Farmland Birds and Habitat Heterogeneity in Intensively Cultivated Boreal Agricultural Landscapes

Ville Vepsäläinen

HELSINKI 2007

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Academic dissertation

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I Vepsäläinen V, Pakkala T, Piha M, Tiainen J. 2005. Population crash of the ortolan bunting *Emberiza hortulana* in agricultural landscapes of southern Finland. Annales Zoologici Fennici 42: 91–107.

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III Vepsäläinen V, Pakkala T, Tiainen J. 2005. Population increase and aspects of colonization of the Tree Sparrow *Passer montanus*, and its relationships with the House Sparrow *Passer domesticus*, in the agricultural landscapes of Southern Finland. Ornis Fennica 82: 117–128.

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CHAPTERS

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Summary

1. Introduction

The biodiversity of farmland ecosystems has decreased remarkably during the latter half of the 20^{th} century, and it is widely recognized that this development is due to intensive farming with its various environmental effects (Matson *et al*. 1997, Krebs *et al*. 1999, Green *et al*. 2005). In the countries of the European Union (EU) the Common Agricultural Policy (CAP) is the main determinant affecting farmland biodiversity, since the agricultural policy defines guidelines of agricultural practices, *i.e.* it affects the ways in which farmers carry out farming in their fields. The practices in agriculture have both direct and indirect effects on organisms living in agro-ecosystems, for example through the reduction of nest sites and food and the effects of pesticides. One of the main objectives of CAP is the further intensification and development of agricultural production, which will affect detrimentally both individual species through the continuing decrease and deterioration of habitats (Stoate *et al*. 2001, Donald *et al*. 2002).

In addition to policies promoting intensive farming, CAP also includes national agri-environmental programmes, which include agri-environment schemes (AES). In AES a part of subsidies paid to farmers is directed to acts that are presumed to promote environmental protection and biodiversity. In order to shape AES into relevant and powerful tools for biodiversity protection, detailed studies on the effects of agriculture on species and species assemblages are needed. It is of primary significance to study in detail what habitats species need in intensively cultivated agro-ecosystems, and the importance of habitat heterogeneity, both in cultivated fields and in uncultivated habitats. With such detailed knowledge it will be possible to predict what kinds of measures would truly benefit the biodiversity of agro-ecosystems. Additionally, the measures ought to be shaped so that they are readily accepted and applied by farmers.

In the following, I will introduce four major topics, namely: 1) the Finnish farmland avifauna, 2) the effects of agricultural intensification and specialization on farmland birds, 3) the significance of habitat heterogeneity for farmland bird diversity and abundance, and 4) the contents of Finnish agri-environmental policy.

1.1. Farmland birds

The Finnish farmland bird community

Birds are a highly visible and audible part of the fauna of agricultural landscapes. Many Finnish bird species use agricultural environments for breeding, or resting and feeding during migration. Most birds breeding in farmland are passerines, but also ducks, gulls, waders, raptors, pigeons and gallinaceous birds are present. Based upon where species predominantly breed in agricultural environments, Tiainen & Pakkala (2001) classified Finland's farmland bird species into four ecological groups which are affected in different ways by farming practices and by environmental changes that fields undergo (Table 1). These four (i-iv) groups are as follows. (i) Species breeding and feeding on arable fields and open verges (*i.e.* 'true' field species) are affected directly by farming practices and availability of food on fields. Direct destruction of nests occurs if breeding coincides with ploughing, pesticide spraying or harvesting. (ii) Edge/bush species breeding and feeding mainly in bushy verges and in other similar tall vegetation (*e.g.* bush islets), along tree- and bush-lined ditches and roadsides, and also in suitable vegetated patches around settlements. Edge/bush species are generally safe from direct and immediate effects of farming work, but are affected by trimming and clearance of ditch and islet vegetation and clearance of other non-cultivated habitat patches. Moreover, these species may occasionally feed on fields and be exposed to direct effects of farming via food availability. (iii) Forest species breed in forest patches and in forests around farmlands (along the field-forest edge), but mainly feed on fields. Nests of these species are usually safe from farming work, and agricultural practices affect these species only through the availability of food. (iv) Farmyard species mostly breed in farms, small villages and other scattered settlements of agricultural landscapes, often in buildings or nest-boxes. Thus, populations of these species can be notably affected by the availability of nest sites. Farmyard species regularly feed in the fields, and in this respect they are affected by farming practices in the same ways as forest species.

Depending on the area and the number of species included in the studies, an estimate for the total density of Finnish farmland birds ranges between *ca* 100 and 160 pairs / km^2 of field area (e.g. Piiroinen *et al*. 1985, Tiainen *et al*. 2004a).

Long-term population trends of the Finnish farmland birds

The main long-term changes in Finnish farmland bird populations are rather well known, as the oldest quantitative census data of farmland birds date back to the 1920s and 1930s (*e.g.* Palmgren 1935, Soveri 1940), and data exist also from the 1950s–1970s (for a detailed description of data sources, see Tiainen & Pakkala 2001). An annual farmland bird survey system was established in the Lammi area (southern Finland) in 1984. Since then, other survey areas, where effective territory mapping method (Bibby *et al*. 2000) has been applied, have also been established in various locations in southern, western and eastern Finland (Tiainen & Pakkala 2001). In addition, national population trends based on line transect censuses are provided by Väisänen *et al*. (1998).

Comparison of Soveri's (1940) results from Lammi with the results of Tiainen *et al*. (1985) from the same area revealed significant long-term changes in farmland bird populations. Generally, in terms of the ecological groups represented in Table 1, densities of true field species, edge/bush species, and forest species had increased, whereas farmyard species had declined. Exceptions to this general pattern were grey partridge (*Perdix perdix*) and corncrake (*Crex crex*), both field species, and kestrel (*Falco tinnunculus*), a forest species, which had disappeared from the area, and hooded crow (*Corvus corone cornix*) which had declined (Tiainen *et al*. 1985).

At national level, the general decline of Finnish farmland birds started during the 1970s (in some species already during the 1960s) and accelerated during the 1980s and 1990s (Väisänen *et al*. 1998, Tiainen & Pakkala 2001, Väisänen 2006). Except for the forest species, all other ecological groups of species have declined during recent decades; the decline has been most pronounced in true field species and farmyard species (Fig 1, Table 1).

Fieldfare (*Turdus pilaris*), yellowhammer (*Emberiza citrinella*) and skylark (*Alauda arvensis*) were,

Table 1. Finnish farmland bird species classified on the basis of their breeding surroundings in agricultural landscapes; adapted from Tiainen & Pakkala (2001). The estimated breeding population size (in pairs) in year 2002 is shown in parentheses after the species name (BirdLife International 2004) — note that the figures are the total sizes of the Finnish populations, not just the population sizes in farmland habitats. After the population estimate is indicated whether the species showed a decreasing (**–**), increasing (+) or stable (0) population trend between years 1983 and 2004, based on national line-transect survey data (Väisänen 2005). N means that the trend is not provided by Väisänen (2005).

