Strien 2001) was used for calculating indices and trends of bird populations and species richness (Articles **II**, **IV** and **VI**). In Article **II** the following models were tested for each species (with 1995 as the reference year): no time effect (N), linear trend without covariates (L), linear trend including the study site as covariate (LC), linear trend without covariates and with stepwise selection of changepoints (LT), and linear trend including the study site as covariate and stepwise selection of changepoints (LTC). Level $P \leq 0.05$ was used as significance criterion in Wald tests to enter or remove the changepoints in the stepwise procedures. Models that included the study site as a covariate were rejected if the significance of covariate exceeded 0.2. The remaining models were compared and the model that gave the best fit according to Likelihood Ratio was chosen. In the few cases when several models gave maximum fit according to this test ($P=1.000$), the model with the smallest Akaike's Information Criterion was chosen. The modelled indices were used for estimating population status.

A time effects model (model 3 in TRIM) was applied to species richness and individual species datasets with the study site (region) as a covariate in Articles **IV** and **VI**. Only data from the 4 study sites where counts had been performed since 1995 were included in these analyses. The trends were classified according to the procedure suggested by Pannekoek and van Strien (2001): according to the significance of the trend, the calculated magnitude of change in a 20-year period and its significance, the trends were classified as substantial decrease or decline, decrease or decline, non-substantial decrease or decline, stable or poorly known.

Patch Analyst (version 3.1) for ArcView (Rempel and Carr 2003) was used to obtain landscape metrics from CORINE Landcover 2000 GIS dataset.

SPSS software was used for the other statistical tests. Name of the test, main test statistics and its significance level is given whenever appropriate.

4. Results and discussion

Bird species richness in Latvian farmland (Articles I and IV)

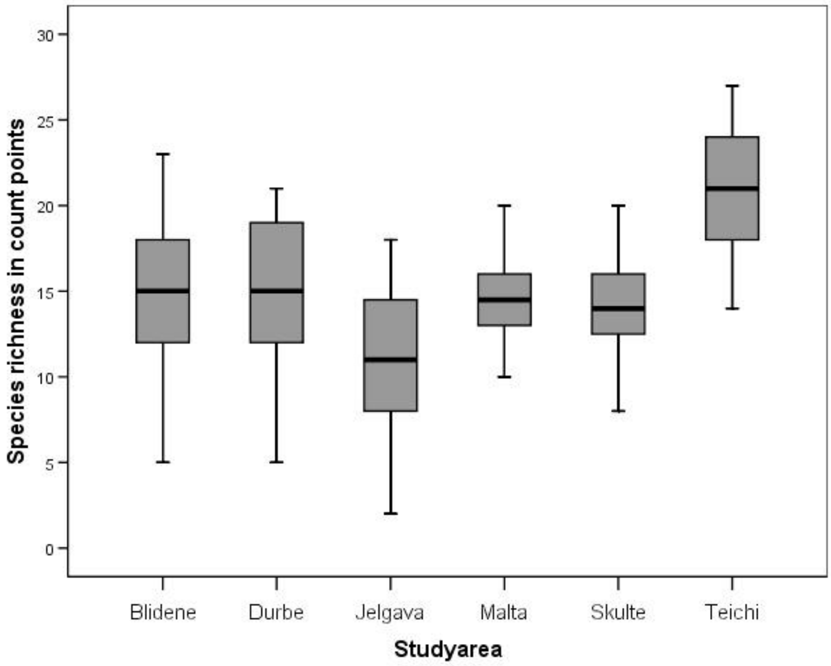
The average species richness (SR) per bird count point (α diversity, excluding non-breeders, *corvids* and aerial feeders) in the first five years of the study (1995 – 1999) was 12.5 species per count point (SD 4.27, range 2–25; all areas pooled). The species richness obtained from unlimited distance counts differed between the study sites every year (1995 – 2004; ANOVA: F=7.4 to 89.6, p<0.001) as did the species richness within 200m radius zones (ANOVA: F=3.1 to 14.3, p < 0.01 to p<0.001).

Multiple regression models relating SR to habitats, crops and landscape features calculated separately for each year in this period (Table 4.1) showed that increasing proportion of annual crops influence overall bird diversity negatively while proportion/number of other habitats or landscape features have positive relationship. This general pattern was consistent all years though the importance of different habitat elements varied. The most persistent positive predictor of species richness was forest (variable WOOD), which was significant all years, followed by shrub patches (SHRUB), stone and brushwood heaps (HEAP) and dry meadows (DRYM; significant 4 years) and ponds/pools with water fringe vegetation (PONDVEG; significant 3 years). Proportion of root crops (ROOTS) was negative predictor 3 years. These results correspond well with results of a later study covering all three Baltic States (Herzon et al. 2006) and Poland (Sanderson et al. 2009).

Table 4.1. Results of the stepwise multiple regression analyses of species richness. For each year, the regression coefficients of predictor variables included in the final model are shown. Only significant variables (p<0.05) are shown. P - years with the variable.

Variables	Year					Sign	P
	1995	1996	1997	1998	1999		
WOOD	5,232	6,175	7,669	6,727	4,814	+	5
SHRUB	3,804	2,746		5,048	3,269	+	4
HEAP	3,160	2,431	3,254		2,554	+	4
DRYM	2,688	2,572	3,012		4,069	+	4
PONDVEG	3,242		3,677		2,978	+	3
SOWNGR		-2,378	2,458	2,361	2,437	+/-	3-1
FENCE			2,143	2,433		+	2
WETM	2,845		2,137			+	2
ALLEY	1,989	4,119				+	2
ROAD	2,508		3,876			+	1
RIVER						+	1
DITCH					2,107	+	1
WINTEER	-1,985	-5,005				-	2
SPRING	-3,860	-3,111				-	2
ROOTS	-2,026		-2,633		-1,900	-	3
Adjusted R^2	0,520	0,475	0,504	0,345	0,412		

A



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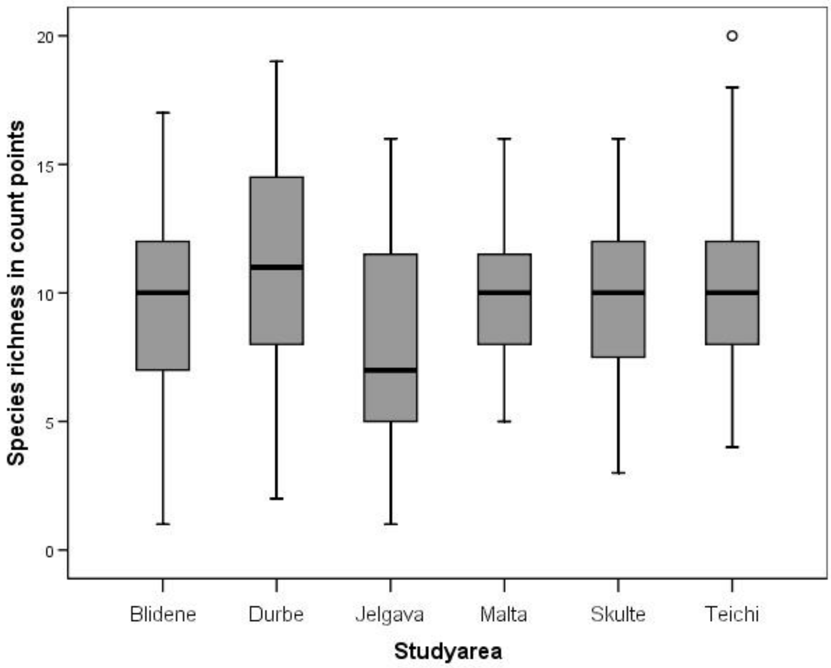

Figure 4.1. Species richness in the six study sites in 2004. Each box shows the median (line), quartiles (box area) and range w/o outliers (bars), outliers are marked as open circles: A – obtained from unlimited distance counts, B – within 200m zones around bird count points.

Regional differences in species α diversity (species richness excluding non breeders) between the study sites were not particularly well pronounced and only two regions clearly stood out (Figure 4.1). These differences could mainly be attributed to differences in landscape structure and farmland management intensity. While structural and habitat diversity at landscape and point level influenced species richness positively, increasing intensity levels had a negative effect. Thus Jelgava, where relatively high agricultural intensity met low percentage of species rich habitats (e.g. forests, shrubs and seminatural grasslands) and uniform landscape dominated by different kinds of arable lands, had the lowest species richness, both without distance limitations and within 200m zones. And this was so in all years of the study (Article **II**). Conversely, Teichi had higher proportion of wetlands, streams and water bodies, compared to other study sites, while having average proportions of farmland and forests on the landscape level. Together with high landscape diversity and low farming intensity (Table 3.1) this pattern gave a high chance of having different important features on both sides of the 200m division line thus contributing to very high overall species richness.

Although the other four study sites had similar average levels of species richness (α diversity), they differed in various aspects of landscape structure, habitat composition at point level or farming intensity (Table 3.1). Effect of this manifested itself in different variances of species richness. Thus Malta had the lowest variance and range of mean species richness compared to the other areas and this can be explained by more uniform habitats on the point level as 49% of the description zones were fallows and abandoned lands (Figure 3.2). In Blīdene, the negative effect of high farming intensity was compensated by high forest proportion, a large proportion of other non-agricultural habitats and high habitat diversity at a landscape level (Table 1).

Bird species distribution gradients in Latvian farmland (Article I)

Environmental gradients existing in Latvian farmland and affecting bird species composition were drawn using canonical ordination of species and habitat variables in multivariate space (Figure 4.2). The relationship between habitat variables and the canonical axes was quite stable from year to year. Three main gradients were described:

First gradient – from uniform arable lands (especially spring cereals) to more natural and structurally diverse (woodland, shrubs, natural grasslands, wetlands)

Second gradient – from dry habitats (woodland, farmyards) to wet (wet grasslands, natural rivers, ponds with water fringe vegetation)

Third gradient – from human dwellings – farms and habitats associated with them (electricity lines, alleys, patches of root crops) to remote, often abandoned areas (old stone and bush heaps, abandoned lands and woodland)

The species vectors in the ordination space varied between the years, but the overall pattern was stable.

The spatial distribution of birds and the structure of their communities may be affected by various factors, and although habitat structural factors are usually thought to be the most important, they leave a large part of the variation unexplained (e.g. Fuller et al. 1997, Petersen 1998, Schifferli et al. 1999). Similar explained/unexplained proportions have been reported also from and a later study in the Baltic states (Herzon et al. 2006). The numbers and distribution of birds are also affected by yearly fluctuations in food abundance, demographic parameters, mortality in different stages of the annual cycle, weather conditions etc. (Wiens 1989, Fuller 1994). These variables were not included in the present study, and together with variation in census conditions (observer differences, variation in date and time of day, meteorological conditions) they are surely responsible for a major part of the unexplained variation.

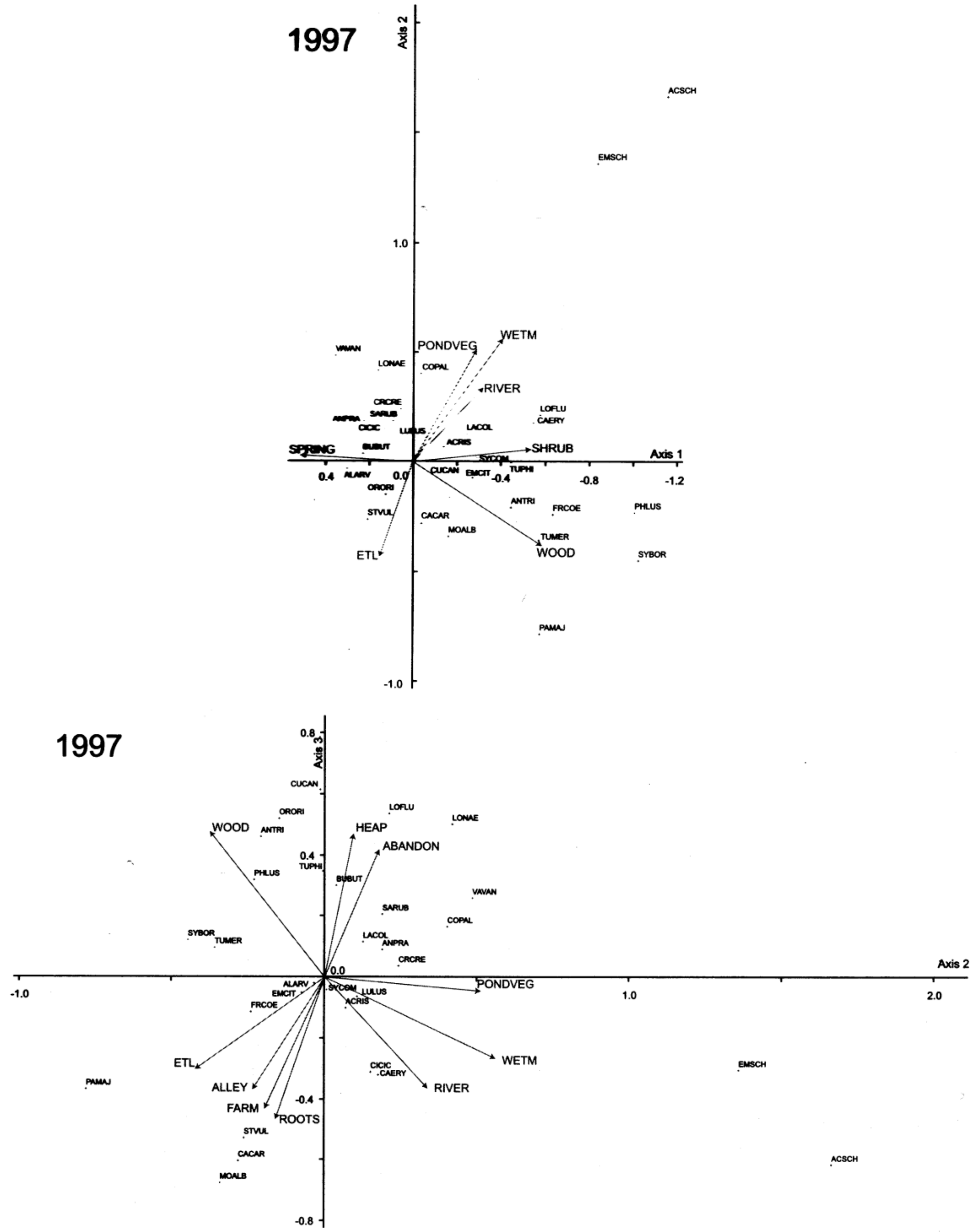

Figure 4.2. Species-habitats relationships according to Canonical Correspondence analysis. Onlv habitat variables with scores larger than 0.10 on one or both axes are plotted.

Abbreviations of the bird variables: CICIC - *Ciconia ciconia*, BUBUT - *Buteo buteo*, CRCRE - *Crex crex*, VAVAN -*Vanellus vanellus*, COPAL - *Columba palumbus*, CUCAN - *Cuculus canorus*, ALARV - *Alauda arvensis*, MOALB - *Motacilla alba*, ANPRA - *Anthus pratensis*, ANTRI - *Anthus trivialis*, LACOL - *Lanius collurio*, SARUB - *Saxicola rubetra*, LULUS - *Luscinia luscinia*, TUMER - *Turdus merula*, TUPHI - *Turdus philomelos*, LONAE - *Locustella naevia*, LOFLU - *Locustella fluviatilis*, ACRIS - *Acrocephalus palustris*, ACSCH - *Acrocephalus schoeniclus*, SYBOR - Sylvia borin, SYCOM - *Sylvia communis*, PHLUS - *Phylloscopus trochilus*, PAMAJ - *Parus major*, STVUL - *Sturnus vulgaris*, ORORI - *Oriolus oriolus*, FRCOE - *Fringilla coelebs*, CACAR - *Carduelis carduelis*, CAERY - *Carpodacus erythrinus*, EMCIT - *Emberiza citrinella*, EMSCH - *Emberiza schoeniclus*. Explanaitions of habitat veriables are given in Table 3.2).

The general pattern of species-habitat associations is roughly similar to the results of a comparable study in Denmark (Petersen 1998), despite the differences in the structure of the landscape. In both studies, the main gradient of species diversity follows a gradient from uniform to structurally diverse landscapes, although more species were associated with the landscape belonging to the uniform part of the first canonical axis in Latvia (Fig. 4.2) than in Denmark. Among these are species of global or European conservation concern like Corncrake and White Stork which are rare in Western Europe but still common in the Baltic countries.

Bird species – habitat models (Article I)

Multiple regression models mathematically describe relationship between the recorded abundance of particular species and provided habitat/landscape feature variables. The best models (considering their statistical performance and yearly stability) were those for species with small territories and specific habitat needs (e.g. Sedge Warbler *Acrocephalus schoenobaenus* and Reed Bunting *Emberiza schoeniclus*) as well as those for woodland species and Skylark *Alauda arvensis*. The models of least predictive value were those for species with large territories, species feeding outside their breeding territories and species easily detectable beyond the 200m zone around the census point (e.g. Buzzard *Buteo buteo*, Corncrake, Woodpigeon *Columba palumbus*, Starling *Sturnus vulgaris* and Golden Oriole *Oriolus oriolus*). The models for species with prominent fluctuations in numbers between the study years (e.g. Marsh Warbler *Acrocephalus palustris* and Red-backed Shrike *Lanius collurio*) were also unstable (Article **I**). For almost all of the 30 species for whom such models were built, they reflected biologically meaningful habitat affinities supported by general field experience and descriptions in literature. For most of the species the affinities existing in Latvian farmland were rather similar to those reported from comparable studies in Western European countries (Fuller et al. 1997, Petersen 1998, Schifferli et al. 1999), although several differences existed, both in the models of particular species and in the overall importance of specific habitat types.

All the habitat and landscape feature variables used in the model building process appeared as significant predictors for at least in one yearly model for at least three species. Although all predictors were not equally important, this shows the dimensionality of the system and importance of the existing structural diversity.

Very few species benefited from the presence of arable fields (Table 4.2). However, both of the species having arable land as stable predictor in their models (Skylark and Lapwing) were farmland specialists. Other species either had negative relationship with them or did not include any of crop variables as a significant predictor. These were the only habitat variables appearing more often as negative variables in the models, the most pronounced this difference was in winter cereals. The low suitability of winter cereals as a breeding habitat for farmland birds have been shown (Wilson et al. 1997, Chamberlain et al. 1999) and massive switch from spring sown crops to winter sown crops is one of the reasons behind farmland bird collapse in UK.

Table 4.2. Importance of habitats and landscape features in Latvian farmland. Summary of species habitats associations in yearly (1995 – 2000) multiple regression models for 30 bird species. This table is summary version of Table 4 in Article I.

Variables or variable groups	**Associations**			**No. of species where stable* predictor**
	Negative	**Positive**	**All significant**	
Forest (WOOD)	19	46	65	10
Shrubs (SHRUB and SHRUBLIN pooled)	16	48	64	10
Permanent grasslands except abandoned lands (CULTM, DRYM and WETM pooled)	17	49	66	7
Arable (WINTER, SPRING and ROOTS pooled)	35	17	52	4
Ponds and pools (PONDVEG and PONDCL pooled)	7	32	39	3
Farmsteads and buildings (FARM and BUILD pooled)	16	23	39	2
Streams (DITCH and RIVER pooled)	4	34	38	4
Overgrown stone and bush heaps (HEAP)	2	34	36	5
Abandoned lands (FALLOW and ABANDON pooled)	6	27	33	2
Alley	2	19	21	2
Sown grass (SOWNGR)	2	12	14	0
Separate trees (TREE)	1	8	9	0
Ruderal	1	9	10	0
Orchards	2	1	3	0
All variables pooled	130	359	489	26

* variable appears as a significant predictor in 3 or more yearly models of the particular species

Forest proportion was the most significant single predictor appearing in more models than any other single variable, showing the high number of positive and negative associations. It appeared as a regular predictor in a third of the analysed species. The species having forest as regular positive predictor belonged to the group of forest species and they had no relation to agricultural land. Most of the typical agricultural bird species are indifferent or avoid areas close to forest. This negative relationship is particularly pronounced in the open farmland species group. Although woodlands rather reduce than increase the densities of typical farmland bird species, small forest patches within the matrix of agricultural land raise the overall biodiversity value of the area on a larger scale (γ diversity).

Shrubs (patches and linear structures pooled) were as important predictors as forest. Moreover, number of positive relationships exceeded those of forests and had less negative relationships. In contrast to forest, they attracted more species that are connected with an agricultural landscape, including farmland specialists (e.g. Whitethroat *Sylvia communis* and Yellowhammer *Emberiza citrinella*). However, while separate bushes and patchy mosaic of shrubs has a positive effect on farmland biodiversity, expansion of shrubs in Latvian conditions is not welcome as most often it takes place in abandoned farmland. Further succession on these areas is going to result in decline and disappearing of open areas and will eventually lead to woodland.

This would be undesirable from the biodiversity point of view, as such areas will become unsuitable for any farmland bird species and also further increase in forest areas is undesirable – forest coverage has doubled during the last century and ca 50% of Latvia is currently covered with forest (Anon. 2010b).

The most important agricultural habitats were permanent grasslands. They held an absolute record of positive affinities, especially for farmland specialists and species with specific habitat needs. Association of several edge species (Thrush Nightingale *Luscinia luscinia*, Scarlet Rosefinch *Carpodacus erythrinus*, Yellowhammer etc.) with dry meadows, reflect the state of overgrowing in this habitat type.

Like the grasslands, abandoned fields are an important habitat, with a number of farmland specialist species (e.g. Whinchat *Saxicola rubetra* and Grasshopper Warbler *Locustella naevia*) being associated with them. However, as a temporary habitat they lose their value with time due to overgrowing or ploughing. From a biodiversity point of view, the most advisable management of this habitat would be an introduction of extensive mowing and/or grazing, allowing these areas to maintain their actual high densities of grassland species, e.g. Corncrake (Keišs 1997).

Farmsteads and other buildings have a less prominent impact on species composition in this study than in the Danish study, where building/garden area was the main predictor of densities of 13 species (Petersen 1998). In large parts of western European farmland, human dwellings with their surrounding vegetation are important habitat islands in a rather uniform agricultural landscape, whereas their importance is much smaller in Latvia, where the population density is lower and agricultural land occurs in a mosaic structure with forest and scrub

High, positive effect on the occurrence of many species had stone and brushwood heaps (HEAP) and wet depressions (ponds and pools, especially those with water-fringe vegetation), indicating the value of such habitat islands in agricultural areas. Within the otherwise uniform arable land, they provide suitable unfarmed patches which can be used as nesting sites, protecting the nests against losses due to mechanised farming and thus ensuring a higher nesting success for various farmland species. Also open drainage ditches play positive role and some specialist species such as Marsh Warbler and Grasshopper Warbler are associated with them. Importance of ditches has been shown in a number of other studies too (see Herzon, Helenius 2008 for review). The possible switch to closed drainage should be regarded as a threat.

Integration of species habitats models with remote sensing data– a demonstration of GIS method (Article III)

The multiple regression models allow using them not only for describing the species-habitats relationships but also for estimating suitability of given locations for these species and predicting their densities. The original models (**I**) were recalculated so that only variables available as appropriate GIS layers for larger territories extending beyond study sites and covering the largest part of the country were available in the stepwise variable selection process. Formulas predicting species densities with these variables were implemented in the spatial models.

Maps of predicted densities of the analysed species were obtained applying the prepared spatial models that represented the established species-habitats relationships (Figure 4.3). Thus each map shows predicted density distribution of these species. This illustrates the potential of using satellite sensor data as a map source for large-scale mapping of predicted bird densities in the open landscape. The range of species whose distributions may be predicted in this way depends on the scale on which the field data that form the basis of the modelling are collected. If census points of birds and corresponding habitat descriptions are used as field source data, densities of species with small- or medium-sized territories in particular may be predicted. If field data are collected on a larger scale, distributions of birds with large territories may be predicted in a similar way by appropriate adjustment of the size of the moving window.

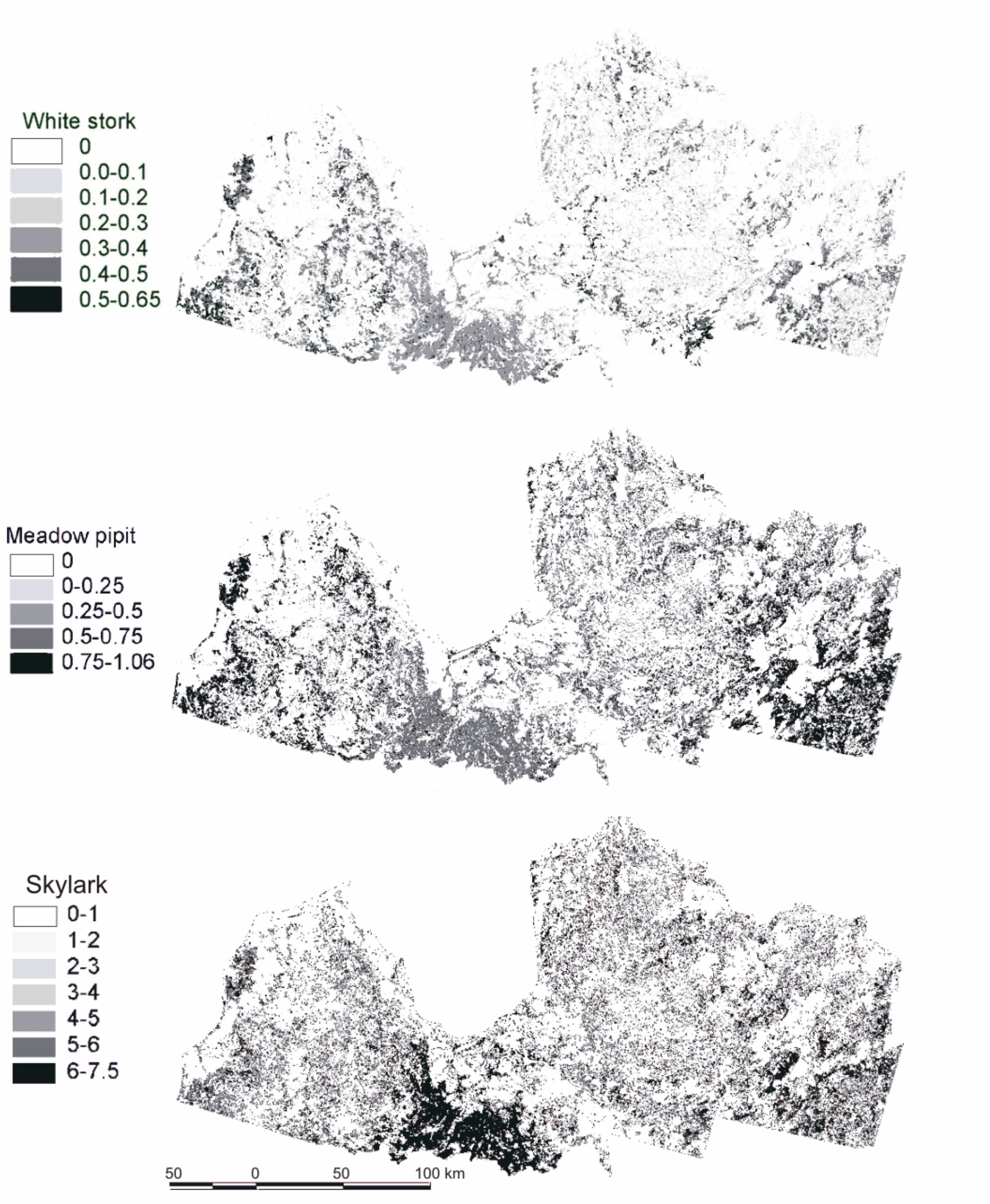

Figure 4.3. Maps of predicted densities of Meadow Pipit, White Stork and Skylark based on multiple regression analysis applied to a seven-class 15m spatial resolution Landsat ETM+ classification.

Usage of more detailed habitat maps would allow more precise predictions for most of the species as the more complex models (Article **I**) performed statistically better than the simplified models used for predictions. Further improvement of models could possibly be achieved by including various landscape metrics, especially habitat and landscape diversity measures (Turner 1989, McGarrigal, Marks 1995) as predictor variables. This would allow better link to structural diversity and landscape configuration at different scales (Jørgensen, Nøhr 1996, Saveraid 2001).

The method presented here could be considered for other programmes for monitoring of the environment in the open countryside. It also represents a way of identifying potentially suitable areas for species of conservation concern. The suggested approach of integrating field observations with classified satellite sensor data seems to have sufficient flexibility to make use of already established field-based monitoring systems that collect quantitative data on biodiversity elements and habitat features. Furthermore, it has the requisite flexibility to be fitted into various field monitoring systems based upon point observations.