Field species	
Grey Partridge (*Perdix perdix*) (3000–5000)	**N**
Quail (*Coturnix coturnix*) (10–100)	**N**
Corncrake (*Crex crex*) (2000–8000)	**N**
Lapwing (*Vanellus vanellus*) (50 000–80 000)	**0**
Common Snipe (*Gallinago gallinago*) (80 000–120 000)	**–**
Whimbrel (*Numenius phaeopus*) (30 000–50 000)	**0**
Curlew (*Numenius arquata*) (35 000–50 000)	**–**
Redshank (*Tringa totanus*) (6000–8000)	**–**
Common Gull (*Larus canus*) (60 000–80 000)	**N**
Short-eared Owl (*Asio flammeus*) (2000–10 000)	**N**
Skylark (*Alauda arvensis*) (300 000–400 000)	**–**
Meadow Pipit (*Anthus pratensis*) (700 000–1 200 000)	**0**
Yellow Wagtail (*Motacilla flava*) (250 000–400 000)	**–**
Ortolan Bunting (*Emberiza hortulana*) (30 000–50 000)	**–**
Edge/bush species	
Pheasant (*Phasianus colchicus*) (10 000–20 000)	+
Whinchat (*Saxicola rubetra*) (300 000–400 000)	**–**
Grasshopper Warbler (*Locustella naevia*) (2000–4000)	**N**
River Warbler (*Locustella fluviatilis*) (500–1000)	**N**
Sedge Warbler (*Acrocephalus schoenob.*) (200 000–400 000)	**0**
Blyth's Reed Warbler (*A. dumetorum*) (5000–8000)	**N**
Marsh Warbler (*A. palustris*) (4000–6000)	**N**
Whitethroat (*Sylvia communis*) (250 000–400 000)	**0**
Red-backed Shrike (*Lanius collurio*) (30 000–60 000)	**0**
Scarlet Rosefinch (*Carpodacus erythrinus*) (250 000–350 000)	**–**
Reed Bunting (*Emberiza schoeniclus*) (200 000–400 000)	**0**
Forest species	
Common Buzzard (*Buteo buteo*) (5000–7000)	**N**
Kestrel (*Falco tinnunculus*) (2000–3000)	**N**
Stock Dove (*Columba oenas*) (2000–4000)	**–**
Wood Pigeon (*Columba palumbus*) (150 000–200 000)	+
Turtle Dove (*Streptopelia turtur*) (5–30)	**N**
Long-eared Owl (*Asio otus*) (2000–10 000)	**N**
Fieldfare (*Turdus pilaris*) (1 000 000–2 000 000)	+
Magpie (*Pica pica*) (150 000–200 000)	**0**
Jackdaw (*Corvus monedula*) (80 000–130 000)	+
Hooded Crow (*Corvus corone cornix*) (160 000–230 000)	**–**
Greenfinch (*Carduelis chloris*) (300 000–400 000)	+
Yellowhammer (*Emberiza citrinella*) (700 000–1 100 000)	**–**
Farmyard species	
Feral Pigeon (Rock Dove) (*Columba livia*) (20 000–40 000)	**N**
Collared Dove (*Streptopelia decaocto*) (100–150)	**N**
Swift (*Apus apus*) (30 000–60 000)	**–**
Barn Swallow (*Hirundo rustica*) (130 000–180 000)	**–**
House Martin (*Delichon urbicum*) (80 000–120 000)	**–**
White Wagtail (*Motacilla alba*) (600 000–900 000)	**0**
Wheatear (*Oenanthe oenanthe*) (150 000–200 000)	**–**
Rook (*Corvus frugilegus*) (1000–1200)	**N**
Starling (*Sturnus vulgaris*) (30 000–60 000)	**–**
House Sparrow (*Passer domesticus*) (200 000–400 000)	**–**
Tree Sparrow (*Passer montanus*) (20 000–40 000)	+
Linnet (*Carduelis cannabina*) (20 000–30 000)	**N**
Goldfinch (*Carduelis carduelis*) (10 000–20 000)	**N**

and still are, the three most abundant species in agricultural areas (Table 1). Examples of species which have notably declined in agricultural environments include curlew (*Numenius arquata*), yellow wagtail (*Motacilla flava*), ortolan bunting (*Emberiza hortulana*), house martin (*Delichon urbicum*), starling (*Sturnus vulgaris*), house sparrow (*Passer domesticus*), wheatear (*Oenanthe oenanthe*), and hooded crow. Some species have increased in number, for example wood pigeon (*Columba palumbus*), greenfinch (*Carduelis chloris*), fieldfare, and tree sparrow (*Passer montanus*) (Väisänen & Solonen 1997, Väisänen *et al*. 1998, Tiainen & Pakkala 2001, Tiainen *et al*. 2004b, Väisänen 2006). Currently, many of the increasing species belong to the forest species group, whereas most of the declining species belong to the true field species and farmyard groups (Fig. 1, Table 1).

To understand the causes underlying the observed population changes in Finnish breeding farmland birds, it is important to be aware of the changes in agriculture, especially about the consequences of agricultural intensification and specialization, which started in Europe after World War II (Stoate *et al*. 2001, Shrubb 2003).

1.2. Agricultural intensification and specialization

The main objective of agricultural intensification is to increase crop yields per unit area. Agricultural intensification is widely recognized as the main cause of loss

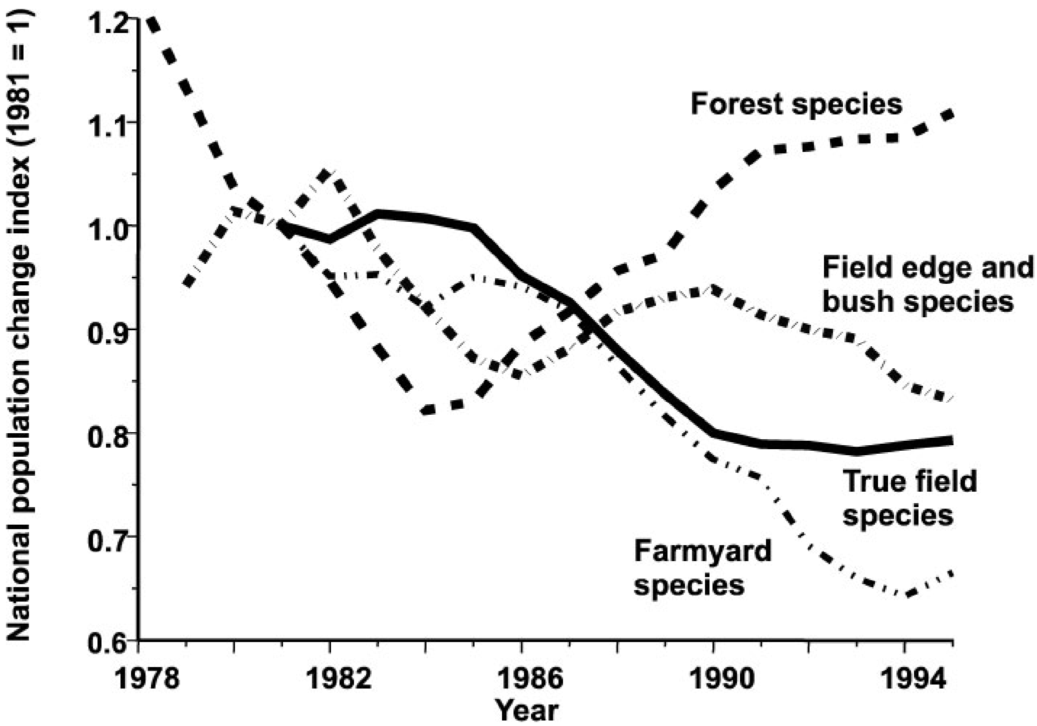
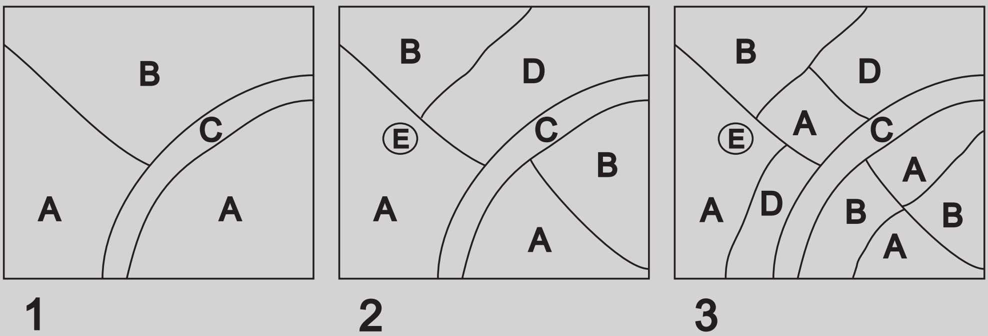


Figure 1. Average population change indices among Finnish farmland birds belonging to different ecological groups; adapted from Tiainen & Pakkala (2001), based on data from Väisänen *et al*. 1998. Indices estimated as in Gregory *et al*. (2000).

of biodiversity and habitat heterogeneity (Box 1) in agricultural environments globally (Matson *et al*. 1997, Tilman *et al*. 2001, Stoate *et al*. 2001, Benton *et al.* 2003, Green *et al*. 2005). The relationships between farmland birds and agriculture have been studied especially in Europe, and it has become clear that modern-day agricultural practices are behind the decline in population of many farmland bird species all over the continent (*e.g.* Fuller *et al*. 1995, Siriwardena *et al*. 1998, Krebs *et al*. 1999, Chamberlain *et al*. 2000, Donald *et al*. 2001, Tiainen & Pakkala 2001, Kujawa 2002, Newton 2004, Laiolo 2005, Wretenberg *et al*. 2006). An adequate indicator for intensification is the cereal yield, which almost tripled between the early 1960s and the late 1990s in EU countries; this increase in crop yield correlates negatively with population trends for farmland birds (Donald *et al*. 2001).

Box 1. Concept of Habitat Heterogeneity

Habitat heterogeneity is a term often used in ecology. Habitat heterogeneity generally refers to the number of habitat types, and/or the number and configuration of habitats in a given area. The three examples below illustrate the concept of habitat heterogeneity visually. Letters A–E stand for different habitat types. An area in example 1 is less heterogeneous (*i.e.* more homogeneous) than areas in examples 2 and 3, because in 1 there are fewer habitat types and habitat patches than in 2 and 3. An area in example 3 has the same number of habitat types than 2 and the total areas of the habitat types are the same as in 2, but 3 is more heterogeneous because there are more patches and the spatial configuration of habitats is more diverse. In 3 there is also more linear edge (*i.e.* border) between habitat patches than in 2. Furthermore, habitat heterogeneity increases from 1 to 3, also because total amount of edge increases from 1 to 3.



In this thesis I have studied habitat heterogeneity by calculating a) number of different land use types (*e.g.* different cultivation types, settlement, forest and bush patches) (IV), b) length of linear landscape objects (ditches, roads) (I–IV), and c) number of point-like landscape objects (*e.g.* barns, big single trees) (I–II, IV). I have studied habitat heterogeneity within patches of farmland (*i.e.* field areas usually surrounded by forests in Finland), using various spatial scales (Table 4).

Habitat heterogeneity is scale-dependent and depends naturally also on the habitat classification that one uses.

Specialization of agriculture means specializing in one production sector, instead of practising traditional mixed farming that combines animal husbandry and rotational cultivation of crops. In its extreme form, specialization means that farms concentrate either on cereal cultivation or on livestock-keeping. Specialization, accompanied by intensification, has led to simplified crop rotations, cereal *versus* grass monocultures (*i.e.* large continuous areas dominated by either tilled land or grassland), increased farm sizes, amalgamation of farms, increased size of fields and field parcels, and removal of field boundaries and non-cropped habitats — all this leading to a decline in farmland biodiversity (Benton *et al*. 2003).

Different processes of agricultural intensification and specialization affect biodiversity in complex ways and interact at multiple spatial and temporal scales (reviewed by Benton *et al*. 2003). The main processes having negative effects on birds include: (i) loss of suitable habitats, which causes loss of food and loss of places for foraging and breeding, (ii) agrochemical use, which may cause direct toxic effects and loss of food via decreased availability of plants and invertebrates, (iii) drainage and irrigation, which alter habitats and food availability, and (iv) mechanization of agricultural practices, which causes both direct nest destruction and losses of and changes in habitats and food availability — comprehensive reviews on the processes and consequences of agriculture on farmland biodiversity are provided by Stoate *et al*. (2001), Robinson & Sutherland (2002), Benton *et al*. (2003) and Newton (2004).

Overall, the consequence of multivariate agricultural intensification is the replacement of heterogeneity in habitat structure, in time and in space, with homogeneity. Thus, habitat heterogeneity is an adequate multivariate measure of the intensity of farming (Benton *et al.* 2003).

Agricultural intensification and specialization of farming in Finland

In the following, description of agricultural intensification and specialization in Finland since the 1950s is mainly based on Tiainen (2001, 2004).