Role of farming intensity on occurrence and abundance of farmland birds (Article V)

Farming intensity plays very significant role on species distribution and abundance in Latvian (Baltic) farmland. Comparing two study sites in each Baltic country with similar landscape structure between area pairs but differing farming intensity, the species richness and bird abundance in all compared species groups consistently were higher in less intensive areas if there was any difference. This was best pronounced in the abundance of farmland specialist birds which was significantly lower in the more intensive areas as compared to less intensive ones (Fig. 4.4) as well as in species richness and abundance of true field species when the effects of habitat composition variables is controlled for (Table 5 in Article **V**). The effects on species richness and abundance of other species groups such as edge species or tree species was less pronounced, especially when the effects of habitat structure were controlled for.

An analysis of the data from arable fields in homogeneous open farmland indicated that agricultural intensification was reflected in a measurable decrease in farmland bird abundance, especially in species in need of edge structures. The fields under most intensive management characterised by dense and even swords of cereals, tramlines and lack of weeds held only half the number of individuals of farmland birds than the least intensively managed fields (Fig. 4.5). The least intensively managed fields more often co-occurred with different crop or grass fields (i.e. higher field variety) and field dividing borders (roads and ditches). The effect was most pronounced on edge species and least pronounced to true field species (Table 6 in Article **V**).

Regarding the level of intensity it has to be taken into account that even in the most intensively managed areas it never reached the average level characteristic for the countries in the Western Europe. Thus one can expect even lower densities of farmland birds if intensification will reach it.

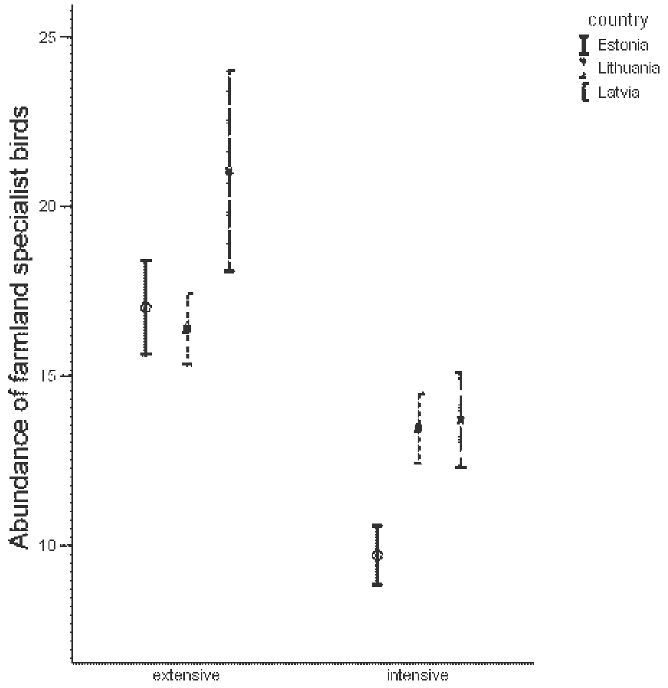

Figure 4.4. Abundance of farmland specialist bird species in agricultural areas under extensive and intensive farming in the Baltic Countries.

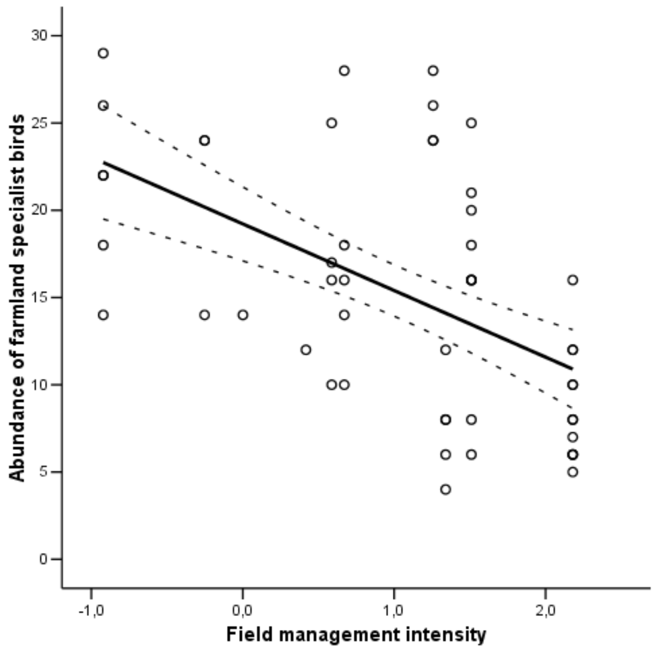

Figure 4.5. Relationship between the gradient of management intensity of arable fields based on field assessment of weed abundance, crop structure, and presence of tramlines, and abundance of farmland specialist birds; dashed lines denote 95% confidence interval.

Population changes of farmland birds in Latvia before joining EU (Articles II, IV, VI)

Changes in farmland bird populations are described in separate chapters for the periods before Latvia joined EU and after it as trends and patterns between these two periods differ significantly as did also the main driving factors (Article **VI**).

Table 4.3. Trends in species richness, diversity and abundance. MI refers to "moderate increase", MD – "moderate decline", S – "stable" according to classification system suggested by Pannekoek, van Strien (2001).

Measure	Group	1995 – 2003		2003 - 2006	
Species richness	All species	1.0234±0.0017	MI**	0.9805±0.0053	MD**
	Rural species	1.0188±0.0023	MI**	0.9917±0.0068	S
	Farmland species	1.0134±0.0023	MI**	0.9818±0.0068	MD**
Shannon-Wiener diversity index	All species	1.0120±0.0012	MI**	1.0006±0.0033	S
	Rural species	1.0099±0.0015	MI**	0.9965±0.0044	S
	Farmland species	1.0075±0.0016	MI**	0.9902±0.0047	MD*
Abundance	All species	1.0357±0.0019	MI**	0.9810±0.0043	MD**
	Rural species	1.0240±0.0023	MI**	0.9780±0.0052	MD**
	Farmland species	1.0221±0.0022	MI**	0.9767±0.0052	MD**

*p<0.05
**p<0.01

Overall farmland bird richness and their abundance increased in the period from the beginning of study until Latvia joined EU (Table 4.3). The increase took place mostly at the expense of species connected with trees and shrubs as well as abandoned lands as populations of these groups mostly increased and no species with significant decline tendency were recorded. Although overall species richness and abundance increase was recorded also in the farmland specialists, statistically significant declines were recorded in individual species in grassland, wetland and farmstead ecological groups and no species significantly increased in these groups (Table 4.4).

Table 4.4. Classification of bird population trends (1995 – 2004) according to species associations with main ecological groups.

Trend / Ecological group	Increase	Stable / Poorly known	Decline
Forests (species breeding in forests but feeding on fields in brackets)	8 + (1)	3	0 + (1)
Bushes and shrubberies	3	5	0
Abandoned farmland	2	0	0
Arable lands	1	1	0
Farmsteads	0	3	1
Wetlands	0	1	1
Meadows	0	1	2
All species	**15**	**14**	**5**

Trends of species richness, however, differed among the regions. In the less diverse and most intensive (measured by cereal yields and mean patch size; Table 3.1) area, where proportion of arable lands increased significantly at the expense of grasslands and increase of winter cereal yields was greatest during the study period (Jelgava), decline in species richness was observed. Increase in species richness was not observed also in Skulte study site which having high proportion of forest, high edge density and landscape diversity and small patch size, experienced further increase in shrubby areas and linear shrub features due to abandonment (Article **IV**).

Population change for majority of the species analysed was not linear and their TRIM models built for the period 1995 – 2000 included significant change points (years) (Article **II**). A large proportion of the changes are caused by yearly fluctuations in numbers due to the influence of various abiotic and biotic factors such as weather conditions (both in wintering areas and breeding grounds), availability of a variety of resources, and nesting success in the previous breeding seasons (Wiens 1989). As half of the species analysed did not include study site as a significant covariate in the population change models, these large scale factors as well as factors acting on national level played major role in the observed change or stability of populations and the local factors were less important. However, the other half of species whose changing patterns differed significantly between the study sites (study site included as a significant covariate in their TRIM models) suggests that local processes played very important role. Changes in breeding populations of these species chiefly have been caused by changes in distribution of agricultural habitats and various landscape features as well as by changes in farming intensity (Article **II**).

Population changes of farmland birds in Latvia after joining EU – impact of changes in agricultural policy (Article VI)

After Latvia joined EU in spring 2004, the funding to agricultural development increased substantially (Anon. 2010b). The different measures included in the national Rural Development Plan served as driving forces causing a rapid change in land use patterns and farming practices. Areas of arable lands rapidly increased and so did the crop yields (Fig. 1.3). These changes were evident also in the study sites (Article **VI**). We tested if these changes are reflected in the trends of the species richness, diversity and abundance of three sets of bird species (see Methods) as well as in individual species. It may be argued that the three year period we used to assess the post-accession effects is not long enough for detection of trends as these may be strongly affected by the yearly population fluctuations caused by various biotic and abiotic factors including local site specific factors (see previous chapter) and thus having large confidence intervals. However, as we are deliberately focusing on short-time effects that might be caused by the recent agricultural policy changes in Latvia and we look at patterns common in larger groups of species instead of individual species performance, we consider the chosen approach appropriate for the given task.

The trends in the period 2 (2003 – 2006) did not follow the earlier trends (1995 – 2003) and the largest proportion of species belonged to the group with increasing trends in period 1 and declining in period 2 (fig. 4.6). Pairwise comparisons of the trends of all 54 analysed species between the two periods showed that trends in period 2 were significantly lower than in period 1 (Wilcoxon signed ranks test, $Z = -4.034$, $n = 54$, $p < 0.001$). Similar pattern although not always statistically significant was observed in all compared species groups divided by their preferred habitat structures, wintering areas and feeding preferences (fig. 4.7). Trends in bird abundance, species richness and diversity changed from “moderate increase” in period 1 to “stable” or “moderate decline” in period 2 in all three species community categories analysed (Table 4.3). There were 11 species showing statistically significant declines and only 5 showing significant increases in period 2 while in period 1 these figures were 4 and 26 respectively (Table 2 in Article **VI**). This difference is statistically significant (χ^2=14.58; df=1; p<0.001).

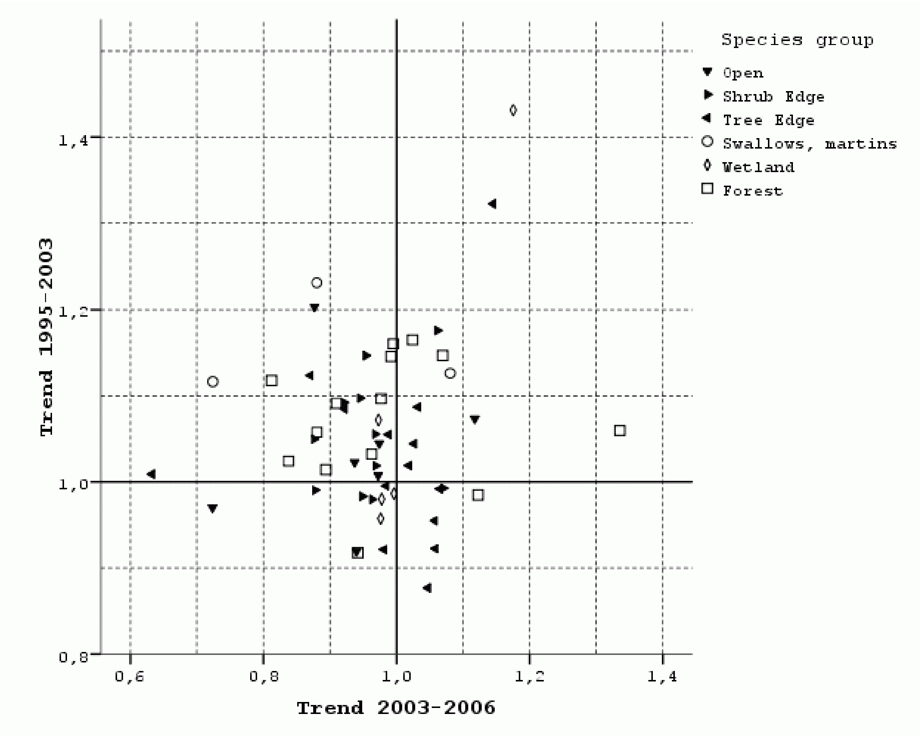

Figure 4.6. Scatterplot of trends in periods 1995-2003 and 2003-2006.

It was expected that the increase in species diversity and abundance that Latvian farmland experienced during the 1990s had to stop and stabilise at some point as the carrying capacity of the environment could not grow endlessly. However, in this study we found reversal rather than the stabilisation of the trends, as the trajectories of many bird populations as well as total bird abundance changed to negative in period 2. This pattern was consistent in almost all the species groups analysed. The most pronounced these differences were found in the species ecologically connected with forests and tree or shrub edge. These are largely the same species that rapidly increased in the period 1 due to encroachment of shrubs and trees but now their habitats in farmland have been most affected by the recent changes: cutting bushes and trees in the overgrown areas as well as along the roads and ditches both to comply with the "good agricultural condition" requirements and to increase the "eligible" area for the "single area payment".

The observed changes cannot be attributed only to the increased and still growing area of the active farmland due to restoration carried out in the previously overgrown areas as the declines in "ShrubEdge" and "Forest" groups might suggest – the reversal of trends has been observed in abundances, species richness and diversity of the farmland specialists too (Table 4.3; Fig. 4.7A). Thus we argue that the reason for the observed declines is in the lower carrying capacity of the environment caused by the changes in agricultural practices and intensity due to increased funding allocated to this sector that are promoting this change.

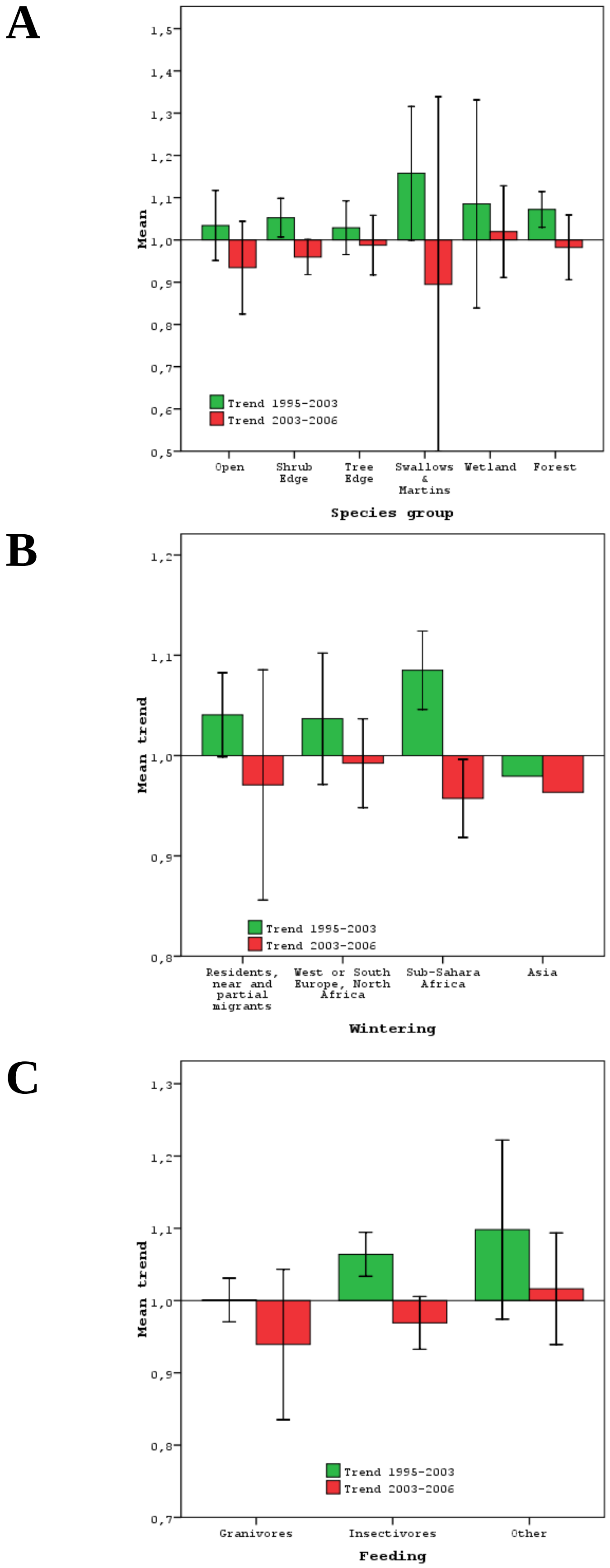

Figure 4.7. Comparison of the mean trends between the periods 1995-2003 and 2003-2006 in different ecological species groups (A), species groups with different wintering regions (B), species groups using different food resources (C).

Conclusions

1. The main ecological gradients affecting bird communities in Latvian farmland are 1) from uniform arable lands to more natural and structurally diverse habitats; 2)from dry to wet habitats; 3) from habitats and features associated with human dwellings to remote and abandoned areas. Species richness on site level (α diversity) increases with proportion of natural and semi natural habitats as well as landscape features but is negatively affected by increasing proportion of arable lands, intensity of their management and lack of landscape elements. Species richness on landscape level (γ diversity) is affected by landscape composition, diversity and intensity of farming.
2. Relationships between birds and habitats in Latvian farmland are stable between years for most of the species. According to the Latvian farmland specific multiple regression models for 30 common bird species all habitats and landscape features play important role either as positive or negative predictor at least for some bird species and none of them is solely negative factor. Semi-natural grasslands and small unfarmed patches are most important positive predictors for farmland specialist species.
3. Species distributions and densities can be modelled by applying species – habitats models to unknown locations with values of predictor variables derived from remotely sensed data. Appropriate scale of data collection and modelling should be chosen for any given species to obtain best results.
4. Populations of majority of species increased in Latvian farmland before Latvia joined EU. Most of the increasing species were arboreal and edge species due to shrub encroachment and overgrowing of abandoned lands. Local changes in habitat composition, farming intensity and availability of landscape features affected trends for half of the analysed species while the rest showed similar patterns across the country.
5. Driving factors behind bird population trends changed in Latvian farmland after joining EU. Increase of arable lands and farming intensity resulted in lower carrying capacity of environment that caused declines in abundance and richness of all analysed species groups.

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Article I

AUNINS A., PETERSEN B. S., PRIEDNIEKS J., PRINS E. 2001. RELATIONSHIPS BETWEEN BIRDS AND HABITATS IN LATVIAN FARMLAND. *ACTA ORNITHOLOGICA* 36/1: 55–64.

Relationships between birds and habitats in Latvian farmland

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Auninš A., Petersen B. S., Priednieks J., Prins E. 2001. **Relationships between birds and habitats in Latvian farmland.** Acta Ornithol. 36: 55–64.

Abstract. This point-count based study (1995–99) provides information on the avifauna of different farmland habitats in Latvia. Ordinations identify the main gradients within the species composition pattern: from arable land to natural habitats and from woodland across open, dry areas to wet meadowlands with rivers and ponds. Regression models describing the relationship between species richness and habitat show that the best positive predictors of species richness are woodland, scrub, natural meadows, unfarmed patches such as piles of stones or brushwood, and ponds. Regression models of the habitat affinities of the 30 most frequently recorded bird species are used to describe the present-day situation and to predict the effects of possible changes in Latvian farmland. The current high bird diversity is largely upheld by a non-intensive agriculture and large set-aside areas. Both further abandonment and development towards western standards of agricultural production may have adverse effects on populations of several species of conservation concern. Environmental considerations should therefore become an integral part of the development of Latvian agriculture.

Key words: species–habitat relationships, farmland birds, species richness

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INTRODUCTION

Farmland in Latvia occupies approximately 40% of the territory. Of this, 71% is arable land, 27% — grassland and less than 1% — natural meadows. Small-scale farming is characteristic: 30% of all farms are less than 5 ha, and only 6% are more than 50 ha. Due to political and economical changes, Latvian farmland has changed dramatically since the early 1990s. The processes of land abandonment on large territories of former collective farms and re-privatisation to former owners have been going on simultaneously. This has resulted in a steep increase in the area of abandoned fields, while grasslands are converted to arable land by the new landowners. No more than 37 to 40% of the agricultural area was sown in 1995–1999, peaking in 1997. The number of cattle declined by 70% in the period from 1990 to 1997 and the process is still ongoing. The usage of fertilisers decreased from 217 kg/ha in 1990 to 23 kg/ha in 1995 followed by an increase to 34 kg/ha in 1997–1999. Pesticide usage was reduced by 88% from 1990 to 1995, but increased from 0.2 kg/ha in 1995 to 0.5 kg/ha in 1996, after which it has been stable.

The principal purpose of the present study was to provide information about the bird fauna in different farmland habitats and to establish a baseline for the monitoring of changes in farmland bird populations in Latvia. Models describing the relationship between the occurrence of farmland bird species and various landscape and habitat features were developed, with the aim of making a prediction of effects of the changes in Latvian farmland possible. Analysis of actual trends and fluctuations of bird numbers as well as regional comparisons are beyond the scope of this paper. The latter subject is partly covered in Priednieks et al. (1999).

MATERIAL AND METHODS

The field studies were conducted in 1995–1999 in four areas (Fig. 1). All study areas are located in mixed farmland, and each has a size of 100 km^2. They are located in different regions of Latvia and were selected to be representative for the dominating farming practice in each region. Together they create a gradient of farming intensity which is representative for Latvian farmland as a whole.

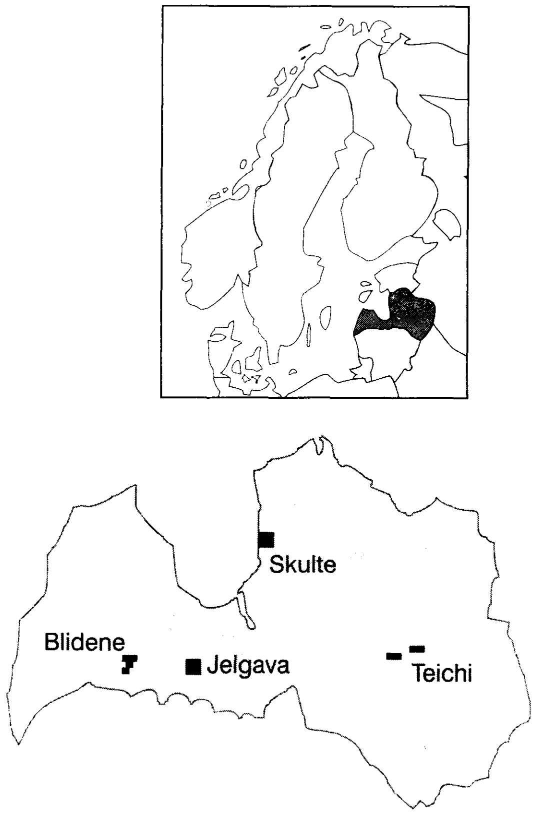


Fig. 1. The location of the four study areas in Latvia.

Landsat TM satellite images were used for obtaining general information about land cover within each study area. The Jelgava area is the most intensively farmed with less than 5% forest, and during the study years up to 68% of the farmland area was used for annual crops. In the Blidene and Teichi areas, forests make up about 25%, and up to 40% of the farmland area was used for annual crops. The least intensively farmed area is Skulte, where 30% is forest and a maximum of 30% of the farmland area was used for annual crops. During the study period, the percentage of farmland being cropped showed a tendency to increase in all study sites, most prominently in the Jelgava area. In terms of yields, the highest farming intensity was found in the Jelgava and Blidene areas (about 25 quintals of cereals per ha in 1999), while yields in the Teichi and Skulte areas were very low (about 10 quintals of cereals per ha in 1999). The mean yield for Latvia was 18.8 quintals per ha in 1999. This figure is typical for the Baltic region but considerably less than in Western European countries like Germany, Denmark, Netherlands, France and UK where cereal yields are above 60 quintals per ha.

In each of the four study areas, 60 bird count points were chosen randomly using a grid pattern layout with a minimum distance of 400m between points (see details in Priednieks et al. 1999). This procedure ensured that the census points constituted a representative sample of Latvian farmland and that the probability of recording an individual bird at more than one point was negligible. The points are not strictly independent, but we believe that no serious biases are introduced by treating them as such. After the 1995 season, the study had to be limited to 40 census points within each area; these points were selected at random from the total sample. Only the 160 points that were used in all five study years were included in the analyses.

At each census point, five-minute bird counts with unlimited distance were performed twice per season: around mid-May and mid-June, respectively. Migrating birds and other birds flying high above the site were excluded from further analysis. So were Swifts *Apus apus* and *Hirundidae* species as their occurrence is very dependent on meteorological conditions. All *Corvus* species were excluded as well, because they are mainly seen in foraging groups on fields, without any relation to their breeding habitat.

The total number of species recorded per point, with the above-mentioned exceptions, was used as a measure of species richness. For each point and species, the number of birds recorded was interpreted in pairs (e.g. two singing birds were considered as two pairs while one bird singing and one bird observed (if not an obvious male) were considered as one pair); the maximum of the two counts was used. The 30 most frequently recorded species were used for analysis of species-habitat affinities. Before analysis, all numbers except species richness and number of Skylarks *Alauda arvensis* were $\log_e(x+1)$ transformed in order to optimise the approximation to a normal distribution.

The area within a circle with radius 200m (area 12.56 ha) around each point was described by means of 26 habitat variables (Table 1).

Table 1. Habitat variables recorded and the transformations used prior to analysis. [1] Coded as 0.5% if present, but occupying less than 1% of area

Variable	Explanation	Transformation
WINTER	Winter cereals (% of area)	arcsin vx
SPRING	Spring cereals (% of area)	arcsin vx
ROOTS	Root (furrow) crops (% of area)	arcsin vx
FALLOW	1st year fallow (% of area)	arcsin vx
ABANDON	Abandoned fields (% of area)	arcsin vx
SOWNGR	Sown grass fields (% of area)	arcsin vx
CULTM	Cultivated meadows (% of area)	arcsin vx
DRYM	Dry meadows (% of area)	arcsin vx
WETM	Wet meadows (% of area)	arcsin vx
PONDVEG	Ponds or pools with water-fringe vegetation (% of area)[1]	arcsin vx
PONDCL	Ponds or pools without water-fringe vegetation (% of area)[1]	arcsin vx
WOOD	Forests (% of area)	arcsin vx
ORCHARD	Orchards (% of area)	arcsin vx
SHRUB	Scrub (% of area)[1]	arcsin vx
FARM	Farmsteads (% of area)[1]	arcsin vx
BUILD	Isolated farm buildings outside farmsteads (% of area)[1]	arcsin vx
RUDERAL	Waste (ruderal) areas (% of area)	arcsin vx
DITCH	Length (m) of ditches and regulated watercourses	not transformed
RIVER	Length (m) of natural rivers	ln (x+1)
ALLEY	Length (m) of tree lines	ln (x+1)
SHRUBLIN	Length (m) of shrub belts and hedges	not transformed
ROAD	Length (m) of roads	not transformed
ETL	Length (m) of electricity and telegraph lines	not transformed
FENCE	Length (m) of fences (including cattle enclosures)	ln (x+1)
TREE	Number of single trees	v (x+0.5)
HEAP	Number of stone or brushwood heaps (remains after amelioration works)	v (x+0.5)

For each year, a correlation matrix was made to check for possible strong correlations between habitat variables. Only 17 out of 1625 (2–5 out of 325 each year) correlations between the variables exceeded 0.30, and none of them exceeded 0.50. The following four pairs of variables were correlated with r exceeding 0.30 in two or more years (numbers of correlations and sign are given in parentheses): FARM and ETL (5+), WETM and RIVER (5+), FENCE and DRYM (2+), and SHRUBLIN and DITCH (2+). Thus, intercorrelation of habitat variables was not a serious problem. A model describing the relationship between bird species richness and the habitat features was derived for each year using stepwise multiple regression (Sokal & Rohlf 1995). SPSS 10.0 for Windows software was used with $p < 0.05$ as entry criterion. Species-habitat ordinations were performed for each year, using Canonical Correspondence Analysis (ter Braak 1986, 1994) with PC-ORD (Multivariate Analysis of Ecological Data) 4.0 for Windows software. To investigate species-habitat relationships in more detail, regression models for each species and year were constructed using the method described for species richness.