In the 1950s agriculture was smallholding-dominated, and *ca* 80% of the farms practiced dairy farming (Figure 2a). Rapid intensification started in the 1960s, when the average farm size started to grow and farmers started to specialize. By the 1990s the majority of farms had given up their dairy cattle (Fig. 2a) and fields were being converted from hay, ley and pastures mostly to spring-sown cereals (Fig. 3). The decline of dairy farming, and the consequential decrease in the area of grasslands and pastures, has had negative effects upon populations of many Finnish farmland birds. For example, the 90% decline of starling between the early 1950s and the late 1980s (Rintala *et al.* 2003, Rintala & Tiainen 2007) has been attributed to decreased breeding success, which, in turn, is caused by the loss of insect food supplies that pastures provide (Tiainen *et al*. 1989, Solonen *et al*. 1991, Varjonen 1991). Other species known to be associated with pastures and cattle include barn swallow (*Hirundo rustica*), house martin, hooded crow, and house sparrow (Møller 2001, Tiainen & Pakkala 2001).

The loss of grasslands and pastures from crop rotations has probably impoverished soils which may reduce availability of food for farmland birds (Tiainen & Pakkala 2001). In Sweden, Berg (1991) suggested this to be a significant

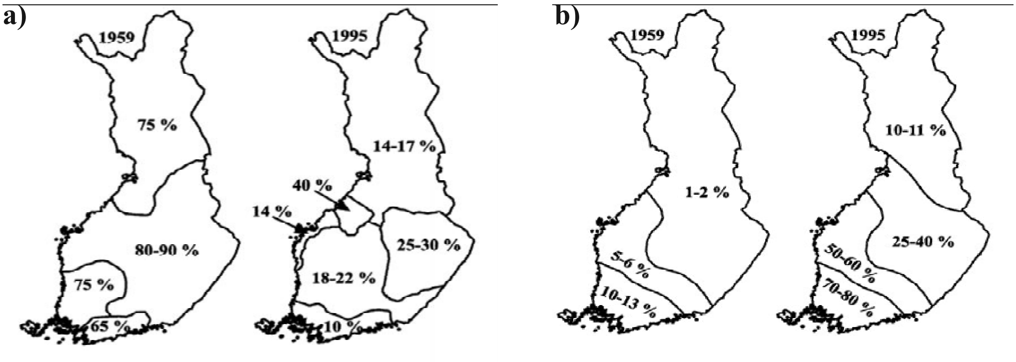


Figure 2 a) The proportion of dairy farms of all farms in different areas of Finland in 1959 and in 1995. **b)** The proportion of fields with subsurface drainage of all fields in different areas of Finland in 1959 and 1995 (Tiainen 2001).

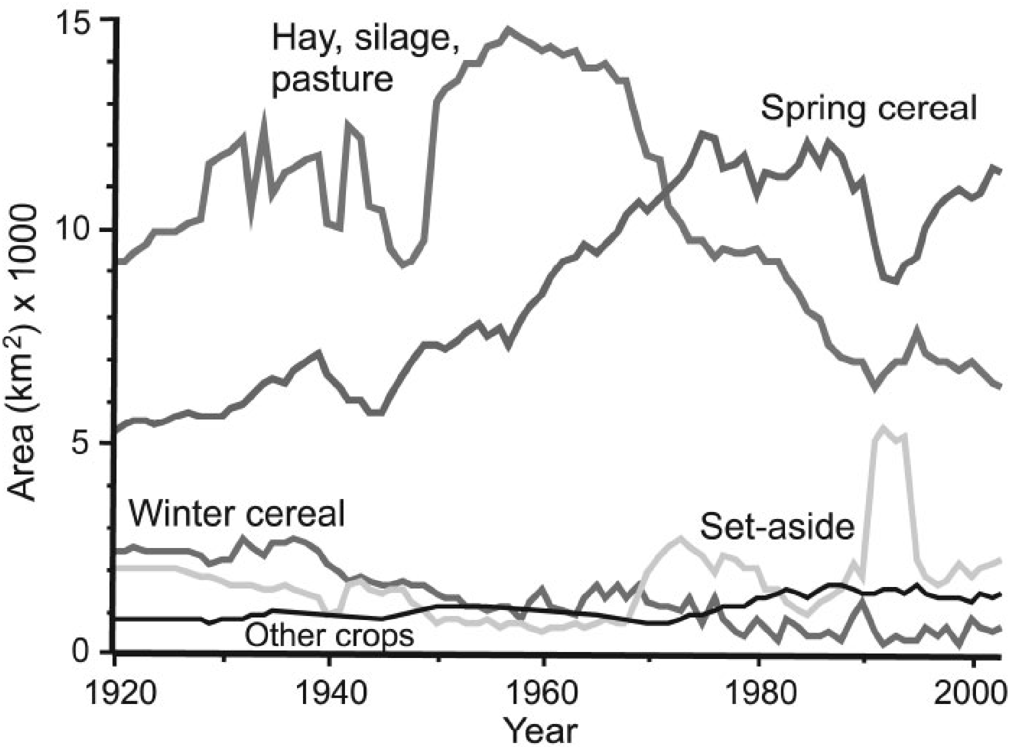


Figure 3. Arable land use in Finland since the 1920s; adapted from Tiainen (2004). Winter cereals are sown in autumn; traditionally, rye has been the most abundant winter cereal in Finland, but nowadays winter wheat occupies *ca* one half of the winter cereal area (Anon. 2006). The most cultivated spring-sown cereal is barley, followed by oats and wheat. Other crops include mainly turnip rape, potato and sugar beet. The two leaps in the set-aside curve in the 1970s and the 1990s illustrate the effects of obligatory national fallowing programmes, which were launched to eliminate cereal overproduction.

cause of the decline of lapwing (*Vanellus vanellus*) and curlew. From the point of view of many bird species, a fundamental difference between spring-sown crops and grasslands, winter cereals (*i.e.* cereals sown in autumn), pastures and set-asides is the height of the vegetation at the onset of the breeding season. Fields under spring cereal or root crop cultivation are managed and sown in spring; thus, they develop vegetation cover later in the breeding season than do grasslands, winter cereals, pastures and set-asides. For birds this signifies inferior cover for breeding and foraging in the early stages of the breeding season. Furthermore, the invertebrate fauna (*i.e.* food for birds) is different and less abundant in spring crop fields than in grasslands (Berg 1991, Varjonen 1991, Kinnunen & Tiainen 1999, Kinnunen *et al.* 2001). Farm work can cause direct negative effects if it coincides with critical periods of breeding. For example, in Finland curlew prefers grasslands over cereal fields as breeding habitat, and uses them also for foraging (Valkama *et al*. 1998), and the reduced breeding success in curlew has been attributed to the increase in spring-sown crops (Valkama & Currie 1999). Grasslands, pastures and set-asides are preferred also by skylark for breeding, as shown by Piha *et al*. (2003), and changes in these habitats explain well the fluctuations in the Finnish skylark population (Piha *et al*. 2007). However, nowadays two thirds of the Finnish grasslands are cultivated for silage (Anon. 2006). Silage fields in southern Finland are harvested during the first half of June, which unfortunately coincides with the nestling or the chick period of many farmland bird species. Thus, harvesting machines can cause direct mortality (Haukioja *et al*. 1985). Hay fields (that constitute 20% of grasslands, Anon. 2006), on the other hand, are harvested for dry hay in July, which is a far better time for ensuring successful breeding of most farmland birds.

One significant aspect of intensification has been the replacement of ditches with subsurface drainage, which makes new land available for cultivation and inhibits nutrient leaching. Nowadays the majority of Finnish fields have subsurface drainage, whereas at the end of the 1950s open ditches dominated (Fig. 2b) and their area with margins constituted over 5% of the total area of fields (Tiainen 2001). Subsurface drainage decreases structural and biological diversity of arable landscapes, and the conversion of open-ditch fields into subsurface-drained ones has been observed to influence negatively the densities of Finnish farmland birds (Halenius 1980, Mehtälä *et al*. 1985, Haukioja *et al*. 1985). Other farm practices that aim to increase cultivated area and to speed up everyday farm work include clearing small-scale habitat elements (*e.g.* tree and bush islets) and straightening the often uneven and complex field-forest border. These kinds of practices impoverish the habitat heterogeneity of agricultural landscapes.

The abandonment of dairy farming led to a decrease in the availability of dung for fertilising, and thus to a rapid increase in the use of artificial fertilizers since the 1960s. This in turn significantly increased yields. Also the use of pesticides started to increase rapidly from the 1950s, and the increase continued until the early 1980s. After that, the use notably decreased, but has started to increase again since the mid-1990s (Evira 2006). The increased herbicide use caused a significant reduction in weed vegetation from 1960s to 1980s (Erviö & Salonen 1987). The decline in weed abundance and diversity, and the consequent decrease in the number of weed-utilizing insects, led to decreased food supplies for birds, for example partridge and stock dove (*Columba oenas*) (Pulliainen 1984, Saari 1984, Helenius *et al*. 1995). A well-known example of the effects of herbicides on birds comes from the UK, where the decline of the partridge population was caused by decreased food supplies for chicks. This was the result of a reduced number of arthropods, which in turn was a consequence of decreased weed abundance due to herbicide use (Green 1984, Rands 1985, Chiverton & Sotherton 1991, Potts & Aebischer 1995).

With intensification, use of machines in farm work increased rapidly, and horses were superseded by tractors by the mid-1970s. The mechanization of agriculture reduces the breeding success of birds through an increase in the direct destruction of nests and nestlings (*e.g.* von Haartman1958, Valkama & Currie 1999).

Currently the area under cultivation in Finland is *ca* 7% (Anon. 2006) of the total land area, and agricultural areas are concentrated in southern and western Finland, where the proportion of farmland comes close to 30%. Approximately one half of the arable land area is covered by spring cereals and about one quarter is grasslands (intensively cultivated mainly for silage production) (Anon. 2006); the remaining animal husbandry is concentrated in eastern Finland and northern parts of central Finland. Forest habitats dominate and cover *ca* 75% of the total land area (Anon. 2005), and thus agricultural areas and patches of farmland are usually surrounded by forests.

1.3. Components and significance of habitat and landscape heterogeneity in farmlands

Table 2 provides a description of main habitat and other landscape components of European farmland environments, and their significance for farmland birds. The list does not aim to be a comprehensive representation of *all* possible habitat types of the European agro-ecosystems — for example, steppic and pastoral habitats of different kinds, rare crops, or a detailed classification of different wetland habitats have not been included. Rather, the most prevalent elements of habitats and other landscape features, which are known to have positive or negative effects on farmland birds in mainly Western, Central and Northern Europe have been included. Continuous forests surrounding patches of farmland (as are common in Finland) have been excluded from the habitat classification. With regard to crops, selected management practices have also been listed, since the negative effects of intensive farming and the positive effects of low-intensity farming are acknowledged by numerous studies. Notably, the positive and negative effects are broad generalizations — species-specific differences exist, of course — but they reveal general effects of different habitat factors on farmland bird abundance and diversity. In crops I have included set-asides, since CAP-set-asides (see section 1.4.1.) are part of crop rotation, and usually short-term.

In Table 2 it can be seen that habitat heterogeneity and diversity, concerning both cultivated fields and non-cropped areas, is of great importance to the abundance and diversity of farmland birds in Europe. A diverse crop mosaic that combines various cereals, other crops and grasslands, accompanied by a diverse mixture of uncultivated habitats and rural settlement, is an ideal combination for nurturing diverse and abundant farmland bird communities. In particular, ditches (both open and those lined with high vegetation) and their banks, patches of trees, bushes and scrubs, permanent

Table 2. Main habitat and landscape components and selected aspects of field management in European farmland environments, with their general effects on farmland birds. References provide some examples of studies, not an exhaustive list.

Factor	Effects		References
***Crops*:**			
Winter cereals			
- In Western and Central Europe; mainly wheat and barley	–	Reduced wintertime food supplies (stubble); too dense and tall vegetation in spring	1,2,3,4,5,6
- In boreal agroecosystems; mainly rye and wheat	+	Height and density of springtime vegetation is suitable, provides safe nesting and foraging places	7, 46
Spring cereals			
- In Western and Central Europe	+	Height and density of springtime vegetation suitable, provides safe nest and foraging places; overwinter food provided by stubble	1,3,4,5
Cereals, in general	+/–	Depends on species: positive effects on open field specialists, while negative on some species	8,9,10
Intensive cereal management	–	Reduced habitat heterogeneity and food supplies; dense and homogenous swards; direct nest losses.	5,6,11,12
Rotational grasslands in boreal agroecosystems	+	Like winter cereal = safer breeding and foraging habitat than springtime ploughed fields	7
Intensively managed grassland (monocultures)	–	Reduced habitat heterogeneity and food supplies; dense and homogenous swards; direct nest losses.	5,6,12,13,14,15
Cultivation of more homogenous, denser and simplified swards	–	Reduced breeding and foraging habitats and food	11,16
Mixture of cereals and grasslands	+	Heterogeneous habitats for breeding and foraging, abundant food supplies	3,5,14,17,18,19,20, 46
Root crops	– (?)	Intensively managed; reduction in food supplies and breeding and foraging habitats. Studies few in number.	5,7
Stubble fields	+	Important food supplies, especially in winter and during migration periods	10,21,22,23
Set-asides (both rotational and long-term)	+	Cover for breeding and foraging; food supplies	9,10,24,25,26,27
Low-intensity farming/'traditional mixed farming'	+	Heterogeneous habitats, abundant food supplies, fewer direct nest losses (compared to intense farming)	5,15,28
Abandonment of farming	+/–	Habitat change negative to species of open arable fields, positive for some bush/edge species during early stages of succession	29,30
***Uncultivated habitats & landscape elements*:**			
Open ditches, ditch banks, field margins/verges	+	Sites for nesting, feeding and hiding	7,20,31,32,33,34,35
Tree- or bush-lined ditches	+	Sites for nesting, feeding, hiding and perching	20
Tree or bush islets/patches and big individual trees	+	Sites for nesting, feeding, hiding and perching	8,9,20,24,36,37,38,39
	–	(negative effect for some open field specialists)	20
Bush and scrub	+	Sites for nesting, feeding, hiding and perching	9,40
Ruderal habitats	+	Sites for nesting, feeding and hiding	40