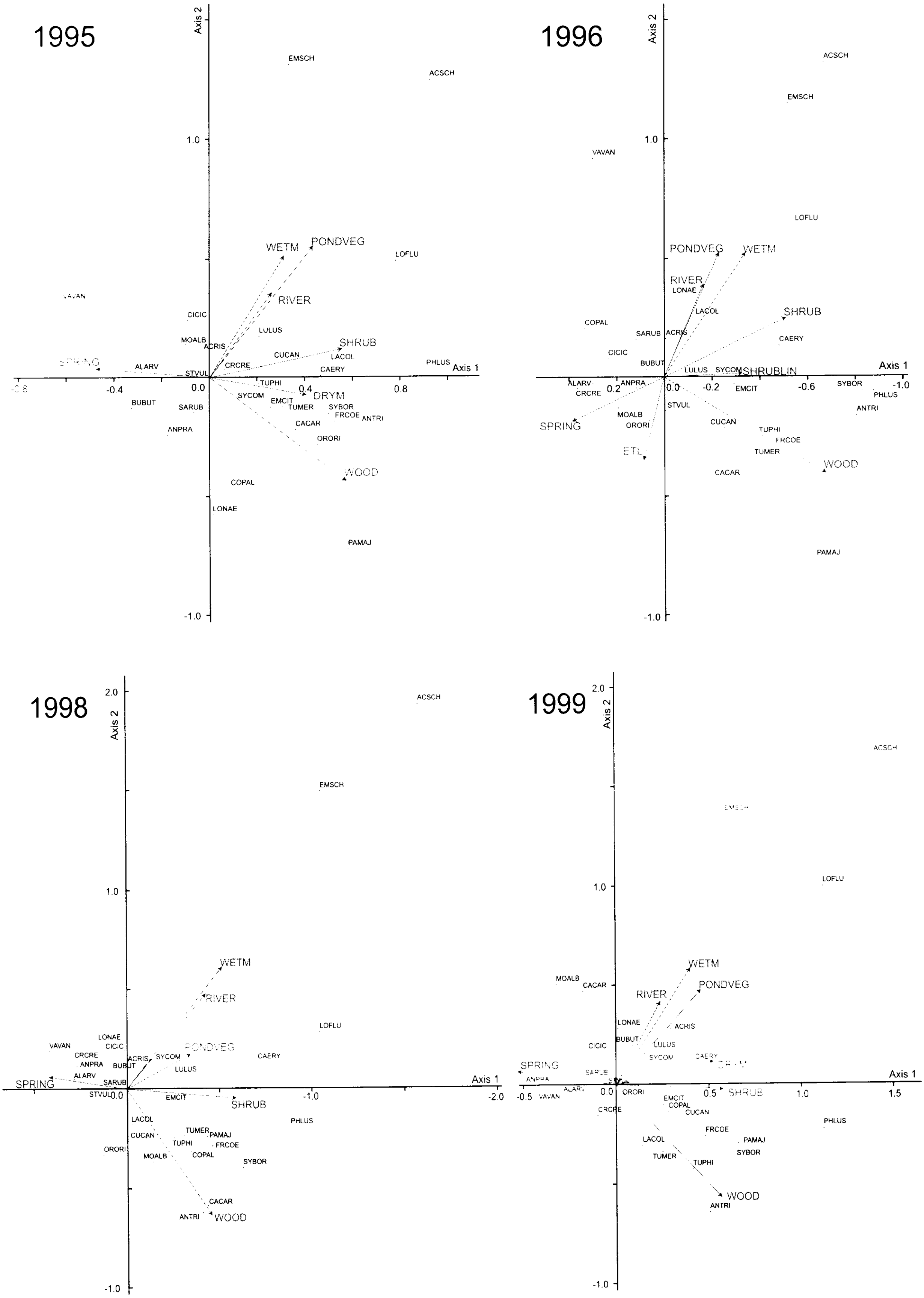
RESULTS

The average species richness (as defined above) was 12.5 (SD 4.27, range 2–25).

The models for species richness (Table 2) indicate that annual crops influence overall bird diver-

Table 2. Results of the stepwise regression analyses of species richness. For each year, the regression coefficients of predictor variables included in the final model are shown. P — years with the variable.

Variables	1995	1996	1997	1998	1999	Sign	P
WOOD	5.232	6.175	7.669	6.727	4.814	+	5
SHRUB	3.804	2.746		5.048	3.269	+	4
HEAP	3.160	2.431	3.254		2.554	+	4
DRYM	2.688	2.572	3.012		4.069	+	4
PONDVEG	3.242		3.677		2.978	+	3
SOWNGR		-2.378	2.458	2.361	2.437	+/-	3-1
FENCE			2.143	2.433		+	2
WETM	2.845		2.137			+	2
ALLEY	1.989	4.119				+	2
ROAD	2.508					+	1
RIVER			3.876			+	1
DITCH					2.107	+	1
WINTER	-1.985	-5.005				-	2
SPRING	-3.860	-3.111				-	2
ROOTS	-2.026		-2.633		-1.900	-	3
Adjusted R^2	0.520	0.475	0.504	0.345	0.412		


1995
1996
1998
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Axis 1
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WETM
PONDVEG
RIVER
SHRUB
WOOD
SPRING
SHRUBLIN
DRYM

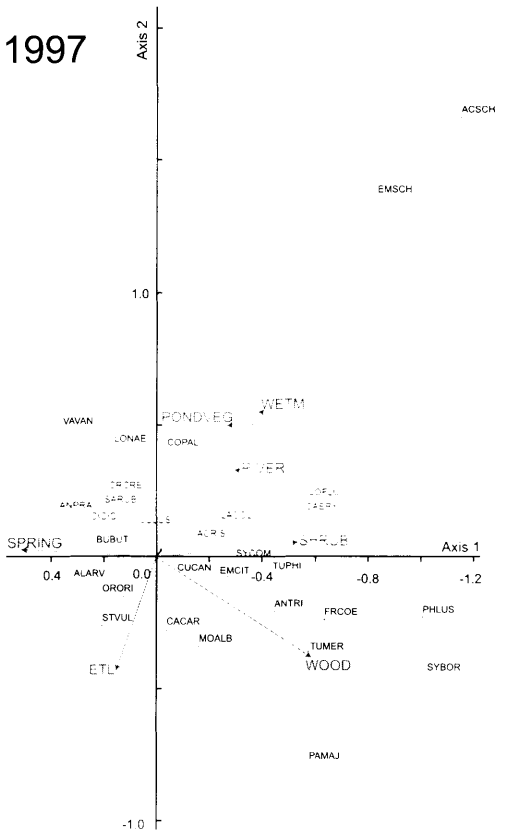

Fig. 2. Species-habitat relationships according to Canonical Correspondence Analysis. For each of the five study years, the first two canonical axes are shown. Only habitat variables with scores larger than 0.10 on one or both axes are plotted. To ease between-years comparisons, the first axis is shown reversed for 1996, 1997 and 1998 (negative values to the right).
Abbreviations of the bird variables: CICIC — *Ciconia ciconia*, BUBUT — *Buteo buteo*, CRCRE — *Crex crex*, VAVAN — *Vanellus vanellus*, COPAL — *Columba palumbus*, CUCAN — *Cuculus canorus*, ALARV — *Alauda arvensis*, MOALB — *Motacilla alba*, ANPRA — *Anthus pratensis*, ANTRI — *Anthus trivialis*, LACOL — *Lanius collurio*, SARUB — *Saxicola rubetra*, LULUS — *Luscinia luscinia*, TUMER — *Turdus merula*, TUPHI — *Turdus philomelos*, LONAE — *Locustella naevia*, LOFLU — *Locustella fluviatilis*, ACRIS — *Acrocephalus palustris*, ACSCH — *Acrocephalus schoenobaenus*, SYBOR — *Sylvia borin*, SYCOM — *Sylvia communis*, PHLUS — *Phylloscopus trochilus*, PAMAJ — *Parus major*, STVUL — *Sturnus vulgaris*, ORORI — *Oriolus oriolus*, FRCOE — *Fringilla coelebs*, CACAR — *Carduelis carduelis*, CAERY — *Carpodacus erythrinus*, EMCIT — *Emberiza citrinella*, EMSCH — *Emberiza schoeniclus*.

sity negatively while other types of landscape features increase it. All the final models were highly significant ($p < 0.001$). This general pattern was consistent between years though the importance of different habitat elements varied. The most persistent positive predictor of species richness was WOOD (significant all years), followed by SHRUB, HEAP and DRYM (significant 4 years).

In the species–habitat ordinations, the cumulative percentage of variance explained by the first two axes ranged from 11.8 (1995) to 15.7 (1999). A large part of the variation thus remains unexplained. The relationship between the habitat variables and the canonical axes was quite stable from year to year (Fig. 2). The eigenvalue of the first axis ranged from 0.118 (1996) to 0.139 (1997) and the percentage of variance explained from 8.3 (1995) to 10.6 (1999). This axis displays a gradient from arable land (especially spring cereals) to more natural habitats like woodland, scrubs and wetlands — i. e. a gradient of general farming intensity. The second axis (eigenvalues ranging from 0.051 (1995) to 0.071 (1997) and percentage of variance explained from 3.4 (1995) to 5.3 (1998)) may be interpreted as a gradient from woodland across arable land and other open, dry areas to wet meadowlands with rivers and ponds.

Although the exact correlations between the bird species vectors and the canonical axes varied between years, the overall pattern was fairly consistent. Several groups of species can be identified. The most clearly demarcated group is the wetland/pond species: Sedge Warbler *Acrocephalus schoenobaenus* and Reed Bunting *Emberiza schoeniclus*, in some years accompanied by River Warbler *Locustella fluviatilis*. Also a group of open area species consisting of, e.g., Skylark, Lapwing *Vanellus vanellus*, Corncrake *Crex crex*, Meadow Pipit *Anthus pratensis* and Whinchat *Saxicola rubetra* is quite well defined. Species that mostly feed on fields and sown grasslands but breed somewhere else, such as Buzzard *Buteo buteo*, Starling *Sturnus vulgaris* and White Stork *Ciconia ciconia* also fit into this group. The woodland and scrub species show a gradient from woodland species like Tree Pipit *Anthus trivialis* and thrushes *Turdus* to species associated with more open areas (e.g. Scarlet Rosefinch *Carpodacus erythrinus*), with most species fitting somewhere between the WOOD and SHRUB vectors.

The woodland/scrub species group is further divided when a third canonical axis is included (two examples are shown in Fig. 3). This axis (percentage of variance explained ranging from 2.7 (1995, 1996) to 4.2 (1997)) seems to represent a gradient from farms and habitats associated with them to more remote areas with woods, abandoned fields and stone and brushwood heaps. Among the arboreal species, Great Tit *Parus major* and Goldfinch *Carduelis carduelis* show an association with farmsteads and alleys, where they meet

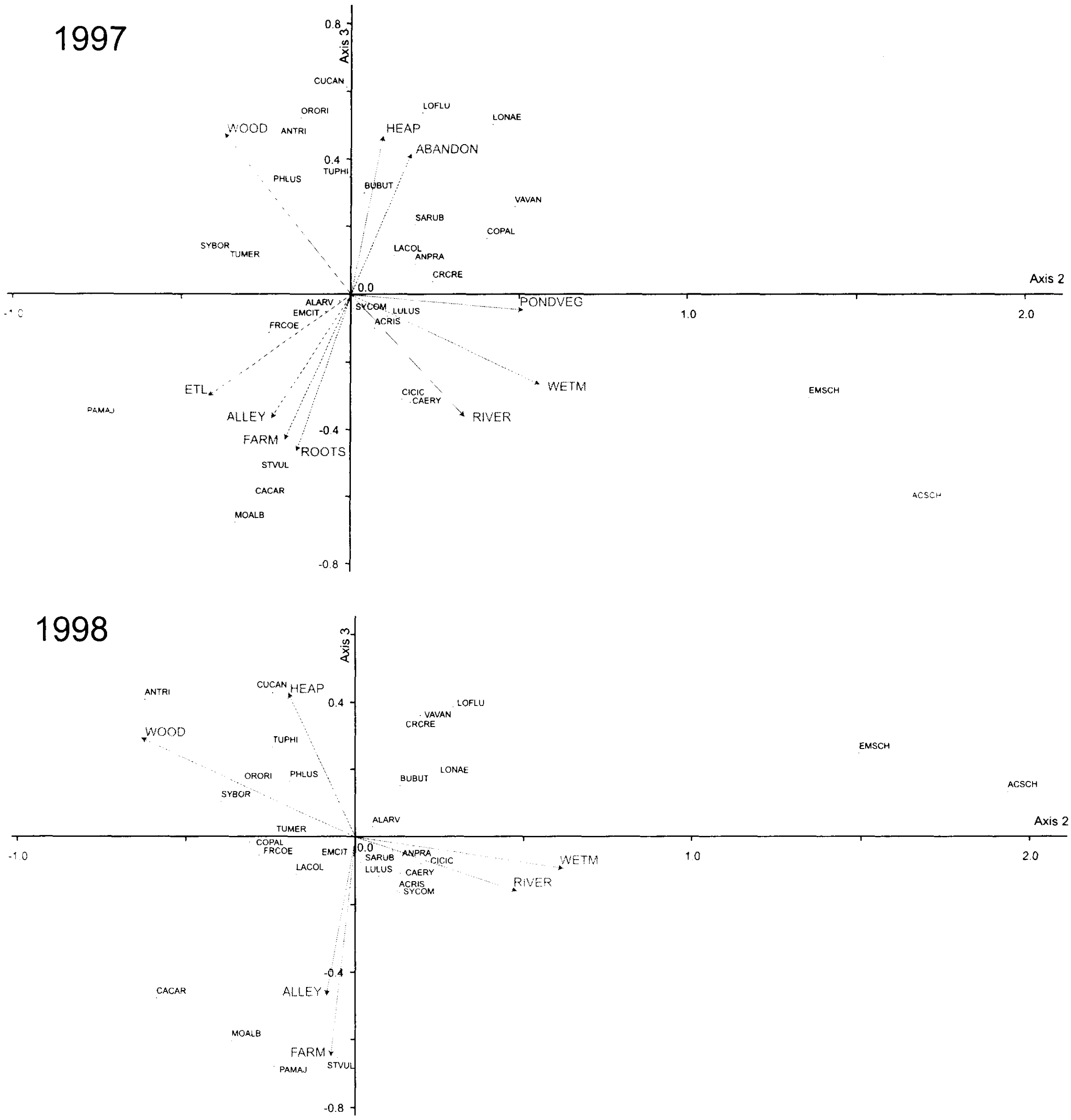

Fig. 3. Additional CCA biplots of species-habitat relationships, showing the second and third canonical axes. 1997 and 1998 are shown as examples. Only habitat variables with scores larger than 0.10 on at least one of these axes are plotted. Abbreviations of bird variables as in Fig. 2.

open land species such as White Wagtail *Motacilla alba* and Starling.

Regression analyses of species-habitat associations (Tables 3 and 4) indicate that there were more positive than negative correlations. All modelsw were statistically significant. Very few species (Skylark and Lapwing) benefit from the presence of arable fields. All other species dealt with here require the presence of one or more of the following habitat types: grassland, wetlands, shrubs or trees.

Persistency and predictive value of the models varied between species. Predictor variables included in 3 or more yearly models were considered as stable. The most stable models were those for species with small territories and specific habitat needs (e.g. Sedge Warbler and Reed Bunting) as well as those for woodland species and Skylark. The models of least predictive value were those for species with large territories, species feeding outside their breeding territories and species easily detectable beyond the 200m zone around the

Table 3. Percentage of variance explained by the yearly species-habitat models resulting from stepwise regression analysis. In brackets - the number of predictor variables in each model. Statistical significance of each model: * - $p < 0.05$, ** - $p < 0.01$, *** - $p < 0.001$.

	1995	1996	1997	1998	1999
Ciconia ciconia	7.8 (4)***	12.2 (3)***	10.9 (3)***	10.8 (4)***	6.5 (2)**
Buteo buteo	6.7 (2)**	2.5 (1)**	5.0 (1)**	2.5 (1)**	11.0 (3)***
Crex crex	2.7 (1)*	14.4 (4)***	4.2 (2)*	9.7 (4)***	2.6 (1)*
Vanellus vanellus	20.9 (4)***	17.3 (6)***	17.8 (4)***	11.7 (4)***	7.7 (2)**
Columba palumbus	9.4 (3)***	9.9 (3)***	6.5 (2)**	8.2 (2)***	16.3 (3)***
Cuculus canorus	19.3 (5)***	35.5 (7)***	12.8 (2)***	29.8 (6)***	30.5 (7)***
Alauda arvensis	33.4 (6)***	34.0 (5)***	42.7 (9)***	47.3 (10)***	47.6 (7)***
Motacilla alba	7.1 (3)**	16.0 (5)***	17.5 (4)***	10.6 (3)***	9.8 (2)***
Anthus pratensis	18.8 (6)***	14.0 (3)***	12.3 (3)***	10.6 (4)***	11.0 (3)***
Anthus trivialis	31.8 (5)***	27.5 (2)***	28.5 (3)***	30.4 (3)***	36.1 (4)***
Lanius collurio	3.3 (1)*	5.3 (2)**	3.7 (1)*	0	1.9 (1)*
Saxicola rubetra	21.2 (6)***	22.2 (7)***	21.8 (5)***	10.7 (3)***	18.8 (6)***
Luscinia luscinia	11.6 (2)***	7.3 (2)**	15.3 (5)***	14.5 (4)***	21.0 (5)***
Turdus merula	18.9 (4)***	21.0 (3)***	21.8 (3)***	14.9 (3)***	8.3 (2)***
T. philomelos	9.4 (3)***	7.0 (1)***	12.9 (2)***	12.7 (2)***	22.2 (5)***
Locustella naevia	4.5 (1)*	8.7 (2)***	21.5 (4)***	7.7 (2)**	16.2 (2)***
Locustella fluviatilis	14.3 (4)***	15.2 (2)***	17.6 (3)***	19.5 (3)***	26.9 (3)***
Acrocephalus palustris	7.5 (3)**	8.9 (3)**	1.8 (1)*	5.2 (1)**	26.8 (4)***
A. schoenobaenus	39.6 (3)***	32.0 (5)***	58.0 (3)***	46.8 (3)***	42.9 (3)***
Sylvia borin	11.2 (4)***	39.1 (7)***	29.0 (4)***	22.0 (3)***	32.0 (4)***
S. communis	11.5 (3)***	16.7 (5)***	16.8 (5)***	14.4 (2)***	12.4 (3)***
Phylloscopus trochilus	40.8 (4)***	30.5 (6)***	32.4 (5)***	18.9 (3)***	44.6 (6)***
Parus major	18.5 (3)***	36.9 (7)***	28.3 (6)***	11.1 (6)***	14.5 (3)***
Sturnus vulgaris	0	2.4 (1)*	14.0 (2)***	21.5 (2)***	13.4 (3)***
Oriolus oriolus	5.2. (2)**	11.6 (4)***	25.3 (5)***	25.2 (4)***	24.2 (5)***
Fringilla coelebs	37.3 (8)***	31.7 (4)***	40.0 (5)***	39.6 (6)***	43.3 (5)***
Carduelis carduelis	5.0 (2)**	10.3 (2)***	13.2 (3)***	11.8 (4)***	11.6 (3)***
Carpodacus erythrinus	21.1 (5)***	17.4 (4)***	15.8 (3)***	20.8 (3)***	21.5 (5)***
Emberiza citrinella	31.3 (7)***	9.2 (2)***	11.2 (4)***	11.2 (4)***	18.0 (5)***
E. schoeniclus	23.9 (4)***	23.3 (2)***	37.1 (6)***	30.2 (7)***	23.1 (3)***

census point (e.g. Buzzard, Corncrake, Woodpigeon *Columba palumbus*, Starling and Golden Oriole *Oriolus oriolus*). The models for species with prominent fluctuations in numbers between the study years (e.g. Marsh Warbler *Acrocephalus palustris* and Red-backed Shrike *Lanius collurio)* were also unstable.

DISCUSSION

The spatial distribution of birds and the structure of their communities may be affected by various factors, and although habitat structural factors are usually thought to be the most important, they leave a large part of the variation unexplained (e.g. Fuller et al. 1997, Petersen 1998, Schifferli et al. 1999). The numbers and distribution of birds are also affected by yearly fluctuations in food abundance, demographic parameters, mortality in different stages of the annual cycle, weather conditions etc. (Wiens 1989, Fuller 1994). These variables were not included in the present study, and together with variation in census conditions (observer differences, variation in date and time of day, meteorological conditions) they are surely responsible for a major part of the unexplained variation.

The species richness per point, as reported here, cannot be compared directly with other studies, due to the limitations in the range of species and individuals included. The general pattern of species-habitat associations is roughly similar to the results of a comparable study in Denmark (Petersen 1998), despite the differences in the structure of the landscape. In both studies, the main gradient of species diversity follows a gradient from uniform to structurally diverse landscapes, although more species were associated with the landscape belonging to the uniform part of the first canonical axis in Latvia (Fig. 2) than in Denmark. Among these are species of global or European conservation concern like Corncrake and White Stork which are rare in Western Europe but still common in the Baltic countries. The decline of these open-land species has been associated with the intensification of agriculture during the last decades in Western

Table 4. Summary of the yearly regression models of species-habitat associations. + — positive associations, - — negative, numbers — years (if > 1).

	WINTER	SPRING	ROOTS	FALLOW	ABANDON	SOWNGR	CULTM	DRYM	WETM	PONDVEG	PONDCL	WOOD	ORCHARD	SHRUB	FARM	BUILD	RUDERAL	DITCH	RIVER	ALLEY	SRUBLIN	ROAD	ETL	FENCE	TREE	HEAP	Stable predictors
Ciconia ciconia	4-				-	+	2+					4-	-		-		-			+							2
Buteo buteo			-		+		+			+					2-		+							-			0
Crex crex	2-	-			+	2+					2+	2-														2+	0
Vanellus vanellus		5+	+					-	+	+				-	2-	-		3+				-		-		2+	2
Columba palumbus		+	-		+	+		+			+	+			-			+		+						3+	1
Cuculus canorus	2-	2-	2-	+	+		-			+		4+								+	-	3+		4+		4+	4
Alauda arvensis	+	4+		+		+	2-	-	4-			5-		5-	2-	-		+		-	2-		+	3+		3+	6
Motacilla alba			+							-				+	3+	4+	2+		+		-		+	-		+	2
Anthus pratensis	-				2+	2+	+			-	+	2-		3-	-			+					+	2+		-	1
Anthus trivialis			2-					2+	-		+	5+		2+									-	+		2+	1
Lanius collurio	+							+							+								-		-		0
Saxicola rubetra	2-	2-	-		3+	+	-	+		-		2-	-	-	2-	2+		+	-	+	-		+	+		+	1
Luscinia luscinia	-						-	3+		2+	+			+	+				2+	+				2+	-	2+	1
Turdus merula						+	+		+			5+		+					2+	+				+-	+		1
T. philomelos						-						4+		+	-					-				+	+	3+	2
Locustella naevia					5+						+							3+			-					+	2
Locustella fluviatilis								+-	4+	+	+			3+							+				2+	+	2
Acrocephalus palustris	-			+				+		+				+		+		4+	+							+	1
A. schoenobaenus									5+	5+	+							+	4+	+							3
Sylvia borin				-	-		2+			-		4+	+	4+	+			+	+		+				+	2+	2
S. communis		2-	-	-	+			+				+-		4+		+		+	+			+	+			+	1
Phylloscopus trochilus					2+			2+		4+	2+	5+		4+							3+	+	+				4
Parus major			2+		2+		+					5+			2+		2+			4+	3+			2+			3
Sturnus vulgaris												+			2+		+		-	2+			+				0
Oriolus oriolus		+		+	2+	2+	-	+	-			2+		+						+				3+		4+	2
Fringilla coelebs		3-	-	+	-		-				-	5+		4+	4+		+	2-	+	+		+					4
Carduelis carduelis		2-							-			-				+	2+			5+				2+			1
Carpodacus erythrinus						+	+	3+	2+			2+		3+	-				2+		+	+		+-	+		2
Emberiza citrinella		-		+			2+	3+				2+		4+				+			3+	2+		+-		+	3
E. schoeniclus					-				5+	5+	2-	2-			-				+		2+		-		+	-	2
Total no. of -	13	13	9	2	4	1	7	3	7	4	3	19	2	10	14	2	1	2	2	2	6	1	3	6	1	2	
Total no. of +	2	11	4	6	21	12	11	20	18	21	11	46	1	34	14	9	9	18	16	19	14	9	7	24	8	34	

Europe (Tucker & Heath 1994). In Latvia, these species benefit from a less intensive agriculture with little use of chemicals, small field sizes ensuring a diverse landscape, extensively managed grasslands and an increased amount of abandoned fields. The habitat model for Corncrake (Table 4), although not highly significant, supports the findings of the Corncrake survey in Latvia in 1996 (Keišs 1997). In the Corncrake survey, abandoned fields appeared to hold the highest densities followed by various grasslands (chiefly sown grass), while the species avoided arable fields. Abandoned fields and grasslands contained almost 30% and more than 50% of the Latvian population, respectively.

The habitat models of most bird species in Latvian farmland are rather similar to those reported from comparable studies in other European countries (Fuller et al. 1997, Petersen 1998, Schifferli et al. 1999), although several differences exist, both in the models themselves and in the overall importance of specific habitat types. The most contradictory results, compared to results of recent studies in Britain (Fuller et al. 1997, Kyrkos et al. 1998, Gregory 1999) and Denmark (Petersen et al. 1995) were found in the Yellowhammer *Emberiza citrinella*. In Latvia, the Yellowhammer prefers meadows (CULTM and DRYM, Table 4) among the agricultural habitats, whereas it shows a strong preference for arable lands in Britain and Denmark. The habitat model for the species in Swiss farmland falls in between these two extremes, with both grasslands and arable lands being positive predictors (Schifferli et al. 1999). Probably the distribution of Yellowhammers in Latvian farmland is mainly governed by the availability of suitable breeding habitat, i.e. scrub (SHRUB and SHRUBLIN) and woodland edges, because hedges along field margins are less widespread than in Britain and Denmark. The association with meadows may reflect the current overgrowing of meadows with bushes.

Farmsteads and other buildings have a less prominent impact on species composition in this study than in the Danish study, where building/garden area was the main predictor of densities of 13 species (Petersen 1998). In large parts of Western European farmland, human dwellings with their surrounding vegetation are important habitat islands in a rather uniform agricultural landscape, whereas their importance is much smaller in Latvia, where the population density is lower and agricultural land occurs in a mosaic structure with forest and scrub.

As might be expected, woodland area appears as a significant predictor in more models than any other variable, showing the highest number of positive as well as negative associations. A large group of species with almost no relation to agricultural land is associated with forests, while most of the typical agricultural bird species are indifferent or avoid areas close to forest. Although woodlands thus reduce rather than increase the densities of typical farmland bird species, small woodland patches within agricultural land raise the biodiversity value of the area on a larger scale.

The variable showing the second highest number of positive correlations, scrub (SHRUB and SHRUBLIN), attracts more species that are connected with an agricultural landscape (e.g. Whitethroat *Sylvia communis* and Yellowhammer). This habitat type is very common as patches or linear structures along roads and ditches and is also a common feature of traditional farmsteads. Patches of scrub are often the result of an overgrowing of open areas - i.e. the habitats of the typical species of agricultural lands - due to abandonment. A further succession on these areas will eventually lead to woodland which would be undesirable from a biodiversity point of view, as 45% of Latvia is already covered with forest. However, a suitable amount of scrub, e.g. along ditches and roadsides, has a positive effect on farmland biodiversity.

Stone and brushwood heaps (HEAP) have an unexpectedly high, positive effect on the occurrence of many species. The same is true for wet depressions (especially PONDVEG), indicating the value of such habitat islands in agricultural areas. Within the otherwise uniform arable land, they provide suitable unfarmed patches which can be used as nesting sites, protecting the nests against losses due to mechanised farming and thus ensuring a higher nesting success for various farmland species.

The most important agricultural habitats, natural meadows (DRYM and WETM), are suffering a continuous decline in Latvian farmland, partly because they are turned into arable land, partly due to overgrowing with bushes after traditional use of the areas has ceased. Several scrub species (Thrush Nightingale *Luscinia luscinia*, Scarlet Rosefinch, Yellowhammer etc.) appear associated with dry meadows, indicating the current stage of the overgrowing of these areas. The natural meadows within the study areas are too scattered and do not have enough uninterrupted open areas to hold the typical meadow species with larger territories (e.g. Lapwing, Redshank *Tringa totanus* and Common Snipe *Gallinago gallinago*); even the habitat model for Corncrake does not include these habitats. A further reduction of the area with wet meadows will also severely affect the presence of species with small territories such as Sedge Warbler and Reed Bunting which are associated with this habitat and do not have any associations with scrublands. A reintroduction of extensive farming on these areas would be desirable. Unfortunately, current state policy is orientated towards afforestation of abandoned land.