Table 2 continuing

Semi-natural grasslands (*i.e.* permanent pastures), meadows	+	Sites for nesting, feeding and hiding	10,15,28,24,41,42,43
Wet habitats	+	Sites for nesting, feeding and hiding	24,35
Farmsteads, barns, rural gardens, orchards	+/–	Sites for nesting, feeding, hiding and perching; effects depend on species	20,39,40,44
Roads and road banks	–/+	May provide foraging habitat and nest sites; effects depend on species	7,20
Electric and telephone poles & lines	+	Song-posts and sites for perching	20,37
Hedgerows (do not exist in Finland)	+	Sites for nesting, feeding, hiding and perching	8,44,45
Diversity of uncultivated habitats	+	Important component of farmland habitat heterogeneity	12,20,40

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42. Virkkala *et al.* 2004
43. Heikkinen *et al.* 2004
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45. O'Connor & Shrub 1986
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pastures, and field margins are extremely important habitat components in otherwise open arable landscapes.

The timing of farm work naturally has significant effects on the temporal and spatial heterogeneity of crops, and thus also on the suitability of these habitats for nest sites of birds. Box 2 describes the average timing of farm work conducted in southern Finnish cereal and dairy farms during the main growing period, and also the time scale of the skylark's breeding period in arable landscapes in southern Finland. It is rather obvious that birds' nests are differently susceptible to the direct effects of farm work, depending on whether they are located among crops or in uncultivated habitats, for example field margins or ditch banks. In non-cropped habitat patches, nests are safe from direct contact with agricultural machines, but are certainly subject to the effects of pesticide sprayings, either directly if nests are located very near to the edge of the field or indirectly via decreased food availability caused by lack of weed seeds and insects.

1.4. The common Agricultural Policy (CAP) of the European Union

In the member states of the European Union (EU) the Common Agricultural Policy (CAP) regulates and sets guidelines for national agricultural policies. As agreed in the Treaty of Rome in 1957, and later by the CAP Reform 1992, the main objectives of CAP are to develop and intensify agricultural productivity, to ensure a reasonable standard of living for farmers, to stabilise markets, to secure the availability of food, and to ensure reasonable consumer prices. It has been argued that CAP is a serious threat to biodiversity, since it is a driving force behind intensification and a powerful inhibitor of extensification (Donald *et al.* 2001, Donald *et al*. 2002). CAP is seen as a threat to biodiversity also in countries that have recently joined the EU and in those that will join in the future (Donald *et al*. 2002, Herzon 2007).

Box 2. Down On the Farm

Growing period in a cereal estate in southern Finland

By mid-April, the snow cover and frost have melted and the growing period begins in early May. After that, in the same month, take place the preparation of the seedbed, fertilizing and sowing of spring cereals, and also fertilizing of winter cereals (if any are included in the farm's crop rotation at all). At the end of May winter cereals are sprayed with herbicides to suppress weed growth, and the same is done for spring cereals in mid-June. Fungicide spraying is conducted at the end of June for winter cereals and in early July for spring cereals, in order to prevent plant pathogens. At the same time fields are usually sprayed with a substance whose main component is 2-chlorine-ethyl phosphonic acid — the aim of this procedure is to prevent the crop being flattened. Harvest of winter cereals starts in early August, and is followed by harvesting of spring cereals. Rye is sown at the end of August and winter wheat in September. Nowadays sowing (both in spring and autumn) with non-inversion tillage or no-tillage are options in which seeds are sown in stubble without thoroughly inverting soil, or without inverting it at all. These practices are becoming more common. In late September, autumn tillage of the next growing season's spring cereal fields takes place. It is done by ploughing or lightened tillage — in the latter case, some vegetation remnants are left on fields. The growing period ends in mid-October, but yet in October or November winter cereals are sprayed with fungicides to prevent snow mould. Permanent snow covers fields in December or January.

Grassland cultivation on a dairy farm

A southern Finnish farm that has dairy cattle usually cultivates cereals and other crops too. With regard to silage and hay production, the following main practices take place during summer: fertilizing takes place in May, often manure is applied. In those parcels where new grass cultivations are founded (average grassland rotation is three years), sowing takes place in May, either into protective cereal growth or without it. The first harvest of silage takes place already in the first half of June, whereas the harvest of hay is in July. The second harvest of silage is in July or early August. Autumn tillage and spread of manure takes place in September.

Skylark's summer in southern Finland

Depending on the onset of spring, skylarks start laying eggs in the end of April or in early May, with laying peak taking place by mid-May. Unfortunately, the laying period often coincides with preparation of the seedbed, sowing and other farm work, and therefore a repeat clutch has to be laid after the first one has been destroyed, if the nest is located in the field and not on the field margin or bank. If the first clutch succeeds, the second clutch is laid by part of the skylark population in the first half of June. Incubation of eggs lasts one and a half weeks, and is followed by a nestling period of approximately the same duration. Thus, if nests are located in managed grassland fields, there is an unfortunate danger that eggs or nestlings will be chopped into silage in June. The survival chances of skylark chicks largely depend on whether nests are located in cultivations or in uncultivated habitats. Naturally, also the precise timing of different phases of breeding, and how they coincide with different phases of farm work, matters a great deal.

The description of farming practices is mainly based on Anon. (2006b) and appendices 3b and 3c there; the skylark text is mainly based on von Haartman (1969).