Like the meadows, abandoned fields are an important landscape element, with a number of species (e.g. Whinchat *Saxicola rubetra* and Grasshopper Warbler *Locustella naevia*) being associated with them. However, as a temporary habitat they can rapidly lose their value due to overgrowing or ploughing. From a biodiversity point of view, the most advisable management of this habitat would be an introduction of extensive mowing and/or grazing, allowing these areas to maintain their actual high densities of the globally threatened Corncrake (cf. Keišs 1997).

CONCLUSIONS

Latvian farmland currently supports a high diversity of birds and high populations of farmland species nowadays rare in Western Europe. This situation is mainly upheld by a non-intensive agriculture and large set-aside areas. Both are subjects to change with the foreseeable increase of the area being cropped and a development towards intensive agricultural production. Therefore, it is of vital importance that environmental considerations become an integrated part of the development of Latvian agriculture.

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STRESZCZENIE

[Zależność występowania ptaków od środowisk terenów rolniczych Łotwy]

Tereny rolnicze zajmują ok. 40% terytorium Łotwy. Charakteryzują się one dużą różnorodnością gatunkową i dużą liczebnością ptaków polnołąkowych, które są już rzadkie w Europie Zachodniej. Celem badań było określenie składników środowiska, które sprzyjają bogactwu awifauny. Badania prowadzono w latach 1995–1999. Wybrano 4 tereny badań, różniące się intensywnością i charakterem użytkowania rolniczego (Fig. 1). Na każdym z nich wybrano losowo 40 punktów i przeprowadzano 5-minutowe liczenie, dwukrotnie w sezonie lęgowym. Co roku teren w promieniu 200m wokół punktu został opisany przy użyciu 26 zmiennych środowiskowych (Tab. 1). Najbardziej skorelowane z bogactwem gatunkowym były: obfitość zadrzewień, krzewów, suchych łąk oraz kęp zarośli i stosów kamieni (Tab. 2). Określono gradient zmian środowiska, związany ze składem gatunkowym ptaków — od pól uprawnych do terenów naturalnych i od lasów poprzez tereny suche i otwarte, do wilgotnych łąk z rzekami i stawami (Fig. 2), jak również od terenów rolniczych do terenów bardziej naturalnych (Fig. 3). Analizy zależności występowania ptaków od czynników środowiska przeprowadzono dla najczęstszych 30 gatunków (Tab. 3 i 4).

Obecna wysoka różnorodność ptaków w środowiskach rolniczych Łotwy jest głównie utrzymywana przez ekstensywne rolnictwo i dużą ilość ugorów. Intensyfikacja rolnictwa, podobna do zachodnio-europejskiej, może negatywnie wpływać na populacje wielu gatunków ptaków. Dlatego rozwój rolnictwa powinien uwzględniać jej wpływ na środowisko przyrodnicze.

Article II

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Ornis Hungarica 12-13: 41-50. 2003

Bird population changes in Latvian farmland, 1995-2000: responses to different scenarios of rural development

A. Aunins and J. Priednieks

Aunins, A. and Priednieks, J. 2003. Bird population changes in Latvian farmland, 1995-2000: responses to different scenarios of rural development. – Ornis Hung. 12-13: 41-50.

After the collapse of the collective farm-based agricultural production system in Latvia during the early 90s, the agricultural sector reached its lowest point in the mid-90s. After 1995, some regions were showing various signs of agricultural recovery while others were experiencing further abandonment. A point count-based system for monitoring bird populations in an agricultural landscape was established in 4 geographically, structurally and economically different regions of Latvia in 1995, as was a scheme for mapping land use changes. Each of the 4 study areas has followed a different scenario of rural development during the study period. Our study analyses the changes of the species' populations and land use during the last 6 years revealing patterns common to all areas as well as prominent differences between them. Populations of several bird species changed considerably during the study period, as did the composition and area of most habitats. There was a general tendency for arable lands to increase whereas grasslands (especially meadows) and cattle enclosures decreased. The increase in abandoned land area peaked in 1997 but stabilised or started to decrease afterwards. However, the initial habitat distribution and the degree of the above changes varied between the areas, thus differently affecting bird populations within the study plots. The diverse patterns and sources of development and of bush clearance made these differences even more prominent.

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1. Introduction

Populations of many farmland birds have declined dramatically in Western Europe (Flade & Steiof 1990, Saris *et al.* 1994, Fuller *et al.* 1995). Numerous papers have analysed these processes and have found that most of the factors are related to intensification of agriculture (*e.g.* Chamberlain *et al.* 2000, Donald *et al.* 2001). It has been acknowledged that cereal yields alone explained over 30% of variation in bird population trends (Donald *et al.* 2001) and thus can be used as a measure of agricultural intensity in arable lands.

The processes in the agricultural sector developed differently in Eastern Europe. The intensity of Latvian agriculture has never been as great as in many EU countries, where cereal yields exceeded 60 quintals per hectare (q/ha) (FAOSTAT Database). After the collapse of the moderately intensive collective farm-based system in the beginning of the 1990s, agricultural production in Latvia reached its lowest point in 1995 (Anon 1996a).

Cereal yields decreased from 23.3 to 16.6 q/ha, cattle numbers decreased by 70% and usage of mineral fertilisers and pesticides decreased by almost 90% at that time (Anon 1996a, 1999a). A more detailed overview of agriculture in Latvia is given in Aunins *et al.* (2001).

Unfortunately monitoring data on bird populations in agricultural lands are scarce for the period 1990-1995 (Priednieks, unpublished data) when these dramatic changes occurred. Thus the recovery and rapid increase of many bird species like Grey Partridge *Perdix perdix*, Kestrel *Falco tinnunculus* and others associated with farmland remain undocumented.

The principal purpose of the present study was to analyse changes of bird populations in Latvian farmland and the possible factors causing these changes. The species-habitats relationships and the importance of different habitats or landscape features have been reported earlier (Priednieks *et al.* 1999, Aunins *et al.* 2001).

2. Study Area and Methods

Field studies

The field studies were conducted in 1995-2000 in four areas (Fig. 1). All study areas are located in mixed farmland, each having a size of 100 km^2. They are located in different regions of Latvia, have different landscape structure and were selected to be representative of the dominant farming practice in each region. Together they create a gradient of farming intensity that is representative of Latvian farmland as a whole. The two

Fig. 1. Location of the study areas.

westernmost study areas are located in regions of intensive farming but each has different landscape structure. Jelgava has very low percentage of forests and shrubland, most of its territory being used for agriculture. Blidene has a very mosaic landscape structure that is comprised of a large percentage of forests and shrubland, the presence of wetlands being characteristic. The other two areas are in areas of low intensity agriculture. The northern area (Skulte) has large percentage of woodlands and shrubland. Most former arable land is abandoned. The eastern area (Teichi) has lower percentage of forests and shrubland, and has still maintained a large percentage of natural (including floodplain) meadows. A more detailed comparison of the study areas has been given in Priednieks *et al.* (1999).

In each of the four study areas, bird count points were chosen randomly using a grid pattern layout as described in Priednieks *et al.* (1999) & Aunins *et al.* (2001). Only the 160 points (40 in each area) that were counted all six study years were included in the analyses.

At each census point, five-minute bird

Tab. 1. Relative occurrence of habitats and landscape features within the described 200 m zones around bird count points of the study areas (mean measurements over the six years taken).

	Blidene	Jelgava	Skulte	Teichi
Habitats measured and displayed as % of area				
Winter cereals	15.4	21.6	3.6	9.0
Summer cereals	5.5	23.7	13.0	17.2
Root crops	3.5	9.6	4.3	3.2
1st year fallow	2.5	3.8	2.6	3.8
Abandoned lands	19.9	7.6	21.4	13.4
Sown grasslands	10.3	15.9	22.8	22.6
Improved meadows and pastures	12.6	3.8	9.3	1.9
Dry and moderately moist natural meadows	11.6	1.1	2.8	11.7
Wet natural meadows	3.2	3.1	1.8	1.1
Ponds and pools with emergent vegetation.	2.4	0.1	0.2	1.1
Ponds and pools w/o emergent vegetation	0.2	0.1	0.0	0.5
Forests	4.6	2.9	9.8	6.7
Orchards	0.7	1.0	0.3	0.0
Shrubs	6.3	0.1	2.8	1.8
Farmsteads	1.1	2.9	4.3	3.4
Isolated farm buildings	0.0	1.7	0.4	1.0
Ruderal areas	0.1	0.9	0.8	1.4
Habitats measured as length (m), displayed as density (m/ha)				
Clean ditches	7.8	11.5	6.7	17.7
Ditches with bushes	8.5	14.8	10.5	8.7
Natural rivers	1.1	3.2	1.5	0.3
Alleys	0.5	2.3	5.1	0.3
Linear shrub belts	3.5	0.9	6.6	4.7
Roads	25.9	28.3	28.6	32.6
Electric and telephone lines	12.3	23.9	41.1	33.7
Enclosures and fences	0.0	1.4	1.7	19.2
Features counted as absolute numbers, displayed as number per 100 ha				
Small ponds and pools with emergent vegtn	0.8	0.3	0.2	2.9
Small ponds and pools w/o emergent vegtn	0.4	0.2	0.3	0.7
Separate trees	25.2	6.7	9.8	18.1
Separate bushes	17.6	16.3	15.0	34.1
Stone and brushwood heaps	1.3	0.2	1.3	8.3

counts (no limitation was placed on the horizontal distance at which birds were reported) were performed twice per season, at around mid-May and mid-June, respectively. Migrants and other birds flying high above the site were excluded from further analysis.

The total number of species recorded per point was used as a measure of species richness. For each point and species, the number of birds recorded was interpreted in pairs (*e.g.* Two singing birds were considered as two pairs, whereas one bird singing and one bird observed (if not an obvious male) were considered as one pair). The higher of the two counts obtained was used.

The area within a circle of radius 200 m (area 12.56 ha) around each point was described by means of 30 habitat variables. The variables, their units of measurement, and their relative abundance within the described zones are shown in Tab. 1. Because the count points were distributed only in agricultural land, the proportions of habitats within the described 200 m zones differ from general landscape characteristics given above.

Tab. 2. Changes in land use and occurrence of landscape features in the four study areas (1995-2000).

	Blidene	Jelgava	Skulte	Teichi
Habitats measured as % of area				
Winter cereals	++	+++	+++	+++
Summer cereals	---(F)	+	0(F)	--
Root crops	0	++	++(F)	--
1st year fallow	F	F	F	F
Abandoned lands	+(F)	+++(F)	++(F)	+++
Sown grasslands	+(F)	---	-	++
Improved meadows and pastures	---	---	---	++
Dry and moderately moist natural meadows	0	--	--	---
Wet natural meadows	-	0	++	-
Ponds and pools with emergent vegetation	-	0	0	-
Ponds and pools without emergent vegetation	++	0	0	++
Forest	0	0	0	-
Shrubberies	--	0	+	++
Linear habitats				
Clean ditches	0	---	---	-
Ditches with bushes	-	+++	++	++
Natural rivers	---	0	0	0
Linear shrub belts	-	0	0	--
Alleys	0	---	0	+++
Roads	0	0	0	0
Enclosures and fences	0	---	-	-
Electric and telephone lines	+	-	0	--
Point objects				
Separate trees	--	0	+	0
Separate bushes	---	+	0	+
Stone and brushwood heaps	+++	0	-	-
Habitat groups				
Active arable	++	++	+++	-
Active arable incl. sown grass	++	0	++	0
Meadows	--	---	---	--
Meadows and abandoned	-	-	--	0

0 = change does not exceed 5%
+ or - = change between 5 and 20%
++ or -- = change between 20 and 50%
+++ or --- = change exceed 50%
F = fluctuating

We used the periodicals of the Central Statistical Bureau of Latvia (Anon 1996b, 1997, 1998, 1999b, 2000) as an information source on annual yields in the relevant districts (1995-1999), but these figures should be treated with care because they are not representative of all types of farming, being biased towards state farms and statutory companies. Nevertheless, they represent the regional differences quite well.

Statistics

TRIM version 3 software (Pannekoek & van Strien 2001) was used for analysis of bird count data. The following models were tested for each species (with 1995 as the reference year): no time effect (N), linear trend without covariates (L), linear trend including the study area as covariate (LC), linear trend without covariates and with stepwise selection of changepoints

(LT), and linear trend including the study area as covariate and stepwise selection of changepoints (LTC). Level *P*≤0.05 was used as significance criterion in Wald tests to enter or remove the changepoints in the stepwise procedures. Models that included the study area as a covariate were rejected if the value of the Wald test for significance of covariate exceeded *P*=0.20. The remaining models were compared and the model that gave the best fit according to Likelihood Ratio was chosen. In the few cases when several models gave maximum fit according to this test (*P*=1.000), the model with the smallest Akaike's Information Criterion was chosen. The modelled indices were used for estimating population status.

An attempt to use the TRIM software for analysing habitat changes was made, but almost all models were rejected, significance being *P*<0.001.

3. Results

Changes in habitats and farming intensity

All the study areas experienced significant changes in land use and the abundance of several landscape features during the six study years (Tab. 2). A steep decrease in meadows was common to all areas, being caused both by abandonment and conversion to arable land. However, there were different patterns of change in the 3 categories of meadows. Blidene did not experience significant decreases of dry and moderately moist natural meadows. Although conversion to arable land persisted, it was balanced by the introduction of mowing, grazing in previously abandoned lands, or both. The main meadow losses in this area were experienced in the category of improved meadows and pastures. Conversion of meadows to arable land was most severe in Jelgava & Skulte, but was less so in Teichi where the decrease in dry and moderately moist natural meadows was caused mainly by their natural improvement and encroachment by bushes after abandonment. An increase of abandoned land was common to all areas to various extents. However, note that the main increase occurred between 1995 and 1997, after which period the rate of abandonment stabilized or started to decrease, except in Teichi where it increased.

An increase in winter cereals was observed in all areas. Only Jelgava experienced increases of other crop types that fluctuated or decreased in the other areas. However, the area of active arable lands increased in all three western study areas.

An important source of differences between the study areas was reflected by changes in distribution of various shrub-dominated habitats (shrubland, ditches with bushes, linear shrub belts and isolated bushes). All these habitats decreased in Blidene and either remained stable or increased in Jelgava or Skulte. The main source of increase was ditches becoming overgrown. In Teichi bush encroachment took place in meadows, abandoned lands and ditches. At the same time, roadside shrub belts decreased. Jelgava experienced cutting down of roadside tree lines (alleys) whereas in Teichi new alleys appeared after removing the roadside bushes and not removing the trees. All study areas experienced reductions in cattle enclosures and other fences as a result of the continuous decrease in livestock keeping.

Tab. 3. Mean number of bird species registered per point and total number of species registered in the study areas.

Study area	1995	1996	1997	1998	1999	2000	Mean
Mean number of bird species registered per point							
Blidene	15.20	13.45	13.78	13.68	14.55	15.55	14.37
Jelgava	11.25	12.60	11.58	12.28	11.35	11.45	11.75
Skulte	14.78	16.25	14.78	16.70	14.25	15.93	15.45
Teichi	14.41	16.61	17.71	17.29	20.46	21.15	17.94
Total	13.91	14.74	14.48	15.00	15.19	16.05	14.90
Mean number of bird species registered per study area							Total
Blidene	77	65	69	67	70	71	104
Jelgava	63	62	65	59	57	57	85
Skulte	68	60	62	62	61	65	97
Teichi	73	76	69	72	70	72	101
Total	105	96	95	96	94	102	134

The intensity of farming (measured by yields) varied between the study areas as well as changing during the study period. The highest winter cereal yields were found in Blidene & Jelgava (31.5 and 30.5 q/ha on average), the values reflecting increasing yields (by 1.6 and 2.8 q/ha respectively). Winter cereal yields in Skulte & Teichi were much lower (19.3 and 15.7 q/ha respectively), the yield in Teichi decreasing significantly by 5.1 q/ha). A rapid growth of yields in Skulte was recorded between 1995 and 1997, followed by a decline, after which the 1999 yields approximated the 1995 levels (an increase of 0.2 q/ha). Summer cereal yields fluctuated synchronously in all study areas without any pronounced tendency, but they were higher in Blidene & Jelgava (23.0 and 23.3 q/ha on average) compared to Skulte & Teichi (13.9 and 12.1 q/ha). Yields of grass production also were higher in Blidene & Jelgava (45.0 and 39.8 q/ha) than in Skulte & Teichi (32.6 and 30.6 q/ha). Although the year-by-year numbers fluctuated, there was a tendency for the grass production yields to grow in Blidene & Skulte and to decline in Jelgava & Teichi.

Changes in bird populations

The mean number of species registered per point was stable in all study areas except Teichi (Tab. 3) where it increased from 14.4 in 1995 to 21.2 in 2000. At the same time the total number of species registered per study area did not increase in any of the study areas (but slightly decreased in Jelgava).

The analysis of the bird population changes is summarized in Tab. 4. Some species (*e.g.* Quail *Coturnix coturnix*, White Wagtail *Motacilla alba*, Sedge Warbler *Acrocephalus schoenobaenus*, Thrush Nightingale *Luscinia luscinia*) show a common change pattern in all study areas suggesting that populations of these species currently are more affected by large-scale factors than by area-specific factors. However, population change patterns for most of the species differ between the study areas suggesting that area-specific factors play important roles there.

In general, increases of shrub and forest generalist species are obvious and differences between the study areas are not as pronounced as for other groups. These

Tab. 4. Trends of bird populations in study areas (1995-2000).

Species	Registrations	Blidene	Jelgava	Skulte	Teichi	Total	Best model
Open agricultural land (arable, grasslands, abandoned lands)							
White Stork *Ciconia ciconia*	494	--	--	++	+++	+	LC***
Quail *Coturnix coturnix*[1]	36	+++	+++	+++	+++	+++(F)	LT(1)***
Corncrake *Crex crex*	310	--	+	++(F)	+++	++(F)	LCT(4)^{ns}
Lapwing *Vanellus vanellus*	505	F	F	+++	F	+?	N/A
Skylark *Alauda arvensis*	5245	--	+	++	++	+	LC***
Meadow Pipit *Anthus pratensis*	681	++	-	--	--	--	LC**
Whinchat *Saxicola rubetra*	877	++	+	++	0	+	LCT(1)*
Shrubby edge of agricultural land							
Grasshopper Warbler *Locustella naevia*	149	F	F	F	F	+++(F)	LT(2)**
Red-backed Shrike *Lanius collurio*	124	+	+	+(F)	+	+(F)	LT(3)***
Scarlet Rosefinch *Carpodacus erythrinus*	485	--	--	--	+++	-	LCT(1)*
Yellowhammer *Emberiza citrinella*	983	-	--	---	+++	-	LCT(2)***
Species feeding on agricultural lands							
Buzzard *Buteo buteo*	239	-	---	---	+++(F)	0(F)	LCT(2)**
Woodpigeon *Columba palumbus*	259	0	0(F)	0(F)	+++	++	LCT(1)^{ns}
Fieldfare *Turdus pilaris*	155	0	0	0	0	0	LT(2)^{ns}
Farmsteads							
White Wagtail *Motacilla alba*	222	---	---	---	---	---	LT(2)***
Icterine Warbler *Hippolais icterina*	115	+++(F)	--(F)	---(F)	+++(F)	+(F)	LCT(1)***
Starling *Sturnus vulgaris*	777	--	++(F)	+++(F)	--(F)	+	N/A
Goldfinch *Carduelis carduelis*	143	0	0	0	0	0	N*
Linnet *Accanthis cannabina*	112	+++	--	---	---	--	LC*
Wetlands							
Marsh Harrier *Circus aeruginosus*	66	0	0	0	0	0	N**
River Warbler *Locustella fluviatilis*	143	0	0	0	0	0	N**
Sedge Warbler *Acrocephalus schoeniclus*	168	--	--	--	--	--	L*
Reed Bunting *Emberiza schoeniclus*	146	0	0	0	0	0	N**
Shrubberies							
Thrush Nightingale *Luscinia luscinia*	979	+++	+++	+++	+++	+++	LT(2)**
Marsh Warbler *Acrocephalus palustris*	747	+++	--(F)	+++(F)	+++(F)	++(F)	LCT(5)***
Whitethroat *Sylvia communis*	1162	+++	++	++	+++	+++	LC***
Garden Warbler *Sylvia borin*	367	+++	+++	+++	+	+++	LTC(3)***
Forest							
Cuckoo *Cuculus canorus*	505	+++	+++	+++	+++	+++	LT(3)***
Tree Pipit *Anthus trivialis*	502	--	+++	+++	+++	+++	LC***
Blackcap *Sylvia atricapilla*	97	++(F)	++(F)	++(F)	++(F)	++(F)	L**
Willow Warbler *Phylloscopus trochilus*	304	--	--	--	--	--	LT(3)***
Chiffchaff *Phylloscopus collybita*	127	+++(F)	+++	+++	+++	+++	LT(1)***
Blackbird *Turdus merula*	463	-	++(F)	---	+(F)	-(F)	LCT(4)***
Song Thrush *Turdus philomelos*	371	--	-	+++	+++	+++	LCT(3)***
Redwing *Turdus iliacus*	103	+++	+++	+++	+++	+++	LT(1)*
Golden Oriole *Oriolus oriolus*	499	++	+++(F)	+++	+++	+++	LCT(3)***
Great Tit *Parus major*	144	+++	++	0	+++	+++	LCT(3)***
Chaffinch *Fringilla coelebs*	957	+++	-	+++	+++	+++	LCT(2)***
Declining		13	13	10	6	8	
Increasing		16	16	20	24	24	

[1] Population of the species was stable at a very low level 1995-1999
N = no time effects
L = linear trend
LC = linear trend, significant differences between study areas
LT = linear trend with significant changepoints, number of changepoints are given in brackets
LTC = linear trend with significant changepoints, significant differences between study areas, number of changepoints are given in brackets
N/A = all models rejected with significance P<0.05, expert judgement used for estimation of trends
0 = stable (change does not exceed 5%)
+ or - = slight increase or decline (change between 5 and 20%)
++ or -- = moderate increase or decline (change between 20 and 50%)
+++ or --- = strong increase or decline (change exceed 50%)
F = fluctuating
*, **, *** = model goodness-of-fit (significance of likelihood ratio test - P>0.95, P>0.99, P>0.999 accordingly)

increases can be associated with the general increase of forest and shrub areas in Latvia due to encroachment of abandoned lands. No such increase can be observed in species groups of agricultural and wetland habitats where the proportion of species having declining trends is larger and differences between the study areas are more pronounced.

Jelgava & Blidene have larger numbers of declining species than the other two areas (Tab. 4). Teichi had the smallest number of such species, half of which were those declining in all areas. This area also had the largest number of increasing species, the difference being due mainly to species of agricultural habitats.

4. Discussion

A six-year period is too short a time span to indicate clear trends that would describe current tendencies for the farmland bird populations for the whole of Latvia. A large proportion of the changes are caused by yearly fluctuations in numbers due to the influence of various abiotic and biotic factors such as weather conditions (both in wintering areas and breeding grounds), availability of a variety of resources, and nesting success in the previous breeding season (Wiens 1989, Fuller 1994). This conclusion mostly applies to species whose best models do not include the study area as a significant covariate (Tab. 4). However, the large proportion of species whose changing patterns differ significantly between the study areas suggests that local processes play very important roles. These changes in breeding bird populations during the study period chiefly have been caused by changes in distribution of agricultural habitats and various landscape features and by changes in farming intensity. In this respect, all the study areas have undergone different scenarios of development.

The only area that experienced decreases not only of the area of active arable lands (Tab. 2), but also of farming intensity, was Teichi. However, the decrease of arable lands was balanced by increase of sown grasslands, and the decrease of meadows by the increase in abandoned lands. Thus the proportion of cultivated and uncultivated areas remained approximately the same. As the total number of species did not increase we believe that the increase of the mean number of species registered per point in this study area occurred due to the increase of shrub-dominated habitats and the decrease of farming intensity. Although encroachment by bushes took place both in ditches and abandoned lands, it did not affect negatively open habitat species, yet here the increase in abandoned lands was more pronounced (Tabs 2 and 4). However, if this area continues to develop this way, it inevitably will lead to a reduction of total open area and a decline of open habitat species.

The other area with low farming intensity (Skulte) has experienced an increase of arable land (*cf* winter cereals) and a strong decrease of grassland areas. The increase in farming intensity has been insignificant and shrub encroachment has been recorded both for abandoned fields and ditches. Unlike Teichi, this area did not experience any rapid increase in the number of species registered per point. Rather, decreases were observed of several typical agricultural species that were increasing in Teichi.

The two westernmost areas are similar to each other; both are more intensively farmed than others and experienced further intensification during the study period, as expressed by increases of yields and of the area of arable land. However, the areas differ very much in their landscape structures, proportions of farmland habitats and the change pattern of shrub-dominated habitats. Nevertheless, in both areas more than twice as many species are decreasing than in Teichi, most of them being associated with agricultural habitats. Although farming intensity is not even close to that in EU countries yet, we expect many private farmers will start, or have started, to use western farming practices that have been a principal cause of declines of most farmland bird species populations in western Europe. Our results, however, are based on the state statistics that are biased towards state and statutory farms, and therefore cannot show the full picture. Although all shrub-dominated habitats decreased in Blidene, it is interesting to note that the species associated with them continue to increase. We explain this paradox as a result of the still-continuing expansion of these habitats in Latvia as a whole, due to widespread encroachment of former arable lands, thus providing these species with ideal living niches, increasing their reproductive success to allow overproduction to export surplus birds to neighbouring sub-ideal habitats.

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Article III

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Using Landsat TM and field data to produce maps of predicted bird densities in Latvian farmland

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Models of farmland bird population densities established from field surveys were applied to classified satellite data for mapping of predicted bird numbers. The field survey system was based upon point counts of birds and descriptions of their habitat within a 200 m radius. The relationship between birds and habitats was analysed by means of multiple regression analysis. The resulting regression models were coded into classified Landsat Enhanced Thematic Mapper (ETM+) data which had similar land cover/use classes as the field observation data. With the use of a circular 200 m radius moving window approach, simulated maps of predicted bird population densities were produced. The results indicate that the method is best suited to species with small- and medium-sized home ranges and non-complex habitat relations. This approach could possibly be used for species other than birds, and could have implications for monitoring agro-environments by means of selected indicators.

1. Introduction

Interest from the international communities on biodiversity in the countryside has increased during the past decade, and the development of agro-environment indicators to monitor biodiversity trends has been in focus (European Union 2000). Recent recommendations (OECD 2003) have included monitoring of birds and the use of remote sensing data to monitor and explain changes in general farmland biodiversity.

To identify and conserve areas of high biological importance, remote sensing technology can provide information on many variables useful for the modelling and monitoring of species richness (Stoms and Estes 1993, Nagendra 2001, Luoto 2002). Several studies have used satellite sensor data to map bird habitats (Sader *et al.* 1991, Thibault *et al.* 1998), to derive habitat data from which bird distributions can be modelled (Palmeirim 1988, Avery and Haines-Young 1990, Lavers *et al.* 1996, Debinski *et al.* 1999), or to develop habitat models for the identification and management of wildlife habitats (Pereira and Itami 1991, Aspinall and Veitch 1993, Herr and Queen 1993, Saveraid 2001). Birds are used as agro-environment indicators because of their high position in food webs, because the ecology of

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several species of interest has been studied in detail and because the efforts of many volunteer ornithologists make the collection of large data samples feasible.

The present study focuses on large-scale mapping of predicted bird numbers by combining models of farmland bird population densities derived from field survey data with a simulated habitat map based on remote sensing data. Five years of field studies provided data for the bio-statistical analyses yielding baseline information about relationships between birds and habitats in Latvian farmland, new in an East-European context (Auninš *et al.* 2001). Through combination with a land cover map, derived from Landsat ETM+ data and vector layers, the population density models were extrapolated to cover more than 70% of the Latvian territory. The aim was to demonstrate the potential of combining such techniques in order to identify and monitor potentially important areas for bird species recognised as environmental indicators. Also, when the habitat affinities of key species are known, monitoring of habitat composition by means of remote sensing may be used as a first indicator of possible population changes in species of conservation concern.

2. Methods

2.1 *Study sites and field data*

Four study sites were used to analyse the effect of habitats and land use on the distribution of birds in Latvian farmland. Each study site covered 100 km^2, and in order to include different agro-environments and land use intensities the study areas were located in different regions of Latvia (figure 1). For statistical analysis of bird habitat relations, the ground surveys in each study site comprised census counts of birds and descriptions of land cover within a 200 m radius (hereafter called field

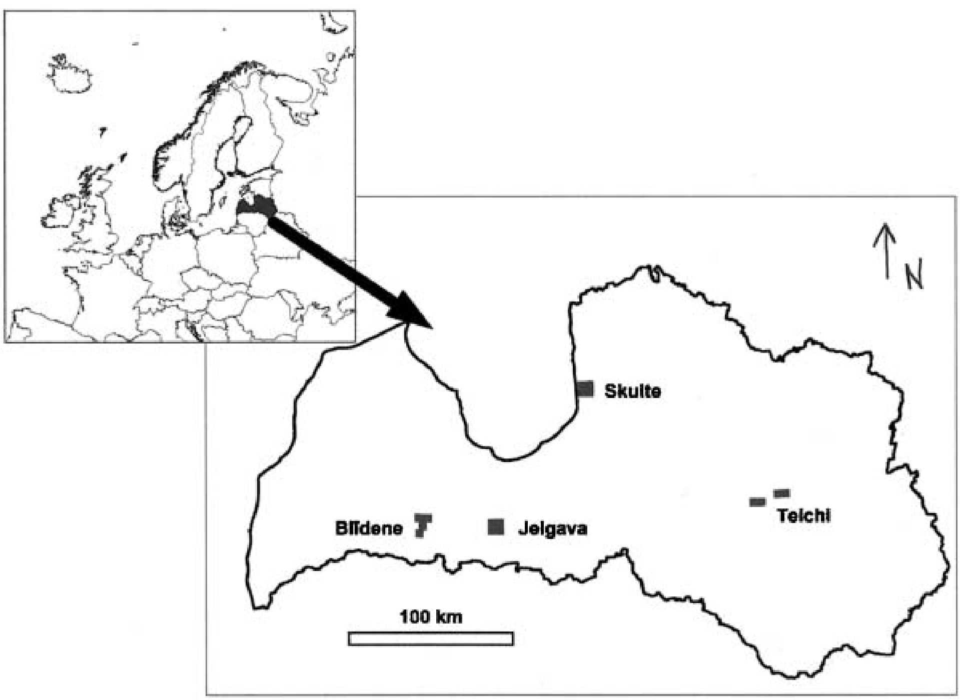

Figure 1. The location of field study sites in Latvia.

plots). Each field plot covered 12.56 ha and each study area contained 40 field plots, resulting in a total of 20 km^2 of surveyed area.

For the selection of field plots, each of the four study areas was divided into four sub-areas of 5 km × 5 km. Within each of these 25 km^2 sub-areas, six 1 km × 1 km squares (based on the grid of former USSR 1 : 10 000 topographic maps) were chosen randomly, after excluding all 1 × 1 km squares with more than 75% forest and/or urban area. In each of these six 1 × 1 km squares, two field plots were chosen from a predefined grid pattern. Three additional field plots were chosen within each 5 × 5 km square to include habitat types not present at the predefined points. Therefore, there were 15 field plots in each sub-area, resulting in 60 field plots for each study area. However, due to budget limitations the 60 field plots were reduced to 40 plots, leaving a good spread of the remaining plots within the sub-areas, yielding a total sample of 160 plots that were surveyed each year for the five-year period.

The stepwise approach and use of a grid pattern layout ensured a high degree of objectivity and also ensured that the major habitats in Latvian farmland were represented in the sample in proportions approximately equal to their occurrence in the landscape. The spacing of the points ensured that the probability of recording an individual bird at more than one point was negligible. The points are not strictly independent.

At each census point, five-minute bird counts with unlimited distance (Blondel *et al.* 1970) were performed from the centre of the plot twice per season, around mid-May and mid-June. For each census point and species, the number of birds recorded was interpreted in pairs or territories (e.g. two singing birds were considered as two pairs while one bird singing and one bird observed (if not an obvious male) were considered as one pair), and the maximum of the two counts was used. Migrating birds and other birds flying high above the site were not included.

The area within the field plot where the vast majority of birds were recorded was described in detail during the first year of study by means of 26 habitat variables, each of which was quantified (table 1) by visual inspection supported by area assessment from the 1 : 10 000 maps. The following year's changes in land use and cover was recorded from each plot and included in the statistical analysis.

Eventually the sub-areas were digitised from the 1 : 10 000 maps as well as the centre point (census point) of field plots, which was located by measured distances from known locations in the 1 : 10 000 maps. This method was considered to be more precise than the accuracy that could be obtained from a single GPS receiver in 1995.

2.2 *Use of Landsat ETM+ data*

All digital satellite sensor data processing was carried out using ERDAS Imagine software. Based upon four full Landsat ETM+ scenes from July–August 1999, a digital land cover/use map with 15 m resolution covering more than 70% of Latvia was produced. Monitoring of the study sites (with known land cover/use) by Landsat Thematic Mapper (TM) data from 1996 to 1999 had shown that the best separation of classes, especially of grasslands, was achieved using mid- to late-summer imagery. The Landsat TM data were resolution merged together with the pan-chromatic channel into 15 m spatial resolution by means of a principal component approach. Images were geo-registered to the national maps (Transverse Mercator) using a cubic convolution resampling algorithm.

Table 1. The original field survey habitat classes and their conversion to image classes.

Habitat	Measured in	Image class
Winter cereals	%	Crop
Spring cereals	%	Crop
Broad-leaved crops	%	Crop
Fields abandoned for one year	%	Abandon
Fields abandoned for two or more years	%	Abandon
Sown grasslands	%	Grass
Cultivated meadows/pastures	%	Grass
Dry or medium–dry natural meadows/pastures	%	Grass
Wet natural meadows	%	Grass
Natural streams (rivers, creeks)	m	Water
Ponds/pools without vegetation	%	Water
Ponds/pools with vegetation	%	Wetveg
Ditches bordered by bushes and trees	m	Shrub
Alleys	m	Shrub
Bushes (separate or in area clusters)	%	Shrub
Linear shrub belts (not along ditches)	m	Shrub
Farms with surrounding gardens	m	Shrub
Forest and groves	%	Forest
Separate trees	%	Forest
Isolated farm buildings (without gardens)	%	—
Ditches without woody vegetation	m	—
Roads	m	—
Electricity and telephone lines	m	—
Fences (enclosures)	m	—
Stone and bush heaps	m	—

The image classification was carried out in several steps. For all study areas the land cover was interpreted in detail. Initially the Landsat TM data were interpreted on the screen (bands 4, 5, 3), together with the field plots to which had been applied a 200 m buffer. Gaps in knowledge of cover were identified and a field survey was conducted within the study areas to identify spectral properties that could not be explained by the information gathered from field plots, 1 : 10 000 maps and aerial photos. In addition, field sampling was carried out in areas outside the study areas; some of this information was gathered in connection with related detailed studies of bogs and forest, while other samples were collected from field visits to places where spectral properties not could be explained by the other studies. Considering the well-established knowledge on image classes, use of a supervised classification (maximum likelihood rule) procedure was selected. In one of the scenes, high percentages of weed occurred in crop fields, which could not be separated from the grassland. Thus, a fuzzy convolution (ERDAS 1997) 3×3 matrix was used for cleaning up this noise by only selecting the involved classes to be used in the convolution of the classified image.

In order to obtain a consistent base map, the 50 land cover/use classes derived from the four classified Landsat ETM+ images were merged into seven classes: arable crops, grass, abandoned fields, wetlands, water bodies, forest and shrub.

2.3 *Use of CORINE digital wetland and digital water course layer*

From the CORINE Land Cover database (European Commission 1993) for Latvia, wetland areas were extracted, converted to raster and added to the classified image data. This was done in order to improve the Landsat ETM+ data classification, where class separability problems were present between wetland/bog areas and grassland in the agricultural areas. Furthermore, since watercourses could not be satisfactorily classified from the satellite image, watercourse data were applied from a digital national watercourse layer, digitised from 1 : 100 000 maps. This information was converted into a 15 m resolution raster, merged into the classified data and coded as water.

2.4 *Generalising field habitat classification with image data*

To make it possible to extrapolate the results from the field surveys to a larger scale by use of classified Landsat ETM+ data, the habitat classification used in the field studies was grouped to fit the classes of land cover/use in the image data (in the following termed 'image classes'). Of the 26 original habitat variables quantified within the field plots, 17 were measured as percent cover, seven as length (m) and two as number of items. Transformation of the 26 field data classes to the fewer image classes was done by merging related classes (table 1). Linear classes such as natural streams, alleys and shrub belts were converted to an area measure by multiplying the length with a standard width of 5 m. Low values were rounded off to 1% cover because their presence (even at much less than 1% cover) was considered of importance to several species of birds. As for single-tree data, each tree was assessed as covering 0.05% of the area within the circle, but a minimum of 1% cover was added to the forest classes. Six of the habitat classes were ignored, partly because no image classes could be linked with them and partly because they were considered unimportant on a larger scale.

2.5 *Modelling of bird densities*

Data from the field plots were used to model bird densities as a function of land cover. Separate models were constructed for each bird species and year by means of multiple regression. All possible subsets of the seven predictor variables were considered, and the minimum value of Mallows' C_p was used as the model selection criterion (Freund and Littell 1991). Except for the three most numerous species (Skylark *Alauda arvensis*, Whitethroat *Sylvia communis* and Yellowhammer *Emberiza citrinella*), bird densities were $\log_e(x+1)$ transformed to optimise approximation to a normal distribution. All analyses were performed using SAS statistical software (Freund and Littell 1991).

In most bird species, the predictor variables selected by the above procedure were fairly consistent between years. Therefore, to generate a single 'best model' for each species, data from all five years were combined and a model selection procedure was run with only predictor variables selected in at least one year being entered. The resulting model was used for integration with the spatial data to produce maps of predicted territories of selected farmland birds.

2.6 *Integration of regression models and spatial data*

Each regression model represents a formula for calculating the predicted number of territories of a particular bird species within the field plots based on the land cover/use within the field plot. For integration with image data, the model premises can be calculated within a circular moving window filter (radius 200 m). The regression models were implemented in the modeller module in ERDAS Imagine software. To produce the predicted species maps, the seven-class land cover map first had to be re-coded. For each species modelled, percent cover of each image class within the moving window was multiplied by its coefficient (positive, negative or zero) in the regression model, and the intercept was added. If appropriate, a back-transformation function (e^y–1) was finally applied. The resulting value was the predicted number of territories of a certain species within each 200 m radius.

3. Results

3.1 *The land cover map*

The land cover map (figure 2) was reduced to seven classes because it was not possible to get cloud-free Landsat TM data for what was considered to be the optimum time of the years (late-summer); in addition, cloud-free Landsat TM data were not available to produce a multi-seasonal analysis. Thus, the period of approximately two months between the recording of the scenes limited the number of classes that could consistently be observed in the agricultural landscape when the output should represent a uniform land cover map from four classified Landsat scenes. In the images recorded in late-August, almost all crops had been harvested and separation of, say, spring and summer crops was not possible. Furthermore, dividing grassland into sub-groupings was not considered as the land cover map had to be consistent.

No statistical accuracy assessment was made on the land cover map. However, based on the comprehensive field work that had been carried out during the

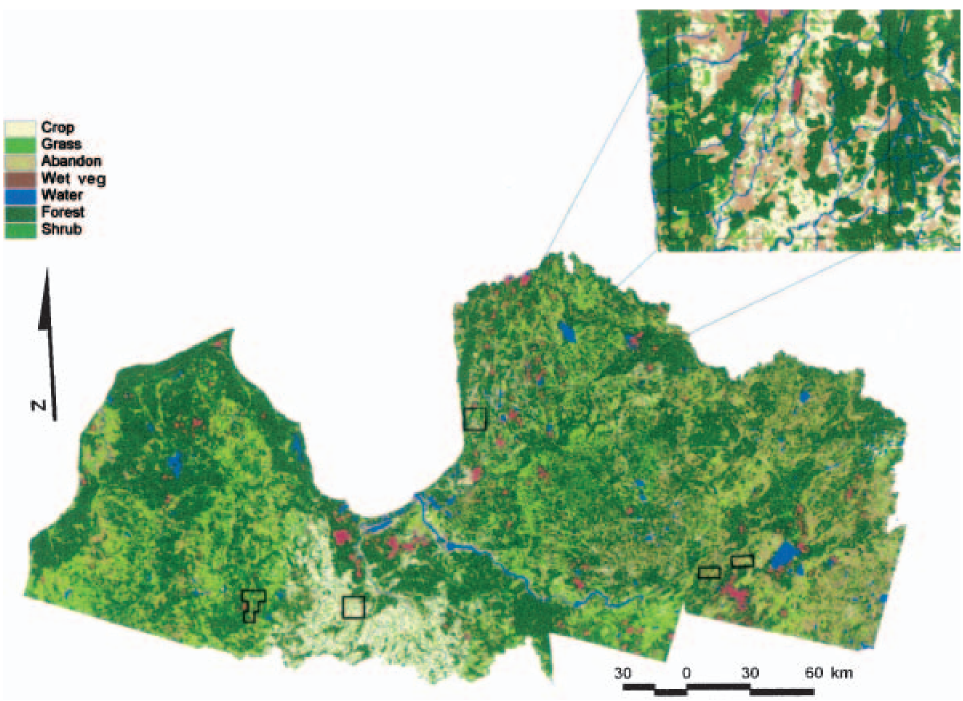

Figure 2. The seven-class land cover map, derived from four Landsat ETM+ scenes, national watercourse and CORINE wetland layer data. The northern study site has been enlarged.

five-year study period, most areas were quite well known. Forest and shrubs were overlaid on the CORINE Land Cover map and only minor differences were observed, mainly due to differences in scale. Crop, grassland and abandoned fields were verified by the use of field plot recordings and field visits and only a few errors were observed.

3.2 *Bird models*

Twelve examples of species models based upon the image classes are listed in table 2. Although birds of agricultural landscapes, few of the 12 species (the field-nesting Skylark and Lapwing) seem to benefit from the presence of cropped fields, whereas seven species show a positive association with abandoned fields and six a positive association with grassland. The presence of shrub and/or water also has positive effects on some species. None of the species considered shows a positive correlation with area of forest. A more detailed statistical analysis of the relationship between the birds and their original habitat variables (Auninš *et al.* 2001) confirms a general geographical consistency in bird distribution patterns, which indicates generally similar habitat affinities across regions and thus allows modelling on a national (if not a wider) scale.

Models for species with small- or medium-sized territories (such as Skylark and Whinchat) have the highest statistical significance (and, supposedly, the highest predictive power) because those territory sizes fit well with, or are easily contained within, the 12.56 ha modelling scale (table 2). Further, the models for very common species such as Skylark are highly significant because of the large amount of data available (few zero counts from field plots). On the other hand, species with large territories, such as Crane *Grus grus* are not well modelled at this scale; factors such as general landscape patterns and farmland/woodland ratios and fragmentation may impact the densities of these species. Species with complex habitat demands, such as Corncrake *Crex crex*, also perform rather poorly in the modelling. This may be due to the simplification of the land cover into seven image classes, but may also reflect the fact that some species respond to factors that cannot simply be expressed by the distribution of land cover, e.g. differences in crop and grassland management.

3.3 *Maps of predicted bird densities*

The significant predictors in the bird–habitat models (table 2) used in the habitat modelling represent well-known relationships between the analysed species and their breeding habitat. Thus, the three maps (figure 3) of predicted bird densities of the modelled species fit rather well with existing ornithological knowledge of the real distributions for these species in Latvia (Anonymous 2002). Meadow Pipits and White Stork reach higher densities in the eastern and western parts of the country that are dominated by grasslands than in the south-central part of the country that is dominated by arable lands with a lesser proportion of grasslands. This is opposite to the case of Skylarks, where the species reaches higher densities in regions with more intensive agriculture as arable land is a positive predictor in the habitat model of this species.

4. Discussion: potential and limitations

The above illustrates the potential of using satellite sensor data as a map source for large-scale mapping of predicted bird densities in the open landscape. The range of

Table 2. Multiple regression models for territory densities of selected bird species developed from five years of bi-annual countings at 160 points, and description of the surrounding habitat within a 200 m radius circle.

Species	Model	*F* Value	*P* value
White Stork *Ciconia ciconia*	Logdens=0.291279+0.002095Grass−0.007243Forest	20.004	3×10^{-9}
Corncrake *Crex crex*	Logdens=0.105815+0.001343Grass+0.002301Abandon+0.023387Water	6.856	0.00015
Crane *Grus grus*	Logdens=0.063321+0.001383Abandon	8.919	0.00291
Lapwing *Vanellus vanellus*	Logdens=−0.260095+0.007379Crop+0.004726Grass+0.005733Abandon	14.435	4×10^{-9}
Skylark *Alauda arvensis*	Dens=5.340464+0.021932Crop+0.013687Abandon−0.105162Wetveg −0.052691Forest−0.122697Shrub	53.322	1×10^{-47}
Meadow Pipit *Anthus pratensis*	Logdens=0.300005+0.003261Grass+0.004297Abandon−0.016476Wetveg −0.012479Shrub	19.394	3×10^{-15}
Thrush Nightingale *Luscinia luscinia*	Logdens=1.327798−0.009050Crop−0.008756Grass−0.009010Abandon +0.045398Water−0.008302Forest	8.402	9×10^{-8}
Whinchat *Saxicola rubetra*	Logdens=0.226569+0.004527Grass+0.007283Abandon	52.355	5×10^{-22}
Grasshopper Warbler *Locustella naevia*	Logdens=0.010539+0.003272Abandon+0.000806Grass	31.657	6×10^{-14}
Whitethroat *Sylvia communis*	Dens=1.144430−0.004450Crop+0.035532Shrub	39.048	7×10^{-17}
Scarlet Rosefinch *Carpodacus erythrinus*	Logdens=0.444474−0.003433Crop−0.002932Abandon+0.035556Water +0.007238Shrub	22.506	1×10^{-17}
Yellowhammer *Emberiza citrinella*	Dens=2.101470−0.014968Crop−0.011410Grass−0.013125Abandon −0.049144Water+0.019943Shrub	14.993	5×10^{-14}

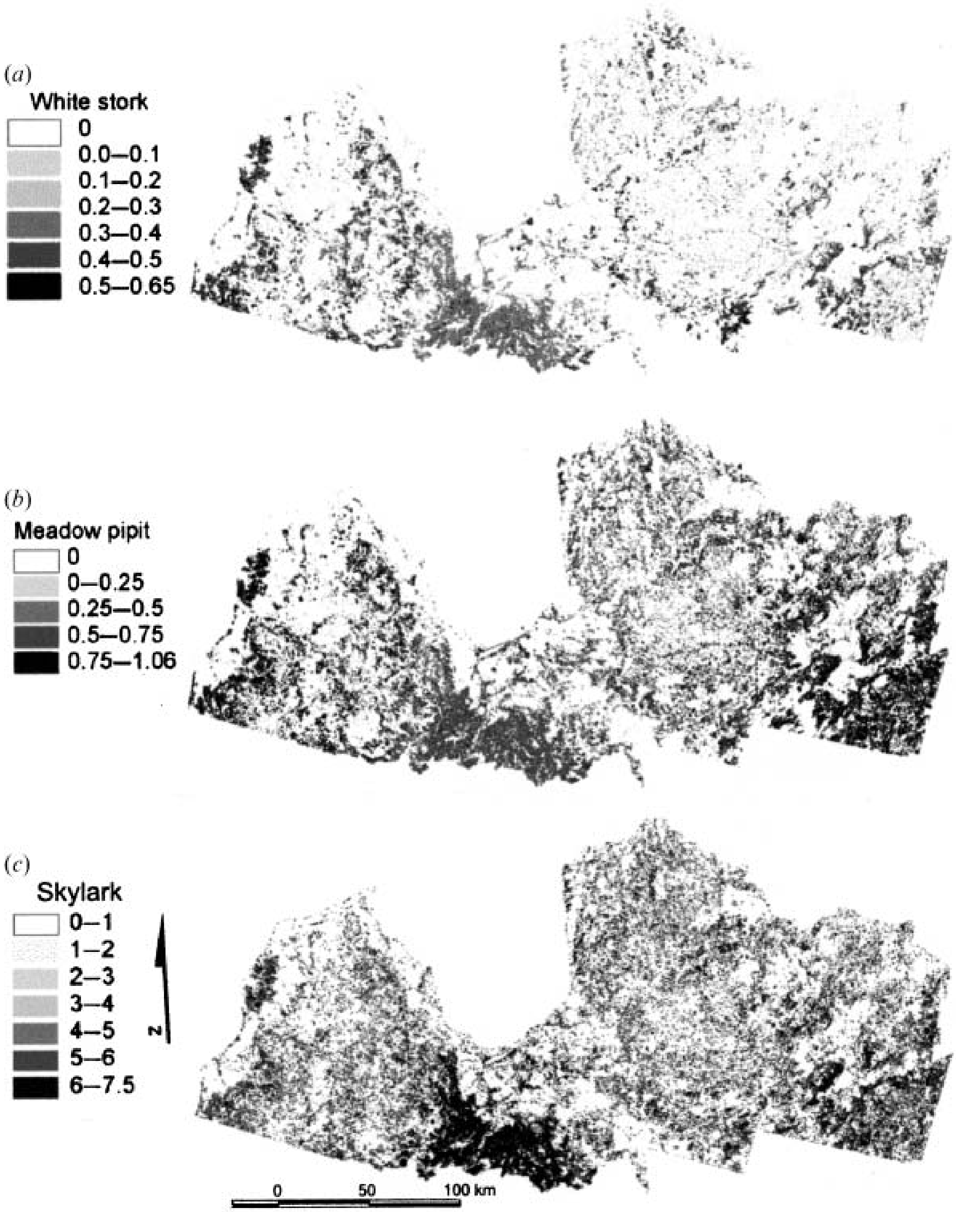

Figure 3. Maps of predicted densities of (*a*) Meadow Pipit, (*b*) White Stork and (*c*) Skylark based on multiple regression analysis applied to a seven-class 15 m spatial resolution Landsat ETM+ classification.

species whose distributions may be predicted in this way depends on the scale on which the field data that form the basis of the modelling are collected. If census points of birds and corresponding habitat descriptions are used as field source data, densities of species with small- or medium-sized territories in particular may be predicted. If field data are collected on a larger scale, distributions of birds with large territories may be predicted in a similar way by appropriate adjustment of the size of the moving window. Provided that suitable field data are available, this approach is, of course, not limited to birds.

The seven-class land cover map derived from Landsat ETM+ data could be improved and more species would probably give a better response to the land cover data if, for example, water bodies and streams were separated and crops were separated into summer and winter crops (see Auninš *et al.* 2001). The necessary reduction of the number of variables is a limiting factor, but this may be improved. Digital maps containing many of the habitat features observed in the field surveys, such as linear and point features (e.g. hedges, ditches and farms), are now becoming available on a national scale in several European countries (e.g. NERI 2000). Integrating these maps with existing map data would yield a more detailed land cover map. Because densities of many species are correlated with the extent of such small habitats (Auninš *et al.* 2001), the inclusion of these layers would certainly improve the predictive power of the models.

Further improvement of models used to predict distributions and densities of selected species could probably be achieved by including habitat and landscape diversity measures (Forman and Godron 1986, Turner 1989) as predictor variables. Jørgensen and Nøhr (1996) used this approach on remote sensing data to link structural diversity with bird species richness; Saveraid (2001) also recommended this approach.

The method presented here could be considered for other programmes for monitoring of the environment in the open countryside. It also represents a way of identifying potentially suitable areas for species of conservation concern. The suggested approach of integrating field observations with classified satellite sensor data seems to have sufficient flexibility to make use of already established field-based monitoring systems that collect quantitative data on biodiversity elements and habitat features. Furthermore, it has the requisite flexibility to be fitted into various field monitoring systems based upon point observations. However, limitations of using this type of mapping depend on the extent and homogeneity of the bio-geographical zone (Cardillo 1999).

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Article IV

AUNINS A., PRIEDNIEKS J. 2008. TEN YEARS OF FARMLAND BIRD MONITORING IN LATVIA: POPULATION CHANGES 1995 – 2004. *REVISTA CATALANA D’ORNITOLOGIA* 24: 53–64.

Ten years of farmland bird monitoring in Latvia: population changes 1995 – 2004

Ainars Aunins & Janis Priednieks

This study analyses the differences in bird species richness in Latvian farmland between regions with different landscape structure, habitat composition and farming intensity. As well as analysing changes in species richness and abundance of common birds in Latvian farmland during the last ten years. Bird counts were performed twice annually each season since 1995 in 160 permanent count points, located in four study areas representing different regions, landscapes and agricultural practices. Two more study areas, with additional 80 count points were established in 2003 to ensure better spatial coverage and to cover landscapes that were previously underrepresented. Habitats and landscape characteristics within a radius of 200m around each bird count point were described annually while general landscape measures were obtained from CORINE Landcover GIS layers. Species richness (number of species recorded per point) differed significantly between the regions, as did landscape structure, farming intensity and the dominating habitat types. Although species richness in Latvian farmland increased during the last 10 years, there were regional differences. The most pronounced increase in species richness was observed in the study area with the lowest farming intensity and abandonment of crop fields, while the most intensive study area with increasing area of arable lands experienced a decline in species richness. Trends and indices of the 34 most frequently recorded species show that there is a general tendency of increase for most of the shrub and forest generalist species due to overgrowing of farmland with bushes. Among farmland specialist species only those associated with abandoned lands increased while those associated with meadows and wetlands declined.

Key words: farmland birds, species richness, population trends, population changes, point counts, monitoring, Latvia.

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Much attention during the last decade has been paid to decline of biodiversity in agricultural farmland in the Western Europe, especially in the UK, due to intensification of farming (e.g. Flade & Steiof 1990, Saris *et al.* 1994, Siriwardena *et al.*1998, Chamberlain *et al.* 2000, Svensson 2000). Since the late 1980s Eastern Europe has experienced the opposite processes –abandonment of farmland and decrease of farming intensity. Although long-term common bird monitoring schemes exist in several East European countries (Vorišek & Marchant 2003), the impact of this agricultural change on birds has not been well described in ornithological literature and mostly in the context of Europe-wide comparisons with the situation in Western Europe (Schifferli 2000, Donald *et al.* 2001).

This study analyses the differences in bird species richness in Latvian farmland between regions with different landscape structure, habitat composition and farming intensity as well as analysing changes in species richness and abundance of common birds in Latvian farmland during the last ten years.

Materials and methods

Study areas and bird count points

The current farmland bird monitoring scheme in Latvia consists of 6 100 km^2 study areas, located in different regions of the country (Figure 1), Each representing different habitat compositions, landscape structures and dominant farmland practices. Combined they represent the range of farmland types currently present in Latvia. Four of the study areas (Blidene, Jelgava, Skulte and Teichi) were established and monitoring started in 1995, while the other two (Durbe and Malta) were established in 2003 to cover wider range of habitats, both geographically and in terms of landscape. Corine Landcover 2000 GIS dataset was used at its finest classification level (level 3) to obtain proportions of general habitat classes and main landscape measures (mean patch size, edge density and Shannon's diversity index) of the landscape level and agricultural class level for each study area (Table 1). Official statistics from the Latvian Central Statistician bureau were used to calculate mean yields for the districts corresponding to the study areas (Table 1).

There were 40 bird count points located in each of the study areas. A combination of random and systematic approaches was used for selection of their positions. First, a square was chosen randomly using a 1 x 1 km grid and then a predefined position within a square was selected. Minor adjustments can be applied during the first visit to the point to avoid its location in inaccessible places. The method of choosing the bird count locations has been given in detail earlier (Aunins *et al.* 2001, Priednieks *et al.* 1999).

Figure 1. The location of the six study areas.
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Bird counts

Five minute long standardised bird counts are conducted in each point twice per season (mid May and mid June). Initially birds were counted without any distance limitation. Since 1998 and 2001, division lines were introduced at

Table 1. Main characteristics of the study areas in landscape level obtained from CORINE Landcover 2000 (habitat composition and landscape structure) and official agricultural statistics (yields).
Principals característiques de les àrees d'estudi a nivell de paisatge obtingudes a partir de CORINE Landcover 2000 (composició d'hàbitat i estructura del paisatge) i estadístiques oficials agrícoles (camps de conreu).