1.4.1. Agri-environment schemes (AES)

A trace of green is brought into the CAP by agri-environment schemes (AES) that are included in national agri-environmental programmes. In AES part of the subsidies paid to farmers are directed at agricultural practices that are thought to maintain or even enhance the environment or biodiversity. All the member states of the EU are obliged to develop and put into action national agri-environment programmes. Currently these schemes cover *ca* 25% of all farmland in the 15 "old" EU countries (*i.e.* those that joined before the 2004 enlargement) (EU 2005). In 2003 3.7 billion euros were spent in AES (Kleijn *et al*. 2006) and over 24 billion euros between 1994 and 2003 (Kleijn & Sutherland 2003). The money targeted at the AES constitutes less than 5% of the total budget of CAP (Donald *et al*. 2006).

There is great variety in the contents of AES among different European countries, the participation of farmers in the schemes varies a lot among countries, and in many countries AES have probably not been applied for long enough for positive effects to appear (*e.g.* Kleijn & Sutherland 2003, Berendse *et al*. 2004, Tiainen *et al*. 2004a, Donald *et al*. 2006). Studies on the effects of AES have failed to prove clear benefits for the environment and biodiversity. Owing to differences in the contents of different kinds of national AES, and differences in temporal and spatial scales and the studied taxa, studies may have yielded unclear or controversial results (*cf.* Kleijn *et al*. 2001, Kleijn & Sutherland 2003, Kleijn *et al*. 2006). Nevertheless, AES are considered the most important policy tools in protecting farmland biodiversity within the EU (Kleijn & Sutherland 2003, Kleijn *et al*. 2006).

Finland has implemented agri-environmental programme with AES since the country joined the EU in 1995. The Finnish AES are predominantly aimed at water protection by preventing nutrient leaching and erosion from fields. The Finnish AES are composed of basic, additional and special measures. Basic measures and one of the additional measures are obligatory, whereas special measures need a farmer to make a proposal for a contract which then will be subject to the approval of authorities. In the first (1995–1999) and the second (2000–2006) AES all or most of the obligatory measures were targeted at water protection, even though they also had biodiversity impacts (Kuussaari *et al*. 2004a, Kuussaari *et al.* 2004b). There are more measures targeted at biodiversity preservation in the special agreement part of the AES, but they probably have little impact on birds because of their limited number and small coverage area (with the exception of organic farming). Table 3 lists the measures undertaken during the latest subsidy period of Finnish AES that in an expert evaluation are considered to have potential to increase biodiversity (Kuussaari *et al*. 2004a).

Outside the Finnish AES, the CAP in Finland includes fallowing obligations, in terms of so-called "CAP set-asides". It means that the farmer has to leave a certain proportion of cultivated land suitable for fallowing as set-aside each year; various different set-aside types (*e.g.* vegetated, stubble) are accepted. Details of obligations change annually, in year 2006 the proportion to be fallowed was in southern Finland *ca* 9% (MMM 2007). Although this system predominantly produces short-term (one growing season) set-asides, it probably supports farmland biodiversity, since fallowing increases the abundance and diversity of many organisms in agroecosystems (reviewed by Van Buskirk & Willi 2004).

The mid-term evaluation of the monitoring study of the environmental impacts of the second subsidy period of Finnish AES concluded that the scheme has in practice promoted in some respects the maintenance of biodiversity, but the current measures are probably insufficient to halt many years of decline in farmland biodiversity (Kuussaari *et al*. 2004b). Moreover, it was concluded that biodiversity receives too little emphasis in AES, and that special measures had a greater impact on biodiversity than the basic ones (Anon. 2004). Most of the measures with potential beneficial biodiversity effects are practiced by a very

Table 3. Finnish AES measures (the second subsidy period 2000-06) that are considered to increase biodiversity (mainly derived from Kuussaari *et al.* 2004a; *see* also Anon. 2004). Other measures not listed here mainly deal with matters like fertilization, prevention of urine and other nutrient releases from livestock keeping, native stocks and water pollution. Basic measures and one of the additional measures are obligatory for each farmer participating in the scheme. Statistics date from 2001–02.

Measure	N of agreements	Covered area (km^2) (% of total agricult. area)
Basic measures:	68 803	22 083 (98.23%)
Environmental planning and monitoring of cultivation		
Formation of margins (min. width 1 m) along main ditches and border strips (*i.e.* protective margins) along larger water systems (min. width 3 m)		length 13 800 km, area 42 km^2
Maintenance of biodiversity [1]		
Additional measures: [2]		
Wintertime vegetation cover or lightened tilling [3]	35 114	8874 (39.50%)
Farm-level biodiversity targets [4]	352	80 (0.36%)
Special measures: [5]		
Formation and management of border zones (wider than border strips, mean width approximately 25m)	2097	54 (0.24%)
Formation and management of wetlands and sedimentation basins	425	48 (0.22%)
Management of traditional habitat(s)	2538	237 (1.05%)
Improvement and management of landscape [6]	1052	40 (0.18%)
Improvement of biodiversity [7]	846	36 (0.16%)
Organic production	4782	1497 (6.66%)

1) Includes management measures to maintain biodiversity targets at the level of the farm, *e.g.* tree-and bush islets, field-forest border zones, big rock piles, and tree avenues. 2) Farmer may choose only one of the total of six additional measures. 3) At least one third of the field area has to be covered by vegetation or stubble outside growing season. It aims to prevent soil erosion. The alternative is to apply non-inversion tillage (a.k.a. low-inversion tillage), in which the seedbed is prepared before sowing so that the soil is disturbed as little as possible and plant residue is left on soil surface. 4) Objectives: to increase the farmer's knowledge of plant and animal species and their habitats on his/her farm, and of management of habitats. 5) Freely selectable, with 5 or 10 year contract. 6) Objectives: to increase openness and diversity of landscape, to promote varied landscape characteristics, and to manage valuable agricultural landscapes. 7) Objectives: to promote diversity of plants and animals, ecosystems, and habitat types.

few farmers and such actions are aimed at extremely small field areas (Table 3). Furthermore, some of the measures, for example "Maintenance of biodiversity" in the basic measures, have to a great extent remained obscure for farmers, and they have had great difficulties in identifying biodiversity targets and thus in directing any actions at them (Kuussaari *et al*. 2004a). However, as AES has voluntarily been accepted and applied up by *ca* 95% of Finnish farmers (Kuussaari *et al*. 2004b), it is a potential tool to enhance farmland biodiversity — presuming that biodiversity considerations are to be included in future AES more explicitly than previously.