	Blidene	Jelgava	Skulte	Teichi	Malta	Durbe
Habitat composition						
Farmland (%)	54.6	93.7	56.6	69.0	76.9	80.3
Forests and shrubs (%)	43.5	6.0	41.9	29.0	23.0	19.2
Wetlands (%)	0.4	0.0	0.4	0.7	0.0	0.2
Streams and waterbodies (%)	1.4	0.0	0.0	0.4	0.2	0.0
Residential/Urban (%)	0.0	0.4	1.1	0.9	0.0	0.3
Landscape structure						
Mean Patch Size (ha)	76.0	169.5	75.1	75.7	90.1	85.5
Edge density (m/ha)	74.2	39.4	77.5	70.5	67.1	68.3
Shannon's Diversity index	4.48	3.19	4.45	4.42	4.34	4.36
Mean farming intensity 1995-2003						
Winter cereal yields (qnt/ha)	31.9	32.7	20.4	17.4	16.5	22.9
Summer cereal yields (qnt/ha)	23.0	24.3	15.0	13.2	15.1	18.3
Grass yields (qnt/ha)	39.8	35.8	30.5	26.0	25.1	30.9

200m and 50 m accordingly, still keeping full compatibility with the earlier data.

Breeders and non-breeders were separated. Breeders were interpreted in pairs while non-breeders were recorded as individuals (see details in Aunins *et al.* 2001). The maximum of the two counts was used in the analyses. The total number of species recorded per point was used as a measure of species richness.

Habitat descriptions

Habitat descriptions were made annually (late June – early July) within a radius of 200m around

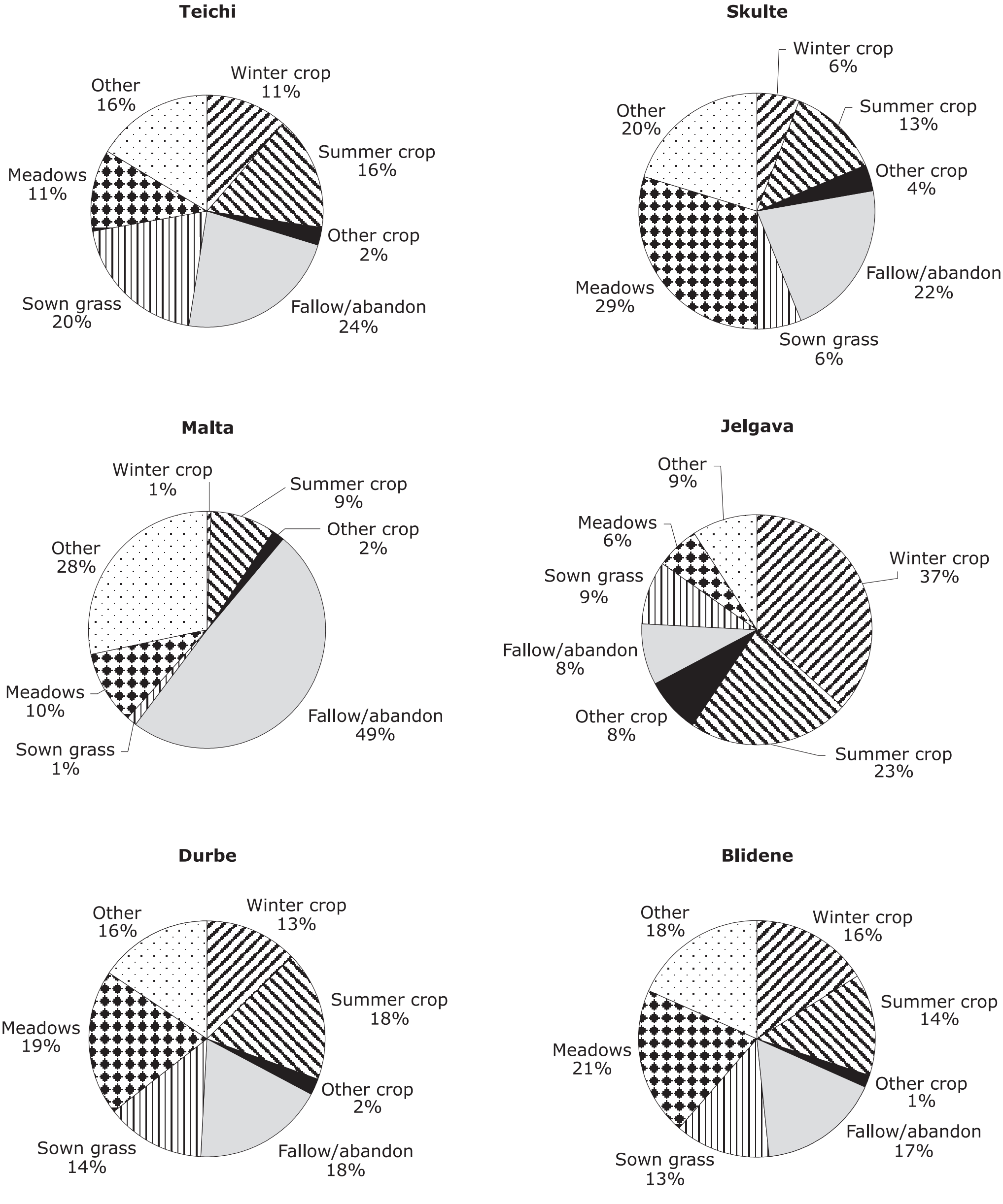

Figure 2. Proportions of the main agricultural and other habitat groups in the six study areas in 2004.
Proporcions dels principals hàbitats agrícoles i d'altres categories a les sis àrees d'estudi.

each bird count point. Hierarchical classification of habitats and landscape elements was used (see details in Aunins *et al.* 2001 and Aunins & Priednieks 2003). Proportions of the main agricultural and other habitat groups within the description zones varied between areas (Figure 2). This depended upon the general landscape structure, farming intensity and other regional factors, although taking into account that the points were located in agricultural lands only.

Data analyses

TRIM software (version 3.3; Pannekoek & van Strien 2001) was used to calculate indices and trends of bird populations, and species richness. A time effects model (model 3) was applied to species richness and individual species datasets with the study area (region) as a covariate. Only data from the four study areas where counts have been performed since 1995 were included in this analysis. Species whose occurrence is very dependent on meteorological conditions (Swifts *Apus apus* and swallows *Hirundidae*) as well as corvids *Corvus spp*. were omitted from the single species analyses. The trends were classified according to the procedure suggested by Pannekoek & van Strien (2001): according to the significance of the trend, the calculated magnitude of change in a 20-year period and its significance, the trends were classified as substantial decrease or decline, decrease or decline, non-substantial decrease or decline, stable or poorly known.

Patch Analyst (version 3.1) for ArcView (Rempel & Carr 2003) was used to obtain landscape measures from the CORINE Landcover 2000 GIS dataset.

SPSS software version 12 (SPSS Inc., 2003) was used for the other statistical tests. Name of the test used, main test statistics and its significance level are given whenever appropriate.

Results

Differences and changes in habitats and landscape elements

Jelgava and Malta were extremes regarding agricultural intensity, with 68% and 12% of active arable land and 8% and 49% of fallows and abandoned lands in 2004 respectively. Shrubby areas increased significantly in all four long-term study areas during the 10 monitoring years, as did the fallows/abandoned lands and ruderal areas, except in the Skulte region (Table 2).

A significant increase in active arable lands was observed in Jelgava area, while an increase in area of summer crops was significant in Blidene. The only area where a possible decline was observed for all kinds of arable lands was Teichi, because only the trend for summer crops was significant (Table 2). There was a tendency for the number of meadows to decline except at the Skulte study site, where due to introduction of mowing in former abandoned lands and continuous mowing of old sown grasslands this trend was reversed. Sown grasslands declined at Skulte, due to the reasons above, and the conversion to arable in the decline at Jelgava was chiefly due to conversion in arable lands. Increase of sown grasslands was observed in Blidene (Table 2).

Linear shrub features (shrub belts along roads and in ditches) did not show any relation with time (Table 2) as clearing of roadsides and ditches was done on a rare but regular basis, covering different parts of the study areas every year, except Skulte where linear bushes increased significantly.

There was a general tendency for mean winter and summer cereal yields (annually published by the Latvian Central Statistician Bureau, available 1995 - 2003) to increase in the country as a whole. Yields increased in the related districts of all study areas, except Teichi (winter cereals only) and Jelgava (summer cereals only). However, the correlation with time was significant only for winter cereals in Jelgava (Spearman rank correlation: $r_s = 0.783$, $n=9$, $p<0.05$).

Differences and changes in species richness

The species richness obtained from unlimited distance counts differed between the study areas every year (ANOVA: $F=7.4$ to 89.6, $p<0.001$) as did the species richness within 200m radius zones (ANOVA: $F=3.1$ to 14.3, $p < 0.01$ to $p<0.001$).

The lowest species richness, both without distance limitations and within 200m zones in 2004 was recorded in Jelgava, this study area had been poorest in all other years of the study (Figure 3). The Teichi study area had the highest species richness measured from counts without distance limitations, while it was on an average level if calculated from 200 m zone counts. The opposite was found in Durbe study area, which had average species richness in unlimited distance counts, though this was slightly higher species richness than the other study areas within 200m zones.

During the 10 years of monitoring species diversity has increased in Latvian farmland in general, from both measured and unlimited distance counts ("substantial increase") and within 200m zones ("increase", Table 3). However, the regional differences are prominent: species diversity without distance limitation declined in Jelgava, was stable in Skulte and increased in Blidene and especially Teichi ("substantial increase"). Within 200m zones, the trends were not as clear (classified as "poorly known") and the only area where changes were statistically significant was Teichi ("substantial increase", Table 3).

Table 2. Trends of abundance of main agricultural and other habitat categories and landscape elements within 200m zones around bird count points represented as correlation of abundance with time from 1995 to 2004 (Spearman rank correlation coefficient and its significance given).
Evolució de l'abundància dels principals hàbitats agrícoles i d'altres categories i els elements del paisatge dins de les zones de 200 m al voltant de punts de comptatge d'ocells representats com una correlació de l'abundància amb el temps de 1995 a 2004 (coeficient de correlació de Spearman i la seva significació).

Habitat categories	Description	Blidene	Jelgava	Skulte	Teichi	All areas
Winter cereals	Winter rye, wheat, barley or triticale	-0.016	0.052	0.096	-0.026	0.019
Summer cereals	Summer wheat, barley, triticale or outs	0.139**	0.053	0.027	-0.102*	0.019
Other crops	Potatoes, beets, rape and various other crops except cereals and fodder crops	0.026	0.094	0.079	-0.073	0.032
All arable lands pooled	Winter and summer cereals and other crops pooled	0.034	0.192**	0.080	-0.054	0.048
Fallows and abandoned lands	Previous arable land with annual and perennial weeds as the dominant vegetation	0.122*	0.128*	0.033	0.222**	0.124**
Sown grasslands	Fields with fodder crops such as grasses and legumes	0.138**	-0.244**	-0.262**	0.046	-0.094**
Improved and unimproved meadows and pastures	Semi-natural grasslands including those improved by either use of fertilisers or sowing additional grasses	-0.085	-0.048	0.119*	-0.198**	-0.045
Shrubby areas	Abandoned fields or overgrowing wetlands reaching the stage of natural succession where shrubs or young trees cover more than 60% of the area	0.130**	0.105*	0.130**	0.248**	0.152**
Ruderal areas	Open areas significantly affected by human activities that are not falling into any of the other categories	0.164**	0.109*	0.001	0.117*	0.092**
Linear shrub features	Shrub belts along roads, ditches and other watercourses	0.054	0.053	0.140**	0.023	0.065*
Fences	Cattle enclosures and other fences	0.184*	-0.132	-0.049	-0.053	-0.022
Separate trees	Single trees not belonging to shrubby areas or forests	0.048	0.053	0.076	0.056	0.057*
Separate bushes	Single bushes not belonging to shrubby areas or linear shrub belts	-0.074	-0.132**	-0.042	-0.083	-0.094**

* p<0.05   ** p<0.01

Table 3. Trends of bird species richness in the four long-term study areas.
Tendències de les espècies d'ocells a les quatre zones d'estudi a llarg termini.

Study areas	Trend	S.E.	Description of trend
Obtained from unlimited distance counts (1995-2004)			
Jelgava	0.9920	0.0036	Decline
Skulte	0.9988	0.0029	Stable
Teichi	1.0485	0.0026	Substantial increase
Blidene	1.0138	0.0032	Increase
All areas pooled	1.0165	0.0015	Substantial increase
Within 200m zones around bird count points (1998-2004)			
Jelgava	1.0103	0.0077	Poorly known
Skulte	0.9909	0.0056	Poorly known
Teichi	1.0277	0.0061	Substantial increase
Blidene	1.0017	0.0062	Poorly known
All areas pooled	1.0073	0.0032	Increase

Table 4. Trends of the most common bird species in Latvian farmland (1995 – 2004).
Tendències de les espècies d'ocells més comunes a les zones agrícoles de Letònia.

Species	Trend	S. E.	Description of trend
Skylark *Alauda arvensis*	0.9989	0.0027	Stable
Whitethroat *Sylvia communis*	1.0883	0.0066	Substantial increase
Thrush Nigtingale *Luscinia luscinia*	1.0817	0.0079	Substantial increase
Yellowhammer *Emberiza citrinella*	0.9993	0.0065	Poorly known
Chaffinch *Fringilla coelebs*	1.0299	0.0074	Substantial increase
Whinchat *Saxicola rubetra*	1.0540	0.0081	Substantial increase
Marsh Warbler *Acrocephalus palustris*	1.0372	0.0084	Substantial increase
Starling *Sturnus vulgaris*	0.9949	0.0125	Poorly known
Meadow Pipit *Anthus pratensis*	0.9247	0.0094	Substantial decline
Cuckoo *Cuculus canorus*	1.1330	0.0125	Substantial increase
Golden Oriole *Oriolus oriolus*	1.1316	0.0142	Substantial increase
Lapwing *Vanellus vanellus*	1.0530	0.0183	Substantial increase
Tree Pipit *Anthus trivialis*	1.0660	0.0116	Substantial increase
White Stork *Ciconia ciconia*	0.9978	0.0106	Poorly known
Blackbird *Turdus merula*	1.0150	0.0101	Poorly known
Scarlet Rosefinch *Carpodacus erythrinus*	0.9712	0.0116	Decline
Song Thrush *Turdus philomelos*	1.0713	0.0125	Substantial increase
Garden Warbler *Sylvia borin*	1.0145	0.0134	Poorly known
Corncrake *Crex crex*	1.0167	0.0169	Poorly known
Woodpigeon *Columba palumbus*	1.0757	0.0162	Substantial increase
Willow Warbler *Phylloscopus trochilus*	0.9831	0.0130	Poorly known
Common Buzzard *Buteo buteo*	0.8725	0.0178	Substantial decline
White Wagtail *Motacilla alba*	0.9401	0.0146	Substantial decline
Grasshopper warbler *Locustella naevia*	1.1359	0.0243	Substantial increase
Fieldfare *Turdus pilaris*	1.0426	0.0237	Poorly known
Sedge Warbler *Acrocephalus schoenobaenus*	0.9881	0.0180	Poorly known
Great Tit *Parus major*	1.0778	0.0225	Substantial increase
Chiffchaff *Phylloscopus collybita*	1.1298	0.0231	Substantial increase
Magpie *Pica pica*	1.0260	0.0186	Poorly known
Goldfinch *Carduelis carduelis*	0.9826	0.0223	Poorly known
River Warbler *Locustella fluviatilis*	0.9637	0.0229	Poorly known
Reed Bunting *Emberiza schoeniclus*	0.9543	0.0206	Decline
Blackcap *Sylvia atricapilla*	1.1397	0.0235	Substantial increase
Red-backed Shrike *Lanius collurio*	0.9906	0.0245	Poorly known

Changes in species populations

Out of the 34 bird species analysed (Table 4), 15 species increased substantially, one was stable, two declined and three species declined substantially. The trend for the remaining 13 species was classified as "poorly known". If we group the species according their primary habitat groups, this being based on both the general knowledge of individual species ecology and the study of species-habitats associations in Latvia (Aunins *et al.* 2001), the species with increasing populations are found mainly in the forests group (Table 5). In addition, the habitat groups of bushes and shrubberies, abandoned lands and arable lands hold species with increasing populations. None of species in these groups declined, except Buzzard *Buteo buteo*, which belonged to the forest group. The declining species were found in the meadow, wetland and farmstead groups, and these groups did not hold any of the increasing species (Table 5).

Discussion

We assume that the measured species richness was affected by bird detectability, which differed between the study areas, due to their differences in landscape structure. In open homogenous areas, birds can be more easily seen or heard, while in structurally diverse areas, the field of view is more limited and distant or soft sounds are likely to be suppressed. The complexity and volume of bird chorus, especially numbers of loud singers in close proximity may also negatively affect the audial detectability of birds too. Therefore, it may be expected that a higher risk of underestimating the actual species richness in structurally diverse, species rich areas than in open and homogenous areas, especially using data from unlimited distance counts.

Table 5. Classification of bird population trends according to species associations with main habitat groups. Numbers in brackets represent the species that are breeding in forest but feeding in farmland habitats (i.e. Woodpigeon *Columba palumbus* and Buzzard *Buteo buteo*).
Classificació de les tendències poblacionals d'ocells amb grups d'hàbitats principals. Els nombres entre parèntesi representen les espècies que crien al bosc però que s'alimenten en hàbitats agrícoles (p. ex. Tudó Columba palumbus *i l'Aligot comú* Buteo buteo*).*

Habitat group	Trend: Increase	Trend: Stable/ Poorly known	Trend: Decline
Forests	8 + (1)	3	0 + (1)
Bushes and shrubberies	3	5	0
Abandoned farmland	2	0	0
Arable lands	1	1	0
Farmsteads	0	3	1
Wetlands	0	1	1
Meadows	0	1	2
All species	15	14	5

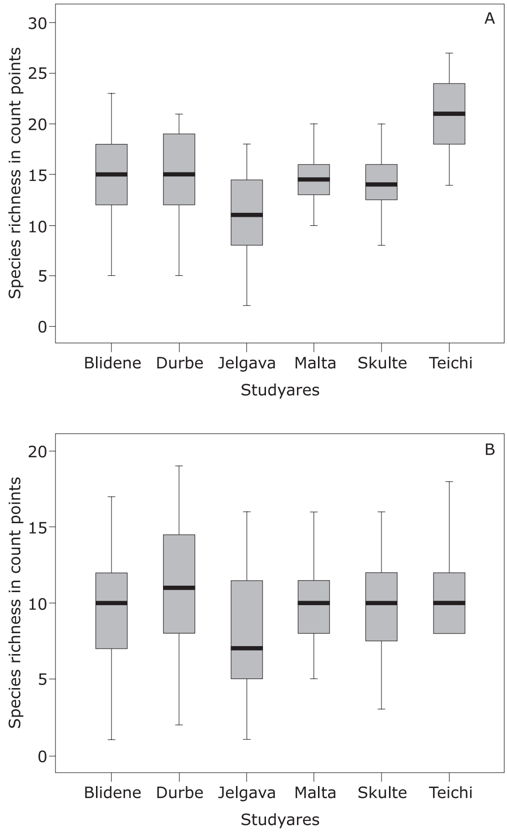

Figure 3. Species richness in the six study areas in 2004: median (black line into the box), quartiles (box area) and outlier range (bars): A – obtained from unlimited distance counts, B – within 200m zones around bird count points.
Riquesa d'espècies en les sis àrees d'estudi el 2004. Mitjana (línia negra dins de la caixa), quartils (àrea de la caixa) i rang dels punt fora de mostratge (barres). A- obtingut dels comptatges sense limitació de distància, B- zones de 200 m al voltant dels punts de comptatge.

Regional differences in species richness between the study areas are not particularly pronounced and only two regions (Jelgava and Teichi) stand out (Figure 3).

The lower species richness in the Jelgava study area (Figure 3) was expected. This study area had the lowest percentage of species rich habitats (e.g. forests, shrubberies and meadows) both on point counts and at the landscape level (Figure 2 and Table 1). This area has a uniform landscape dominated by different kinds of arable lands, and had the highest agricultural intensity compared to the other areas. This is the only long-term study area where species richness declined during the monitoring period. This decline can be attributed to the significant increase of arable lands and decline of grasslands (Table 2) as well as the increase of farming intensity.

In Teichi study area, the difference between the species diversity levels calculated from unlimited distance and 200m zone counts if compared to other areas (Figure 3) this suggests that these are mainly species recorded outside the 200m zones that contribute to the high species richness values of unlimited distance counts. This study area has rather low proportion of agricultural lands, an average proportion of forests/shrubs on the landscape level, a larger proportion of other habitat groups and high landscape diversity (Table 1). Thus, there is a higher chance of important features being both inside and outside the 200m zone, contributing to species richness during the count. This study area experienced substantial increase in species richness measured from both unlimited distance and 200 m zone counts (Table 3). This is the result of the steep increase in the area of shrubby areas and abandoned lands, accompanied with declines in arable lands, especially summer cereals (Table 2).

Although mean species diversity both without distance limitations and within 200m zones is similar for other study areas, they differ in terms of variance and range. Malta has the lowest variance and range of mean species diversity compared to the other areas. This is caused by more uniform habitats on the point level. 49% of the description zones are fallows and abandoned lands (Figure 2). As monitoring of this study area was started in 2003, we do not have information on how the trends of species richness and habitat occurrence have changed during the last decade, and if the species richness is benefiting from current level of lands abandonment. It is obvious, however, that diversity of farmland birds will decline in near future due areas overgrowing with bushes, and a reduction in open areas, if no changes in land use (re-establishment of farming in abandoned areas) occur.

It could be predicted that the Blidene study area, having the highest forest proportion, a large proportion of other non-agricultural habitats and high habitat fragmentation at a landscape level (Table 1), will have higher species richness. However, it was at an average level, although it had a high variance and range of the mean species diversity value (Figure 3). This can be explained by the location of this study area within the zone of intensive agriculture (Table 1) having a fairly large number of both species-poor (intensive arable land) and species rich (high habitat diversity) count points. Nevertheless, the overall species richness increased in this study area (Table 3), as did the area of scrub habitats (Table 2).

The pronounced increase of generalist species associated with forest and shrub habitats (Tables 4 and 5) was expected, as was the increase in species associated with abandoned lands, taking into account that areas of scrub habitats and abandoned lands have increased in all 4 long-term study areas (Table 2).

The only declining species in the forest group, Buzzard *Buteo buteo*, can only partly be attributed to forest group when it is breeding, as this species mainly forages in open farmland habitats, preferring grasslands and abandoned lands (A. Petrins, unpublished data). As there have been no marked declines in availability or quality of such foraging habitats, the only obvious reason for the observed decline of this species might be human activities in the forest. Most of the small forest clusters and edges of larger forest tracts, which are the preferred species breeding places, are privately owned. According to statistics from the Latvian State Forest Service these areas are more affected by intensive forest management than state owned forests. Therefore, the species may be suffering from loss of breeding habitats at forest edges and from disturbance during the start of breeding period. As a result, birds may retreat further in the forest for breeding (where possible) and a larger proportion of their feeding habitat may become clear-cuts and the species to become less frequently observed in farmland. Similar patterns occurring in all study areas (Figure 4 A) suggest that this may be a countrywide process. Note that declines for the corresponding period have not been found in Buzzards at a European scale (Vorišek 2003; but note the wide confidence intervals for European data). A change in forestry practices in Latvian private forests would allow a possible reversal of the trend of this species.

The increase of shrub areas is among the factors causing a decline in meadow species, as this is a result of overgrowing meadows and abandoned lands with bushes. This process of the overgrowing of the grassland dominated abandoned lands and meadows is best characterised by conflicting population changes in two pipit species: in all study areas, except Blidene, the Meadow Pipit *Anthus pratensis* is declining and Tree Pipit *Anthus trivialis* is increasing (Figure 4, B and C). In Blidene, where there is no pronounced decline in Meadow Pipit, no increase is observed in Tree Pipit.

Although overall bird species richness is increasing in Latvian farmland, the diversity of the farmland specialists is not, because the recorded increase is due to the non-farmland generalist species that have little or no conservation value at the present time. In fact, farmland bird diversity is declining, as almost all observed declines are in species either directly connected to agricultural lands or species connected to habitat diversity within a farmland

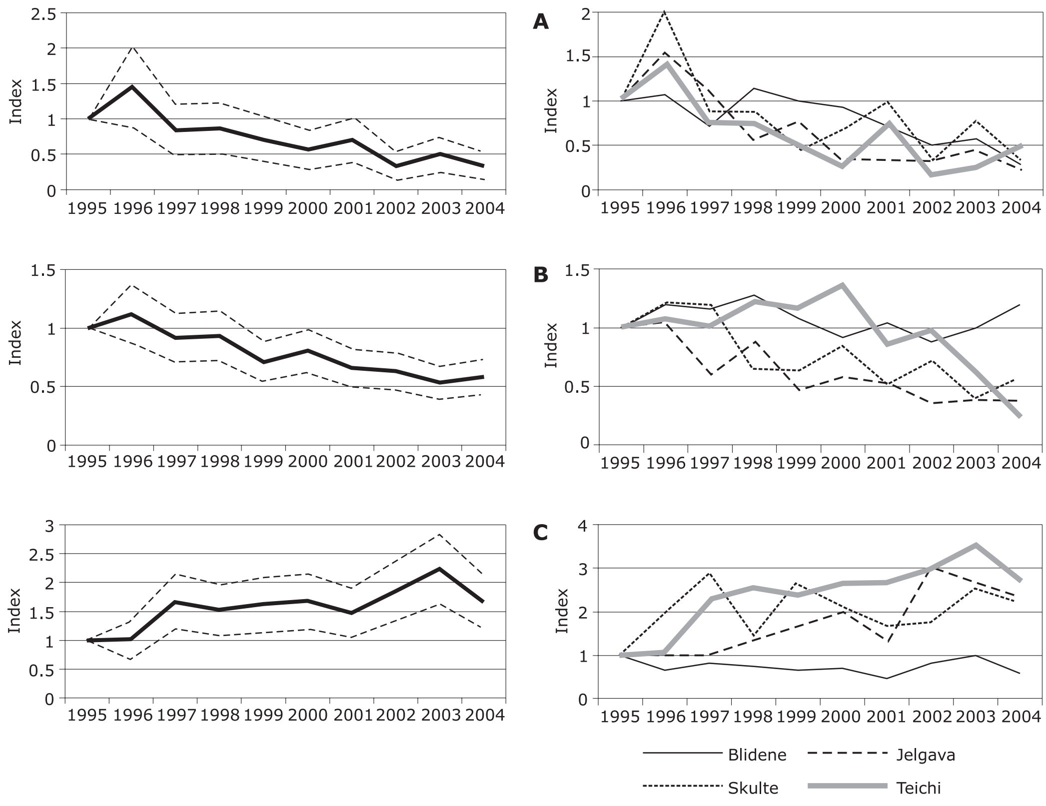

Figure 4. Changes of population indices (solid lines) and their 95% confidence limits (dashed lines; all areas pooled only) of selected species for all study areas pooled and separately. A - Buzzard *Buteo buteo*, B - Meadow Pipit *Anthus pratensis*, C - Tree Pipit *Anthus trivialis*.
Canvis dels índexs poblacionals (línies sòlides) i el seus límits de confiança del 95% (línies puntejades) d'algunes espècies seleccionades per a totes les zones d'estudi i de forma separada. A- Aligot comú Buteo buteo*, B- Titella* Anthus pratensis*, C- Piula dels arbres* Anthus trivialis.

landscape. The trend of increase shown by species connected with abandoned lands will soon reverse due to the temporary nature of these habitats. There is already evidence of this: although the Corncrake *Crex crex* primarily is a meadow species, its population growth during 1990s was connected with increased areas of abandoned land (Aunins *et al.* 2001, Keiss 2001). However, since 2000 the species show a tendency to decline. We might expect similar 'peak-shaped' population responses from other species too.

Latvian farmland is on the verge of rapid changes, due to country's accession to EU. This will cause a significant increase of funds invested into the intensification of agriculture. It will mean a possible reduction in the areas of abandoned lands with the reversion of these areas back into arable lands or into managed grassland, depending on which type of farming will become dominant, although afforestation also is possible. It can be forecasted that these changes will have different effects on farmland bird populations in different regions in Latvia. The two south central study areas (Jelgava and Blidene), are likely to experience further declines in farmland bird populations with further agricultural intensification, and conversion of abandoned lands into intensive arable farmland, as these areas have the most fertile soils in Latvia. It would be important to promote cattle farming in this area, to ensure a sufficient proportion of grasslands in this region. Farmland bird populations in other regions of Latvia may benefit from the intensification of the agriculture in the short term, as currently there is a risk of large open areas being converted into forestry. Arable farming is considerably less profitable in most of the other territories in Latvia, compared to the south central region giving preferences for cattle farming in these regions. The introduction of agri-environmental schemes should become an important instrument for ensuring appropriate management of farmland in different regions of Latvia.

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Resum

Deu anys de seguiment d'ocells en zones agrícoles de Letònia: canvis poblacionals 1995-2004

Aquest estudi analitza les diferències de riquesa d'espècies d'ocells en zones agrícoles de Letònia amb diferent estructura del paisatge, composició d'hàbitats i intensitat d'explotació, així com els canvis en la riquesa d'espècies i abundància d'ocells comuns en zones agrícoles de Letònia durant els darrers deu anys. Els comptatges d'ocells es van realitzar dues vegades per temporada des de 1995 en 160 punts de comptatge permanents situats en quatre àrees d'estudi que representen diferents regions, paisatges i pràctiques agrícoles. Es van establir dues àrees d'estudi amb uns altres 80 punts de comptatge en 2003 per garantir una millor cobertura espacial i per cobrir els paisatges que abans estaven insuficientment representats. Es van analitzar també els tipus d'hàbitats i els elements del paisatge en una zona circular amb un radi de 200 metres al voltant del punt de comptatge mentre que les variables de paisatge general es van obtenir a partir de capes de SIG amb CORINE Landcover. La riquesa d'espècies (nombre d'espècies registrades per punt) va diferir significativament entre les regions així com l'estructura del paisatge, la intensificació agrícola i els tipus d'hàbitat dominant. Encara que la riquesa d'espècies a les zones agrícoles de Letònia va augmentar durant els últims 10 anys, hi va haver diferències regionals. L'augment més pronunciat en la riquesa d'espècies es va observar a l'àrea d'estudi amb la menor intensitat d'explotació i abandonament dels camps de cultiu, mentre que l'àrea d'estudi amb un major augment de superfície de terres cultivables va experimentar una disminució en la riquesa d'espècies. Les tendències i els índexs de més de 34 espècies registrades amb freqüència mostren que hi ha una tendència general d'augment per a la majoria de les espècies forestals i arbustives generalistes a causa de l'augment de terres de cultiu amb arbust. En el

cas de les zones que no eren estrictament zones agrícoles només aquelles espècies associades a les zones de guaret van augmentar la seva riquesa mentre que aquelles associades a pastures i zones humides es van reduir.

Resumen

Diez años de seguimiento de aves en zonas agrícolas de Letonia: cambios poblacionales 1995-2004

Este estudio analiza las diferencias de riqueza de especies de aves en zonas agrícolas de Letonia con diferente estructura del paisaje, composición de hábitats e intensidad de explotación, así como los cambios en la riqueza de especies y abundancia de aves comunes en zonas agrícolas de Letonia durante los últimos diez años. Los conteos de aves se realizaron dos veces por temporada desde 1995 en 160 puntos de conteo permanentes situados en cuatro áreas de estudio que representan diferentes regiones, paisajes y prácticas agrícolas. Se establecieron dos áreas de estudio con otros 80 puntos de conteo en 2003 para garantizar una mejor cobertura espacial y para cubrir los paisajes que antes estaban insuficientemente representados. Se analizaron también los tipos de hábitats y elementos del paisaje en una zona circular con un radio de 200 metros alrededor del punto de conteo mientras que las variables de paisaje general se obtuvieron a partir de capas de SIG con CORINE Landcover. La riqueza de especies (número de especies registradas por punto) difirió significativamente entre las regiones así como la estructura del paisaje, la intensificación agrícola y los tipos de hábitat dominante. Aunque la riqueza de especies en las zonas agrícolas de Letonia aumentó durante los últimos 10 años, hubo diferencias regionales. El aumento más pronunciado en la riqueza de especies se observó en el área de estudio con la menor intensidad de explotación y abandono de los campos de cultivo, mientras que el área de estudio con un mayor aumento de superficie de tierras cultivables experimentó una disminución en la riqueza de especies. Las tendencias y los índices de más de 34 especies registradas con frecuencia muestran que hay una tendencia general de aumento para la mayoría de las especies forestales y arbustives generalistas debido al aumento de tierras de cultivo con arbusto. En el caso de las zonas que no eran estrictamente zonas agrícolas sólo aquellas especies asociadas a las zonas de barbecho aumentaron su riqueza mientras que aquellas asociadas a pastos y zonas húmedas se redujeron.

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Article V

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Intensity of agricultural land-use and farmland birds in the Baltic States

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Abstract

There was a clear indication that the more intensively farmed areas across the Baltic States of Estonia, Latvia and Lithuania provided habitat for fewer bird species and individuals. The abundance of farmland specialist birds was significantly lower by 20% in the more intensive areas as compared to less intensive ones. The difference could partly be explained by the more heterogeneous landscape and field areas in the latter. An analysis of the data from homogeneous arable fields indicated that agricultural intensification was reflected in a tangible decrease in farmland bird abundance, especially in species in need of edge structures. Considerable improvements are needed in conservation safeguards for the region facing intensification of production.

Keywords: Agri-environmental policy; Biodiversity decline; Bird community; Breeding abundance; Ecological groups; Heterogeneity

1. Introduction

The conservation importance of the CEE region for Europe is well documented (EEA, 2004). Despite the relatively intensive agriculture during its politically socialist past, the region retained a high proportion of extensively managed farmed habitats. For example, semi-natural grasslands represent half of all permanent pastures in the CEE countries (EEA, 2004). Intensity of production also never reached the levels of the EU (FAOSTAT, 2006). The opening of the EU market to the new member states and the introduced CAP subsidies have already triggered intensification of agricultural production in the region. The likely decline in farmland biota, which is expected to follow (Donald et al., 2006), will undoubtedly impair achievement of the EU Council's Göteborg commitment to halting biodiversity declines in the EU by 2010.

The main objective of this analysis was to compare bird communities across the Baltic region in areas contrasting in their agricultural intensity, as well as to study local effects of field management on bird numbers so that it is possible to draw predictions as to the scale of impacts of agricultural intensification following EU enlargement.

2. Material and methods

The research was carried out in the Baltic States of Estonia, Latvia, and Lithuania. The region lies in the hemiboreal zone of Europe, occupying 175.116 km^2 and stretching for about 700 km in a North-South direction. Prior to the field data generation a pilot study was conducted in all three countries. Initial selection of the counties from each country was based on available agricultural records such as proportions of agricultural lands under arable and grassland fields, fertilizers inputs, machinery use per farmed area, and yields of the cereals and potatoes. The statistics records were entered into the PCA analysis to grade the counties within each country according to the dominance of farmland and agricultural inputs. The regional yield levels correlated well with the

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Table 1
Agricultural statistics used in the selection of regions in the Baltics of predominantly intensive and extensive farming types with the number of survey points, and the countries' average

Region	Lithuania			Latvia			Estonia[a]		
	Extensive	Intensive	Average	Extensive	Intensive	Average	Extensive	Intensive	Average
	Prienai	Sakai		Skulte	Blidene		Valga	Jögeva	
Farmland, % of total	59	66	53	55	73	60	23	30	21
Arable, % of agricultural	82	93	84	30	58	36	84	53	84
Cereal yield, 100 kg/ha	24.9	33.4	24.5	16.6	25.9	21.5	19.1	22.3	19.0
Points	60	60		37	30		39	48	

Total $n = 274$.
[a] Yields between the countries can not be compared directly because of the climatic difference (e.g. yields in Estonia are low relative to land-use intensity; data from Central Statistical Bureaus of Estonia, Latvia, and Lithuania).

amounts of fertilizers used, and an average cereal yield from commercial enterprises for the 5 years preceding the field survey for each region was used as a main indication of its farming intensity (Table 1). In each country two regions different in the intensity of agricultural land-use were selected. The least intensive region of the pair was selected so that it did not exceed the country's average in terms of the proportion of farmland or cereal yield. Farming was required to be practiced on a commercial level rather than predominantly for subsistence. A more intensively farmed region was chosen to be as similar as possible in the overall landscape structure and proportion of farmland, and not further than 200 km from the less intensive area.

In each region an area of 100 km^2 was chosen, from where 1 km^2 squares were selected at random. Four points were placed systematically in each square at approximately equal distances from the corners, with a minimum distance of 300 m between them. In Latvia, where the counts were performed as part of an existing monitoring scheme, two points per square were placed. Initially, an equal number of squares and points were surveyed in each pair of regions within a country, but for this analysis points within abandoned fields (wherever over 80% of a 100 m circle area around a point was abandoned) or in close proximity to a forest (closer than 50 m) were excluded. The total 296 points in 94 squares were sampled out of which 274 points confirmed to the above criteria.

In order to look at the effect of actual field management of arable fields in a homogeneous landscape a second data set was analysed. It was generated by bird counts in the most farmland-dominated and agriculturally productive part of the Baltic region in the neighbouring counties of Jelgava in Latvia and Pasvalys in Lithuania. These have about 90% of land under agricultural use, over half of which is annual crops. Average cereal yields were 2.5–3 t/ha in 1998–2002, which was above the countries' average. Only points within open fields, that is, with the distance to the field edge over 100 m, and with over 80% of a 100-m radius area around the points being under an annual crop were selected for this second dataset (total of 49).

Fieldwork was conducted in spring–summer 2002. A point count method with unlimited distance was used (Bibby et al., 1992). Bird registrations were marked on a field map to relate sightings to field type and the approximate distance from a point. Points were visited for 5 min twice a season at central dates around mid May and mid June. Counts were started 1 h after sunrise to avoid the dawn peak in bird activity under good weather conditions. The sequence with which points were visited was reversed between the visits.

Habitat variables were selected on the basis of their importance for the farmland birds in the region (Auninš et al., 2001). The extent of each habitat was measured within a 100-m radius around the counting points, which is within the majority of the foraging trips by adult passerines when feeding nestlings (e.g. Schifferli et al., 1999). The habitat types were sketched onto field maps, and the percentage of their coverage estimated from the field maps using LUPA software (LUPA, 2002). Additionally to the habitat composition, field management characteristics which reflected the actual intensity of field management were assessed: weed abundance was scored from 0 to 3, crop structure was rated as being even or patchy, and the presence of tramlines was noted.

All habitat variables with non-zero values in over 90% of the points as well as those with a different extent between areas paired by intensity were summarised using principal components analysis (PCA) with varimax rotation (Table 2). Distance to the nearest edge of farmland (up to 200 m), number of field types and of non-cropped habitat elements within 100 m around count points were included into the PCA summarising habitat descriptors. Field management characteristics were largely inter-correlated and were also summarised by PCA (Table 2). The first PCA component was used to corroborate the division of areas into more and less intensive types for the first dataset, and used as an explanatory variable in the analysis of the second dataset from exclusively arable fields.

For each point the maximum count of individuals from two visits was used. Only records of individuals breeding within fields and edges were included in the analysis. Birds with large ranges of activity, passing high overhead or

Table 2
Principal component analysis components (1–5) based on the habitat composition and field management characteristics for (i) six areas of contrasting intensity and (ii) arable points in the intensive part of the Baltic region (major loadings are highlighted in bold)

Components	(i)					(ii)		
Variable	1	2	3	4	5	1	2	3
Winter cereal	0.060	0.030	0.039	**0.871**	0.018	0.224	**−0.705**	−0.168
Spring cereal	−0.336	**−0.769**	0.366	−0.206	0.071	**−0.669**	−0.025	0.123
Seeded grassland	−0.157	**0.837**	**0.386**	−0.218	0.009	0.175	**0.709**	−0.036
Natural grassland	−0.008	0.026	**−0.910**	−0.069	−0.110			
Abandoned	**0.514**	−0.088	0.060	0.021	−0.108	0.401	0.404	−0.156
Scrub	0.374	0.067	0.008	**−0.527**	0.002			
Forest	**0.396**	0.284	0.080	0.035	0.268			
Road	0.153	0.033	**0.412**	−0.010	−0.193	**0.706**	0.218	0.237
Electric lines	**0.436**	0.046	0.062	0.196	−0.338	−0.066	−0.291	**0.704**
Ditch	0.314	−0.070	0.186	0.011	**0.625**	0.032	0.316	0.627
Vegetated ditches and rivers	−0.091	0.043	−0.221	0.040	**0.718**	0.478	−0.279	−0.015
Distance to the edge[a]	**−0.698**	−0.260	0.002	0.284	0.044	−0.062	0.068	**−0.773**
Variety of field types	**0.792**	0.041	−0.013	0.047	0.183	**0.675**	0.258	0.366
Number of non-cropped habitats	**0.823**	0.043	0.102	−0.129	0.148			
% of Variance	16.76	11.53	10.39	9.93	9.69	20.13	15.1	13.8
Weed	0.417					0.780		
Crop	0.802					0.771		
Tramlines	−0.784					−0.725		
% of Variance	47.7					57.62		

[a] Distance from a counting point to the end of the open field area (e.g. forest) up to 200 m.

species whose abundance is strongly affected by meteorological conditions, such as swallows, were not included into the community indices. The subset of ‘‘farmland specialists’’ is based on an independent assessment of species for Europe (Tucker and Evans, 1997) and adapted to the region by the authors (Herzon et al., 2006). Ecological guilds of true open, edge and tree species as well as insectivores and granivorous species within the farmland specialist group were studied separately (see Herzon et al., 2006 for details).

Generalised linear models with Poisson error distribution and logarithmic link function in S-Plus 6.1 were created for the number of species and abundance of two species subsets, and five ecological groups. Variables were selected in a stepwise selection algorithm based on Akaike's information criteria corrected (AICc) for a small sample size (Burnham and Anderson, 2002). The effect of the intensity type (two-level factor) was first assessed together with a country affinity (three-level factor reflecting possible regional differences). Then five PCA components of the habitat composition were added into the models as covariates, to assess whether the difference between the area pairs remain as significant as in the first model set. Both the linear and quadratic terms of the covariates were entered into the initial models. Standard errors and significance levels in over-dispersed models, that is, with the dispersion parameter exceeding two, were corrected by a dispersion parameter as recommended by Crawley (1993). For the second dataset from arable fields, the respective GLMs included the PCA component based on the field management, and three PCA components for the habitat composition.

3. Results

A total of 6396 birds of 88 species were registered across the study areas, 5291 of which belonged to one of 48 farmland specialist species. Twelve of the species were significantly commoner in the more extensive areas, five of which – *Crex crex*, *Vanellus vanellus*, *Alauda arvensis*, *Carduelis cannabina*, and *Sturnus vulgaris* – are declining in Europe. Two species – *Columba livia* and *Ciconia ciconia* – were significantly more abundant in the more intensive areas (Table 3).

The PCA on field management characteristics captured 48% of variation in one component for the six areas and 58% of variation for the arable points (Table 2). It represented a gradient of points in fields with more weeds, patchy crop structure, and without tramlines to those with no weeds, even crop and with tramlines. The PCA component loadings significantly differed between each country's pairs of sites, but their values overlapped between countries (Table 4).

Five PCA components captured 58% of variation in the habitat composition (Table 2). The first component represented a gradient from open fields to the non-cropped and edge habitats, and to abandoned fields (referred to EDGE hereafter). The second axis was a gradient from spring cereal to seeded grassland (SEEDGR); the third – from natural to seeded grassland (NATGR), the fourth – from scrub to winter cereal fields (SCRUB); and the fifth indicated the presence of ditches (DITCH). Local habitat structure, summarised by PCA components, varied somewhat between the areas of contrasting intensity, but only in Lithuania differences were significant (Table 4). The first

Table 3
Species abundance and occurrence frequency for intensive and extensive sites across the Baltic States

	Intensive (n = 138)		Extensive (n = 136)		p (Chi)[a]	
	Total, individuals	Occurrence (%)	Total, individuals	Occurrence (%)		
True field species						
C. pygargus	2	1.4	1	0.7	nt	
Perdix perdix	2	1.4	3	2.2	nt	G
Coturnix coturnix	16	5.8	14	5.1	nt	G
Charadrius dubius	2	0.7	0	0	nt	
Gallinago gallinago	2	1.4	3	1.4	nt	
Crex crex	28	10.1	56	19.1	*<0.01*	
Vanellus vanellus	42	17	92	20.9	*<0.001*	
Numenius arquata	1	0.7	14	6.6	*<0.001*	
Tringa totanus	1	0.7	1	0.7	nt	
Alauda arvensis	917	96.4	1067	98.5	*<0.001*	G
Anthus pratensis	45	15.9	106	37.5	*<0.001*	I
A. campestris	2	0.7	4	1.5	nt	I
Motacilla flava	57	23.9	47	20.6	>0.1	I
Edge species						
Circus aeruginosus	10	7.2	15	8.8	>0.1	
Phasianus colchicus	0	0	5	2.2	nt	G
Saxicola rubetra	107	36.2	280	71.3	*<0.001*	I
Locustella naevia	26	8.8	17	6.5	>0.1	I
Acrocephalus palustris 42	5.7	36	13.2	>0.1	I	
A. schoenobaenus	21	5.8	18	5.2	>0.1	I
A. dumetorum	0	0	2	0.7	nt	I
Sylvia communis	106	40.6	213	61.8	*<0.001*	I
Oenanthe oenanthe	1	0.7	6	2.2	nt	I
Lanius collurio	12	4.3	5	2.2	nt	I
Carpodacus erythrinus 31	10.8	30	10.3	>0.1	I	
Emberiza schoeniclus	6	2.8	8	2.9	nt	G
Forest species						
Buteo buteo	7	5.1	8	5.9	>0.1	
Aquila pomarina	2	1.4	1	0.7	nt	
Falco tinnunculus	0	0	1	0.7	nt	
Columba palumbus	30	12.3	33	11.8	<0.1	G
Lullula arborea	0	0	5	2.2	nt	G
Turdus pilaris	16	6.6	40	14	*<0.001*	I
Pica pica	15	7.2	20	11	>0.1	
Corvus frugilegus	142	11.6	286	4.4	*<0.001*	
Corvus corone cornix	37	8.8	90	33.1	*<0.001*	
Carduelis chloris	16	4.3	8	2.9	nt	G
Carduelis cannabina	6	1.4	19	8.8	*<0.01*	G
Carduelis carduelis	8	2.8	9	4.4	nt	G
Emberiza citrinella	103	36.2	127	39.7	<0.1	G
Farmyard species						
Ciconia ciconia	39	18.1	23	16.1	<0.1	
Columba livia	39	7.2	11	2.8	<0.001	G
Apus apus	2	0.7	3	0.7	nt	
Hirundo rustica	118	31.2	121	25.7	>0.1	
Delichon urbica	34	5.7	41	2.8	>0.1	
Motacilla alba	8	3.6	11	5.9	>0.1	I
Corvus monedula	61	9.4	50	7.4	>0.1	
Sturnus vulgaris	17	5.1	90	17.6	*<0.001*	I
Passer domesticus	0	0	30	0.7	nt	G
Passer montanus	21	4.3	16	6.6	>0.1	G

Species in bold are declining in Europe (BirdLife International, 2004). ''nt'', not-tested; G, granivorous; and I, insectivore birds.
[a] p value of Chi-squared from log-linear regression; in italic are species significantly ($p < 0.05$) more abundant on extensive sites and underlined—on intensive sites.

(EDGE) and third (NATGR) components had statistically different loadings between the intensity area types overall (Table 4). In the second dataset of arable points, habitat was summarised in three PCA components (Table 2) with the first being a gradient from exclusively spring cereal fields to a mixture of field types divided by roads as well as the

Table 4
Mean scores of the PCA components derived from the local habitat composition and structure, and in-field management in intensive and extensive agricultural areas

Region	Lithuania		Latvia		Estonia		All	
	Extensive	Intensive	Extensive	Intensive	Extensive	Intensive	Extensive	Intensive
	Prienai	Sakiai	Skulte	Blidene	Valga	Jögeva		
PCA1 (EDGE)	0.4	−0.7***	1.1	0.9	−0.6	−0.6	0.3	−0.3***
PCA2 (SEEDGR)	−0.02	−0.06	0.2	0.2	0.05	−0.2	0.07	−0.1
PCA3 (NATGR)	−1.1	0.3***	0.4	0.2	0.6	0.8	−0.2	0.2*
PCA4 (SCRUB)	0.0	0.7***	0.03	−0.03	−0.5	−0.4	−01	0.1*
PCA5 (DITCH)	0.3	0.05**	0.2	0.2	0.08	−0.06	−0.1	0.1
PCA (Field management)	0.8	1.3***	−0.5	0.2***	1.7	2***	0.7	1.3***

Differences significant in Mann–Whitney tests are denoted as '*' for $0.01 < p < 0.05$, '**' for $0.001 < p < 0.01$ and '***' for $p < 0.001$. For original variables see Table 1.

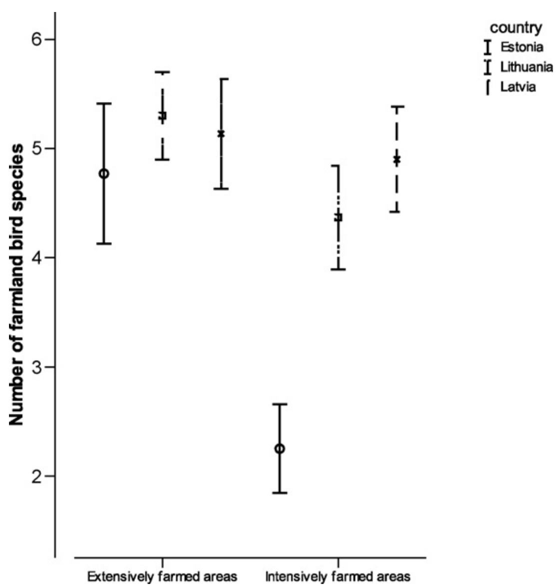

Fig. 1. Number of farmland specialist bird species in agricultural areas under extensive and intensive farming in the Baltic States of Estonia, Lithuania and Latvia.

proximity of abandoned fields (ONLY CEREAL). The second gradient was from winter cereal fields to seeded grassland (WINTER), and the third from points further away from the edge of an open field towards the presence of electric lines (EDGE).

The country factor was significant in all models, except for the number of edge species. There was a clear indication that the more intensively farmed areas across the region provided habitat for fewer bird species and individuals. Some of the response variables did not differ significantly between paired areas in one or two of the countries but, where the difference existed, its direction was always consistent in favour of the less intensive area (Fig. 1), and in only one case in Lithuania it was the reverse (Table 5).

Only half of species and individuals of the "other" species, and about 20% fewer species and individuals of the farmland specialists were counted in the more intensive areas as compared to the less intensive ones (Table 5). However, species registered only in the latter areas (*Phasianus colchicus*, *Acrocephalus dumetorum*, *Falco tinnunculus*, *Lullula arborea*, and *Passer domesticus*) were generally rare (Table 3), and, without them, the overall species composition was similar in areas of contrasting intensity. There was a major difference on how inclusion of the PCA habitat covariates affected the respective models of the groups of farmland specialists and the "other" species. The importance of a region being intensive or extensive in explaining the difference in abundance of "other" birds dropped greatly (as indicated by the respective estimates and their rate of change) once the differences in local habitat composition were controlled for in the model. The proximity to the farmland edge and extent of natural grassland and scrub were significant covariates explaining the distribution of these species, and they associated more with the less intensive areas. However, for the farmland specialist group the explaining power of the intensity level remained unchanged and no habitat covariates were retained as significant, which indicates the relative importance of other factors characteristic of the less intensive sites, such as heterogeneity of sward or better feeding resources, apart from habitat composition.

The ecological characteristics of the species determined the magnitude of difference between areas of two intensity levels (Table 5). The most pronounced difference was for edge species: their overall abundance in the more intensive areas was only third of that in more extensive ones. Intensity level remained a highly significant predictor for abundance in the models with habitat covariates. The initial difference in the number of species and individuals was the lowest for true field species (about 20%). However, this was the only ecological group for which, once the habitat was controlled for, the significance of the intensity level increased in most of the final models. Both species richness and abundance differed strongly for the insectivore species, but only abundance was significantly different for the granivorous group.

In the region's most intensively farmed area, 1795 individuals of 32 species of farmland specialists and 101 individuals of 15 "other" bird species were recorded. A

Table 5
Estimation results from Poisson regression models when (i) taking into account intensity level and country as factors, and (ii) same as previous but with PCA axes for habitat composition as covariates

	Ratio[a]	Intensity level and country	Intensity level, country and habitat covariates	Retained PCA components
		Estimates (CI) for ES, LT, LV	Estimates (CI) for ES, LT, LV	
Farmland SR	1.37	53 (55–51), 18 (13–22), =0	52 (50–54), 18 (16–20), =0	EDGE
Farmland IND	1.47	43 (42–44), 18 (16–20), 35 (33–37)	43 (42–44), 18 (16–20), 35 (33–37)	None
Other SR	2.08	80 (77–93), 72 (66–73), =0	79 (76–82), 53 (44–61), =0	EDGE + SCRUB
Other IND	1.93	76 (73–78), 72 (68–76), =0	71 (74–76), 44 (38–48), =0	EDGE + NATGR + SCRUB
True field SR	1.24	44 (40–47), =0, =0	26 (25–26), 26 (12–37), 26 (19–37)[b]	−EDGE
True field IND	1.28	30 (28–31), >0, 44 (42–47)	39 (32–44), 39 (25–50), 39 (26–49)[b]	−EDGE − SEEDGR − NATGR − SCRUB − DITCH
Edge SR	1.45	67 (63–71), >0, =0	66 (63–69), =0, <0	EDGE + SEEDGR
Edge IND	1.85	71 (69–73), 40 (35–45), 17 (11–23)	69 (67–70), 17 (14–21), >0	EDGE + SEEDGR + NATGR
Tree SR	1.41	26 (23–28), 26 (22–29), 26 (22–29)[b]	ns	EDGE + SCRUB
Tree IND	1.54	31 (29–32), 21 (22–38), 21 (22–38)[b]	25 (20–29), −76 (69–83), 24 (23–26)	EDGE + SCRUB + DITCH
Granivorous SR	1.11	ns	ns	−EDGE + NATGR
Granivorous IND	1.21	12 (10–13), >0, 37 (34–39)	14 (13–16), 13 (11–15), 38 (38–39)	−EDGE − SEEDGR
Insectivore SR	1.70	72 (68–75), 38 (28–44), =0	70 (27–73), 26 (18–34), =0	EDGE + SEEDGR
Insectivore IND	2.17	74 (72–76), 52 (47–56), 34 (28–39)	73 (71–75), 44 (39–48), 30 (26–23)	EDGE + SEEDGR

Estimates and 95% confidence intervals (in parentheses) for the intensity factor for Estonia (ES), Lithuania (LT) and Latvia (LV) are given as percentage increase in bird species number (SR) and abundance (IND) when comparing an intensive area with an extensive one in a respective country. Only estimates at significance level of $p < 0.05$ are given, and for $p > 0.05$ only the direction of the change is presented as <0, >0, or =0 if confidence intervals included both increase and decrease. Species groups are farmland specialists and their ecological groups, and the other species.
[a] Ratio of the sample means of the more extensive areas to the more intensive ones.
[b] No significance difference in the intensity effect between the countries.

tangible negative effect of the intensity of field management on community characteristics, especially on the abundance of recorded birds, was detected also here (Table 6, Fig. 2). In fields under the most intensive management about 50% less species and individuals of farmland birds were registered as compared to fields characterised by lack of regular management. The intensity of field management was related most strongly to the ecological group of edge species, and least with true field birds. Insectivore species were related strongly to the field management regime, but granivorous birds much more weakly so.

The effect size for the abundance of farmland specialists was in the range of 40–50%. This means that if the fields in the studied region are characterised by an evenly dense crop structure, are kept clean of weeds, and are regularly treated with agrochemicals, the number of individuals of specialist birds using fields may be reduced by half (Fig. 2). Similarly, the effect size for true field group was about 20% but up to 80% for edge group.

4. Discussion and policy implications

The intensively farmed regions across the Baltic countries supported less diverse communities of farmland birds than in the regions under less intensive use. Partly the

Table 6
Total mean and S.D. of the response variables, and results from Poisson regression models for farmland birds and their ecological groups related to the intensity of management and structure of arable fields in regions of Pasvalys in Lithuania and Jelgava in Latvia

	Mean (S.D.)	Estimate (CI)	Retained habitat gradients
Farmland SR	3.32 (2.094)	47 (32–59)**	- ONLY CEREAL
Farmland IND	15.30 (7.237)	44 (37–50)***	- ONLY CEREAL
True field SR	1.40 (0.535)	>0	None
True field IND	10.48 (4.604)	17 (4–28)**	- ONLY CEREAL
Edge SR	1.02 (1.253)	76 (63–84)**	- ONLY CEREAL
Edge IND	2.74 (3.527)	79 (73–84)***	- ONLY CEREAL + EDGE
Tree SR	0.90 (1.147)	>0 ns	- ONLY CEREAL
Tree IND	2.46 (3.903)	55 (41–66)**	- ONLY CEREAL
Granivorous SR	1.60 (0.833)	>0 ns	None
Granivorous IND	11.46 (5.433)	31 (21–40)***	- ONLY CEREAL
Insectivore SR	1.20 (1.229)	70 (55–80)***	- ONLY CEREAL
Insectivore IND	2.94 (3.365)	72 (64–78)***	- ONLY CEREAL

Estimates and 95% confidence intervals (in parentheses) are given as percentage change in bird species number (SR) and abundance (IND) when management intensity changes from a minimum to its maximum value in the study. Levels of significance are denoted as '*' for $0.01 < p < 0.05$, '**' for $0.001 < p < 0.01$, '***' for $p < 0.001$, "ns" for $p > 0.05$, accompanied by >0 for a direction of the difference. $n = 49$.

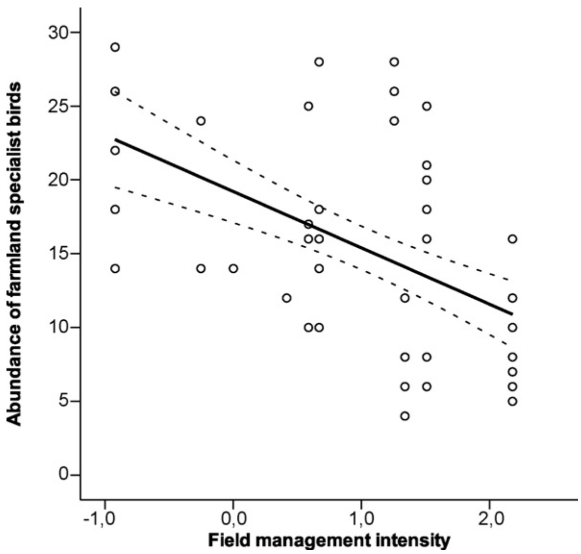

Fig. 2. Relationship between the gradient of management intensity of arable fields based on field assessment of weed abundance, crop structure, and presence of tramlines, and abundance of farmland specialist birds; dashed lines denote 95% confidence interval.

reason is in the less diverse landscape in such regions, which impoverished the community in the past and provides fewer dispersal sources at the present. The fact that the significance of the intensity level in the model for true field species increased once the habitat covariates were added, may indicate that the surrounding habitat has a minor influence on these species. Although true field species avoided edge habitats and scrub, both of which were more characteristic for the less intensive areas, they were nonetheless more abundant in these areas. Once the adverse effect of the habitat structure was removed statistically, the effect size of the difference between the two became even larger in favour of the less intensive area.

The field area homogenisation as a result of farming intensification is especially relevant for the species dependant on edge habitats for both breeding and feeding. Granivorous birds are better off because adult birds of most species are able to utilise cropped grain though their abundance may be affected by reduced resources within fields. Many declining species in Western Europe are granivorous birds (Siriwardena et al., 2001) and also true field species (Pitkänen and Tiainen, 2001). Their conservation depends primarily on what happens within crop fields. The results obtained in the most intensively managed region indicated a decrease in the carrying capacity of the intensively managed fields also for true field species, most of which are granivorous. Sampling points in the less intensively farmed fields were associated with a higher degree of field variety and with roads and ditches as field dividing borders, that is higher in-field and in-crop heterogeneity. Edge bird species were most vulnerable to the increased ‘‘neatness’’ of fields and dominance of cereals.

The levels of agricultural intensity studied here can be regarded as relatively low, and do not come close to the ones currently observed in West Europe as measured by the use of inputs and yields (FAOSTAT, 2006). However, even an observed difference in cereal yield of about 30% between the studied areas was reflected here in clearly reduced numbers of typical farmland birds. The species composition of farmland specialists was little affected. The available statistical data show a further increase of about 0.5 t (25%) within 2003–2005 for the Baltic countries. One can expect a further tripling of cereal yields across the region if the respective yields for West European countries are to be reached: up to 5 t on average in Estonia, and up to 8 t for Southern Latvia and Lithuania. This study indicates that species associated with edge structures will decline most strongly at the beginning of intensification with farmland homogenisation, removal of non-cropped elements, and agronomical improvement of the less productive field patches, while intensive crop management will trigger declines in the numbers of true field birds.

Decoupling EU farming subsidies from production as introduced in 2005 can be regarded as a positive policy change, especially for the CEE region: it gives farmers an indication that intensity of production as such is not a policy target anymore. Already now the area-based subsidies motivate farmers in the region to mow old abandoned fields, preventing them from overgrowing and so keeping them as semi-natural grasslands (A. Auninš, unpublished data). However, there exist other subsidies in the region for turning grasslands into cereal and bioenergy crop fields, and forest. Further, total area payments provide incentives for removing non-cropped habitat elements such as scrub areas in order to increase the eligible area, which was documented for e.g. Slovenia and Latvia (A. Brunner, personal communication; A. Auninš, unpublished data).

In order to achieve the Göteborg Summit target of halting biodiversity decline in the EU by 2010, there should be considerable improvement in conservation safeguards within the EU agricultural policy for the CEE region. There are signs that most of the CEE countries are currently failing to achieving conservation targets through insufficient funding of national agri-environment programmes, selection of unsophisticated schemes of little benefit to birds and the environment, and lack of advisory services or political will to improve the situation (BirdLife International, 2006). The national programmes rightly focus on the most valuable farmed habitat types such as semi-natural grasslands (BirdLife International, 2006). However, taking into account the likely prospects of increasing intensity of crop and silage production, especially in the regions with best soils, there may be a need already now to envision agri-environment schemes specifically designed for biodiversity of the ‘‘ordinary’’ fields.

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Article VI

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Recent changes in agricultural landscape and bird populations in Latvia: impacts and prospects of EU agricultural policy

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Abstract – Since Latvia joined the EU in 2004, the amount of funds allocated to the agricultural sector has increased substantially. The different measures included in the national Rural Development Plan serve as driving forces causing a rapid change in agricultural land use and farming practices. We used data from the Latvian Farmland bird monitoring scheme to describe the ongoing changes on Latvian farmland. We compared population trends of 54 individual species and species groups as well as species richness, diversity and total bird abundance between the periods 1995-2003 (period 1) and 2003-2006 (period 2). Pairwise comparisons of the trends of all the analysed species between the two periods showed that trends in period 2 were lower than in period 1 and this difference was significant. Splitting the species into six ecological groups, the pattern was consistent in all groups. However the differences were significant only in the "ShrubEdge" and "Forest" groups and near significant in the "Open" group. The trend comparisons grouping species by their wintering areas and main food sources also showed a similar pattern, however, the differences were significant only in the species wintering in Sub-Saharan Africa and insectivore group. Overall bird abundance as well as farmland bird abundance declined in period 2 and so did farmland bird species richness and diversity. Eleven species declined and only five species increased statistically significantly in the period 2 contrasting with four and 26 species in the period 1, respectively. The observed changes can be linked to ongoing changes on Latvian farmland: intensification, restoration of the overgrown areas as well as removal of various landscape elements to increase the "eligible" area for EU subsidies. Although these changes do not cause immediate threat to farmland birds, future development is very important.

INTRODUCTION

The Latvian farmland bird monitoring scheme was introduced in 1995. At that time the state's agricultural sector was undergoing a deep crisis due to changes in the political and economic system: agricultural production decreased by more than 50% and use of agrochemicals by more than 90% while over 40% of the arable land was abandoned (Anon 2000). Many bird species profited from this situation and their populations as well as species richness in farmland increased substantially during the 1990s (Aunins and Priednieks 2003, Keišs 2005, Aunins and Priednieks 2008).

After 2001 and especially since Latvia joined the EU in 2004, the amount of funds allocated to the agricultural sector increased substantially. The different measures included in the national Rural Development Plan served as driving forces causing a rapid change in land use patterns and farming practices. Thus, cereal yields experienced a growth since 2003 (Anon 2006), as did the area of arable land, while the area of abandoned land and grassland declined (Table 1, Aunins 2006). The aim of this study is to test whether any changes in farmland bird communities and population trends have occurred since the country joined the EU. The results could serve as a basis for more specialised studies in future on the causes of the changes.

METHODS

We used data on 54 of the most commonly recorded species in the Latvian farmland bird monitoring scheme to calculate population trends for the periods 1995-2003 (period 1) and 2003-2006 (period 2). The details of the monitoring scheme can be found in Aunins *et al.* (2001), Aunins and Priednieks (2003), and Aunins and Priednieks (2008). The year 2003, the last one before Latvia accessed to the EU and the massive funding for the agricultural development became available, was chosen as a break year.

Following the idea of Tiainen and Pakkala (2001, see also Herzon *et al.* 2006) the species were divided into six ecological groups for separate analysis according to their

Table 1. Areas occupied by main farmland habitat categories within the 200m zones around bird count points and cereal yields in Latvia.

	1995	2000	2003	2005
Arable lands (ha)	645	794	750	882
Abandoned fields (ha)	201	314	343	242
Grasslands (ha)	878	616	604	576
Cereal yields (ha)	17.1	22.7	21.8	28.0

preferred habitat structures (Table 2) and these were analysed separately:

1) "Open" - typical farmland species requiring open areas (fields or grasslands) for both breeding and feeding
2) "ShrubEdge" - typical farmland species requiring high herbaceous or shrubby edges or patches. Some species using such structures in farmyards were also included here
3) "TreeEdge - typical farmland species utilising forest-farmland edges. Most are the species breeding in forest or tree stands and feeding in fields. Some species using such structures in farmyards were also included here
4) "Swallows and martins" - the Swallow, House Martin and Sand Martin were grouped as aerial feeders that can feed far from their breeding places
5) "Wetland" - species dependent on presence of wetland elements for breeding and feeding, however also may feed on fields
6) "Forest" - species majority of whose populations breed in forests and where the presence of farmland is not mandatory.

The species grouping was based on an earlier study on birds - habitats associations in Latvian farmland (Aunins *et al.* 2001), as additional information sources were used other studies from the Baltic countries or Finland (e.g. Tiainen and Pakkala 2001, Herzon *et al.* 2006). We made separate groupings also according to wintering areas and feeding preferences (Table 2). For wintering, species were classified as those spending the winter in or near breeding areas (including partial migrants), in W or S Europe or N Africa, in Sub-saharan Africa, and in southern Asia. For feeding, groups were granivores, insectivores and other according to the primary food source. Information on species wintering areas and feeding habits was collected from relevant literature sources (cf. Snow and Perrins 1998) and adjusted by ringing recovery records in the database of the Latvian Ringing centre. A species could be assigned only to one group in each of the three main grouping categories.

For the bird abundance (total number of all individuals counted, all species combined) and species diversity analyses we used three species sets:

1) all species: all breeding species recorded during the counts
2) rural species: species successfully utilising farmland and its typical elements for breeding or feeding or both
3) farmland specialists: species primarily dependent on farmland.

PC-ORD 5.0 software (McCune and Mefford 2006) was used for calculating the community parameters (abundance, Shannon-Wiener index and species richness). SPSS 15.0 software package (SPSS Inc. 2006) was used for the statistical tests. TRIM 3.5 software was used for trend calculation (Pannekoek and van Strien 2005). The trends were classified according to the classification system suggested by Pannekoek and van Strien (2005).

RESULTS

There was no correlation between population trends (estimated using a Time-effects model in TRIM) between the two periods (fig. 1; Spearman rank correlation: $r_s = 0.031$, $n = 54$, $p > 0.8$) thus generally the new trends were inconsistent with the previous ones. The largest proportion of species belonged to the group with increasing trends in period 1 and declining in period 2.

Pairwise comparisons of the trends of all 54 analysed species between the two periods showed that trends in period 2 were lower than in period 1 (Wilcoxon signed ranks test, $Z = -4.034$, $n = 54$, $p < 0.001$). Trend differences were significant also in "ShrubEdge" and "Forest" groups ($Z = -2.578$, $n = 11$, $p = 0.01$ and $Z = -2.040$, $n = 14$, $p = 0.041$) and near significant in "Open" group ($Z = -1.690$, $n = 7$, $p = 0.091$). Although the pattern for trends in period 2 to be lower than in period 1 was similar, the differences in other groups were not significant (Fig. 2). "Open", "Wetland" and "Swallows and Martins" groups have small sample sizes (number of species per group) and when these groups were pooled the difference was statistically significant ($Z = -2,556$, $n = 15$, $p = 0.011$).

The trend comparisons grouping species by their wintering areas and main food sources also showed a similar pattern, however, the differences were significant only in the Sub-Saharan Africa wintering ($Z = -3.857$, $n = 24$, $p < 0.001$) and insectivore groups ($Z = -3.669$, $n = 35$, $P < 0.001$), respectively. There was a strong mutual relationship between these two species groups as only 2 of 24 species wintering south of the Sahara were not classified as in-

Table 2. Species trend estimates for the time periods 1995-2003 and 2003-2006 and species grouping according to their preferred habitat structures (see details in text), migrant status (**sed**: sedentary and partial migrants. **Eur**: wintering in southern or western Europe or North Africa. **Afr**: wintering in sub-Saharan Africa. **Asia**: wintering in southern Asia) and dominant food sources (**Ins**: Insectivores. **Gran**: granivores. **O**: other). * refers to significance of change at $p < 0.05$ and ** to $p < 0.01$.

SPECIES	Trend estimates				Ecological group	Ecological group	Feeding
	1995-2003		2003-2006				
	Slope	SE	Slope	SE			
Ciconia ciconia	0.9952	0.0121	0.9841	0.0349	Tree Edge	Afr	O
Anas platyrhynchos	0.9860	0.0681	0.9960	0.1251	Wetland	Sed	O
Buteo buteo	0.8767**	0.0195	1.0468	0.0754	Tree Edge	Eur	O
Tetrao tetrix	0.9700	0.0710	0.7233*	0.1213	Open	Sed	Gran
Coturnix coturnix	1.2029*	0.0663	0.8766	0.1553	Open	Afr	O
Crex crex	1.0224	0.0200	0.9370	0.0462	Open	Afr	Ins
Grus grus	1.4315**	0.0952	1.1752*	0.0694	Wetland	Eur	O
Vanellus vanellus	1.0733**	0.0212	1.1176*	0.0478	Open	Eur	O
Columba palumbus	1.0867**	0.0191	1.0322	0.0384	Tree Edge	Eur	Gran
Cuculus canorus	1.1647**	0.0152	1.0242	0.0217	Forest	Afr	Ins
Jynx torquilla	1.3227**	0.0775	1.1451	0.1065	Tree Edge	Afr	Ins
Dendrocopos major	1.0595	0.0462	1.3356*	0.1549	Forest	Sed	Ins
Alauda arvensis	1.0075**	0.0027	0.9726**	0.0080	Open	Eur	Ins
Riparia riparia	1.1162	0.1749	0.7238	0.2986	Swallows & Martins	Afr	Ins
Hirundo rustica	1.1260**	0.0181	1.0805	0.0584	Swallows & Martins	Afr	Ins
Delichon urbica	1.2311**	0.0357	0.8802	0.0793	Swallows & Martins	Afr	Ins
Anthus trivialis	1.0845**	0.0132	0.9221**	0.0264	Tree Edge	Afr	Ins
Anthus pratensis	0.9191**	0.0108	0.9398	0.0389	Open	Eur	Ins
Motacilla alba	0.9212**	0.0165	0.9812	0.0542	Tree Edge	Eur	Ins
Luscinia luscinia	1.0918**	0.0093	0.9212**	0.0162	Shrub Edge	Afr	Ins
Saxicola rubetra	1.0444**	0.0095	0.9741	0.0199	Open	Afr	Ins
Turdus merula	1.0140	0.0113	0.8939*	0.0278	Forest	Eur	Ins
Turdus pilaris	1.0546*	0.0271	0.9882	0.0707	Tree Edge	Eur	Ins
Turdus philomelos	1.0910**	0.0143	0.9096**	0.0346	Forest	Eur	Ins
Turdus iliacus	1.1174**	0.0418	0.8121**	0.0894	Forest	Eur	Ins
Locustella naevia	1.1465**	0.0294	0.9535	0.0433	Shrub Edge	Afr	Ins
Locustella fluviatilis	0.9901	0.0256	0.8776	0.0757	Shrub Edge	Afr	Ins
Acrocephalus schoenobaenus	0.9797	0.0207	0.9777	0.0507	Wetland	Afr	Ins
Acrocephalus palustris	1.0495**	0.0095	0.8763**	0.0250	Shrub Edge	Afr	Ins
Acrocephalus arundinaceus	1.0718	0.0493	0.9730	0.0931	Wetland	Afr	Ins
Hippolais icterina	1.0240	0.0279	0.8379*	0.0668	Forest	Afr	Ins
Sylvia curruca	0.9222	0.0488	1.0582	0.1238	Tree Edge	Eur	Ins
Sylvia communis	1.0970**	0.0072	0.9453**	0.0161	Shrub Edge	Afr	Ins
Sylvia borin	1.0552**	0.0152	0.9678	0.0391	Shrub Edge	Afr	Ins
Sylvia atricapilla	1.1455**	0.0287	0.9916	0.0539	Forest	Eur	Ins
Phylloscopus sibilatrix	0.9173**	0.0319	0.9419	0.0783	Forest	Afr	Ins
Phylloscopus collybita	1.1466**	0.0273	1.0694	0.0457	Forest	Afr	Ins
Phylloscopus trochilus	0.9845	0.0145	1.1225**	0.0458	Forest	Afr	Ins
Parus caeruleus	1.0575	0.0642	0.8804	0.0987	Forest	Sed	Ins
Parus major	1.0964**	0.0266	0.9769	0.0507	Forest	Sed	Ins
Oriolus oriolus	1.1603**	0.0163	0.9949	0.0281	Forest	Afr	Ins
Lanius collurio	1.0184	0.0273	0.9687	0.0778	Shrub Edge	Afr	Ins
Pica pica	1.1758**	0.0385	1.0613	0.0627	Shrub Edge	Sed	O

→

SPECIES	Trend estimates				Ecological group	Ecological group	Feeding
	1995-2003		2003-2006				
	Slope	SE	Slope	SE			
Corvus corone cornix	1.0186	0.0100	1.0188	0.0461	Tree Edge	Sed	O
Corvus corax	1.1233**	0.0238	0.8704	0.0923	Tree Edge	Sed	O
Sturnus vulgaris	0.9916	0.0139	1.0652	0.0434	Tree Edge	Eur	Ins
Passer montanus	0.9546	0.0359	1.0573	0.0879	Tree Edge	Sed	Gran
Fringilla coelebs	1.0321**	0.0086	0.9627	0.0195	Forest	Eur	Gran
Carduelis chloris	1.0441	0.0352	1.0262	0.0925	Tree Edge	Sed	Gran
Carduelis carduelis	1.0089	0.0255	0.6324**	0.0646	Tree Edge	Sed	Gran
Carduelis cannabina	0.9830	0.0268	0.9482	0.0871	Shrub Edge	Eur	Gran
Carpodacus erythrinus	0.9794	0.0131	0.9634	0.0424	Shrub Edge	Asia	Gran
Emberiza citrinella	0.9925	0.0072	1.0704**	0.0221	Shrub Edge	Sed	Gran
Emberiza schoeniclus	0.9571	0.0230	0.9763	0.0712	Wetland	Eur	Gran

sectivores. To test whether wintering areas or food sources were responsible for the significant differences in trends between the two periods in the "ShrubEdge" and "Forest" groups, the pairwise comparisons were repeated with only these two categories (pooled) included in the analysis. There were more negative than positive ranks in all the categories tested, and differences in the Sub-Saharan group and the group wintering in West or South Europe and North Africa as well as the insectivore group were statistically significant (Z = -2.691, n = 13, p = 0.007, Z = -2.201, n = 6, p = 0.028 and Z = -2.875, n = 20, p = 0.004 respectively).

Trend in bird abundance, species richness and diversity changed from "moderate increase" in period 1 to "stable" or "moderate decline" in period 2 in all three species community categories analysed (Table 3).

There were 11 species showing statistically significant declines and only 5 showing significant increases in period 2 while in period 1 these figures were 4 and 26 respectively (Table 2).

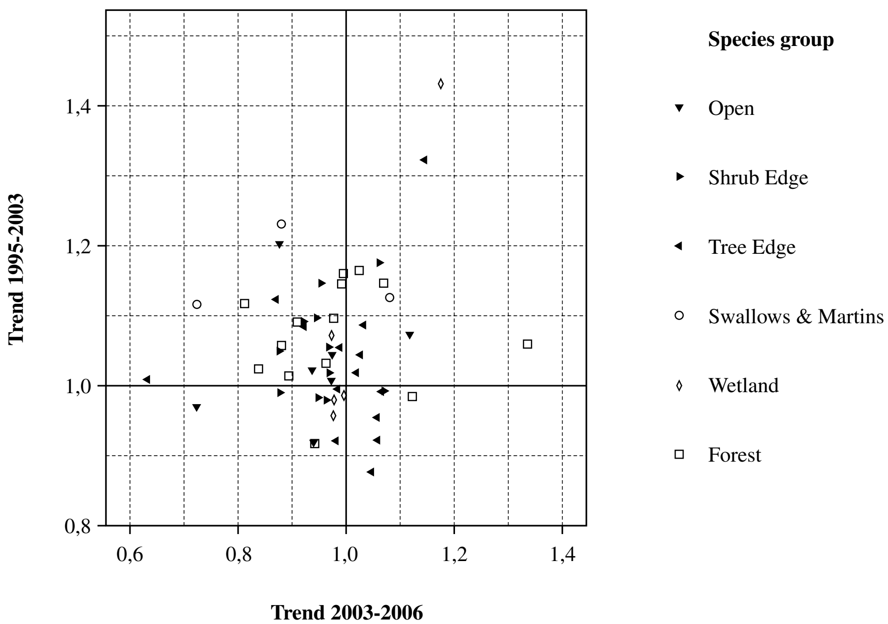

Figure 1. Scatterplot of trends in periods 1995-2003 and 2003-2006.

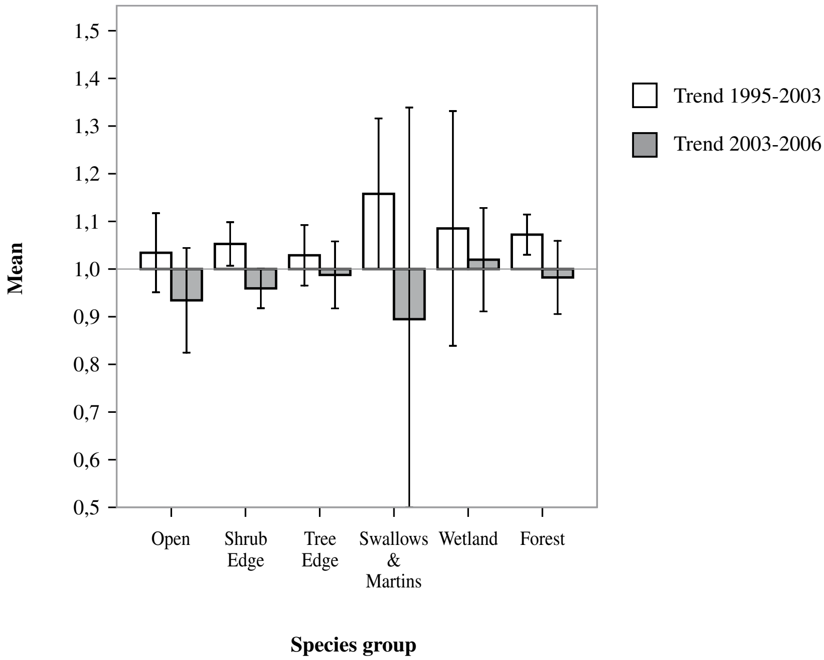

Figure 2. Comparison of the mean trends between the periods 1995-2003 and 2003-2006 in different ecological species groups. Open (n = 7), Shrub Edge (n = 11), Tree Edge (n = 14), Swallows & Martins (n = 3), wetland (n = 5) and forest (n = 14).

DISCUSSION

It may be argued that the three year period we used to assess the post-accession effects is not long enough for detection of trends as these may be strongly affected by the yearly population fluctuations caused by various biotic and abiotic factors and thus having large confidence intervals. However, as we are deliberately focusing on short-time effects that might be caused by the recent agricultural policy changes in Latvia and we look at patterns common in larger groups of species instead of individual species performance, we consider the chosen approach appropriate for the given task.

It was expected that the increase in species diversity and abundance that Latvian farmland experienced during the 1990s had to stop and stabilise at some point as the carrying capacity of the environment could not grow endlessly. However, in this study we found reversal rather than the stabilisation of the trends, as the trajectories of many bird populations as well as total bird abundance changed to negative in period 2. Although not always statistically significant, this pattern was consistent in almost all the species groups analysed. Statistically significant differences were found in the "ShrubEdge" and "Forest" groups whose habitats in farmland have been most affected by the recent changes: cutting bushes and trees in the overgrown areas as well as along the roads and ditches both to comply with the "good agricultural condition" requirements and to increase the "eligible" area for the "single area payment".

It has been reported earlier that the trends of African wintering species are worse than those wintering in Europe (Sanderson *et al.* 2006). In this study the trends of the species wintering south of Sahara became significantly worse in period 2, however, this wintering area factor does not account for all of the differences in trends, as the SW Europe and N Africa wintering group also had significantly worse trends in the "ShrubEdge" and "Forest" groups. The significantly more negative trends found in the insectivore group suggests that the abundance of insects might have decreased as a result of the ongoing changes.

The observed changes cannot be attributed only to the increased and still growing area of the active farmland due to restoration carried out in the previously overgrown areas as the declines in "ShrubEdge" and "Forest" groups might suggest - the reversal of trends has been observed in abundances, species richness and diversity of the farmland specialists too (Table 3). Thus we argue that the reason for the observed declines is in the lower carrying capacity of the environment caused by the changes in agricultural practices and intensity due to increased funding allocated to this sector that are promoting this change. Further research is needed to assess the role of political and

Table 3. Trends in species richness, diversity and abundance. **MI**: refers to "moderate increase". **MD**: "moderate decline". **S**: "stable" according to classification system suggested by Pannekoek and van Strien (2005). * refers to significance of change at $p < 0.05$ and ** to $p < 0.01$.

Measure	Group	1995 - 2003		2003 - 2006	
Species richness	All species	1.0234 ± 0.0017	MI**	0.9805 ± 0.0053	MD**
	Rural species	1.0188 ± 0.0023	MI**	0.9917 ± 0.0068	S
	Farmland species	1.0134 ± 0.0023	MI**	0.9818 ± 0.0068	MD**
Shannon-Wiener diversity index	All species	1.0120 ± 0.0012	MI**	1.0006 ± 0.0033	S
	Rural species	1.0099 ± 0.0015	MI**	0.9965 ± 0.0044	S
	Farmland species	1.0075 ± 0.0016	MI**	0.9902 ± 0.0047	MD*
Abundance	All species	1.0357 ± 0.0019	MI**	0.9810 ± 0.0043	MD**
	Rural species	1.0240 ± 0.0023	MI**	0.9780 ± 0.0052	MD**
	Farmland species	1.0221 ± 0.0022	MI**	0.9767 ± 0.0052	MD**

economic changes in the agricultural sector in changes in farmland bird diversity (but see Herzon and O'Hara 2007 for analysis on conservation policy implications to structural diversity of farmland and farmland birds in the Baltic countries).

Nevertheless, despite current developments, the agricultural intensity level in Latvia still does not reach the level characteristic for Western Europe (faostat.fao.org). It is unrealistic to expect that it would be possible to maintain agricultural intensity as low as it was during the 1990s. Economically driven low intensity in most cases is co-occurring with land abandonment that is also causing serious problems to biological diversity of farmland birds, especially the farmland specialists, dependant on open areas. Although the current increase in intensity might have been responsible for the observed slight reduction of the biodiversity level reached during the 1990s, it should not be regarded as a major threat that calls for immediate solutions yet. It is important at what level the agricultural intensity will stabilise and whether or not sufficient areas of low intensity farmland supported by agri-environmental schemes will be available. The Latvian Rural Development Plan 2007 - 2013 provides only one agri-environmental measure directly targeted at the management of diversity of wild species ("Maintenance of biological diversity in grasslands"). This is eligible in less than 2% and currently being implemented in less than 1% of the Latvian farmland. The current situation should be regarded as unsatisfactory as the scheme has negligible effect on countrywide biological diversity. The agri-environmental schemes aimed at maintaining biologically diverse species communities in a wider range of agricultural habitats, and applied on a significant proportion of farmland, are urgently needed.

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