2. Aims of the thesis

In my thesis I have investigated the importance of habitat heterogeneity and effects of different habitat and landscape characteristics on farmland bird abundance and diversity in typical cereal cultivation-dominated southern Finnish agricultural environments. It was of special interest to study the relative importance of cultivated *versus* non-cultivated habitat and landscape elements, and their importance as components of farmland habitat heterogeneity and as factors explaining population trends (**I, III**), territory occupancy (**II**), colonisation characteristics (**III**), abundance/occurrence (**I, III, IV**), species richness (**IV**), and community composition (**IV**) of birds. Studies **I–III** were based on long-term data and **IV** on one-year data. Data were collected by using a territory mapping census method (Koskimies & Väisänen 1991, Bibby *et al*. 2000) especially suited for open environments (Tiainen & Pakkala 2000). Compared to point count or line-transect census methods, the territory mapping provides a rather realistic picture of real territory numbers and locations in the surveyed area, whereas point count and line-transect surveys often produce more inaccurate estimates of densities with no possibility of locating territories (Järvinen & Väisänen 1975, Koskimies & Väisänen 1991, Underhill & Gibbons 2002). Negative sides of territory mapping are that it is time consuming, and it requires special skills and experience from observers. Studies **I–III** were conducted in the long-term study area of Lammi (Fig 1 in **IV**). In Lammi, the area of farmland included in the studies varied between 12 and 30 km^2, and also the number of separate patches of farmland included in the studies varied; for details, see material and methods section in **I–IV.** Data for study **IV** were collected from 37 sub-areas (including Lammi) within an extensive area of southern and south-western Finland, and the total area of farmland censused was 92 km^2 (Fig 1 in **IV**).

My two main study species are representatives of "losers" and "winners" among Finnish farmland birds. The ortolan bunting (*Emberiza hortulana*) (**I, II**), is a species of Finnish farmland avifauna that has declined the most during the past two decades, whereas the tree sparrow (*Passer montanus*) (**III**) is a species that has shown a phenomenal population increase in Finland during recent decades — of farmland birds only the population growth of the greenfinch is somewhat comparable to the tree sparrow's trend.

The population crash of the ortolan bunting was studied over an extensive time-period by applying a multi-scale approach, in which different habitat and landscape factors were related to density and occurrence of ortolan buntings from the territory scale to the landscape scale (**I**). Moreover, I studied the relationships between the changes in different habitat factors and the changes in ortolan bunting abundance (**I**). The ortolan bunting is generally known to breed in loose territory aggregations, *i.e.* breeding groups, and to display intraspecific sociality. Hence, I studied the relationships between the occupancy of ortolan bunting territory sites and environmental and breeding-group-related factors, and the dependence of importance of different factors on population density before, during, and after the population crash (**II**). Again, the study was conducted by using extensive (20 years) data from a large area of farmland.

I studied the tree sparrow's conquest

of southern Finnish rural environments by examining the importance of different habitat, landscape and other factors for the colonisation of new areas by the species (**III**). To explain patterns of colonisation over an extensive time period at local landscape scale (0.25 km^2 grid), I took into account the presence of nearby conspecifics, the abundance of resources, various land use and habitat types, the presence of a potential competitor (the house sparrow *Passer domesticus*), and the amount of human impact.

Based on data from a large area of agricultural environments, I studied the significance of different crop types, other habitat and landscape factors, and habitat heterogeneity on density and species richness of two ecological groups of farmland birds, namely species breeding in open arable habitats (*i.e.* 'true field species', 8 species included) and species breeding in edge and bush habitats (12 species included) (**IV**). Species of both groups are especially vulnerable and susceptible to the negative effects of agricultural practices, and both groups show a clear declining population trend (Fig. 1). By applying this multi-species approach, I aimed to find environmental associations common to a set of 20 species, and thus to reveal which habitat and landscape features have favourable or detrimental effects on farmland birds in general. I used multivariate methods to study the composition of species assemblages, and also to reveal associations between the individual species and the habitat factors. In the light of my results, I discussed whether the measures of the recent AES are relevant from the point of view of farmland birds, whether the measures are applied widely enough in Finland for positive impacts on birds to be achieved, and whether some important components or features of habitat and landscape have not been taken into account in the AES.

One driving force behind my research was the ambition to find significant positive and negative associations between farmland birds and environmental factors that could be used as evidence-based reliable advice when shaping the contents of future AES. Study **IV** in particular was connected to the AES context, but also in studies **I-III** the examined factors were chosen bearing in mind the usefulness of the results for AES. Overall, I aimed to provide tools for decision-makers in agri-environmental policy to maintain or even enhance farmland biodiversity under the pressure of the intensification-driven CAP of the EU.

3. Spatial and temporal scales used and other methodological issues

The concept of habitat heterogeneity is scale-dependent, and also the habitat classification used contributes to the outcomes of studies. The issue of scale is of major importance in ecology, since different ecological processes appear and interact at different scales, and species and individuals respond to environmental conditions at a unique range of scales (Wiens 1989, Levin 1992).

I used the spatial scale of 25 ha to study the tree sparrow colonization (**III**) and the abundance, species richness and species assemblage composition of true field species and edge/bush species (**IV**) (Table 4). This scale was comparable to the average arable area of farms in Finland (28 ha in 2000; Anon. 2001), and thus relevant when studying the effects of farming. In addition, in other studies in Finland this scale has been shown to capture various aspects of land-use and landscape structure variation that are important for birds (Heikkinen *et al.* 2004, Luoto *et al.* 2004). When studying the abundance of ortolan buntings (**I**), I applied a multi-scale approach (Table 4) and hence I could attribute patterns of different environmental factors to patterns of abundance from smaller than territory-sized scale to the landscape scale (*i.e.* separate patches of farmland). When studying in detail the occupation of traditional territory sites of ortolan buntings (**II**), it was a natural choice to operate at the territory scale. The breeding group effect of the ortolan was, however, examined within the separate patches of farmland (Table 4), which is a relevant scale considering group sizes and the distribution pattern of groups in arable landscapes (**I, II**).

In the habitat classifications, I classified crops on the basis of main crop types (*e.g.* spring cereals, grasslands), and also uncultivated habitats were classified into rather broad classes (*e.g.* bush and forest patches, settlement, ditches) (for details see Table 5, and **I—IV**). Uncultivated habitat types included area-objects, linear objects and point-like objects, whereas crop types were always area-objects. When classifying habitats, I carefully took into account the ecology of the bird species that I studied, and also the previously published literature on Finnish farmland birds and their habitat associations.

The long-term survey data I used do not provide direct information on parameters of breeding biology which could be attributed to demographic factors that underlie decreases and increases of bird populations. On the other hand, the territory mapping census method that was used for collecting the data enables us to situate individual territories. Thus, applying geographical information systems (GIS) it is possible to relate territory locations to geographically referenced habitat data, and study relationships between changes in habitats and changes in bird populations. When this approach is connected to species-specific demographic studies published about various species in Europe (*cf* Newton 2004), conclusions on effects of agriculture on birds can be plausibly drawn. The existence of long continuous time series from permanent study areas enabled my studies **I-III**, and in all studies also the total area of farmland covered was extensive. Only study **IV** was not based on long-term data, because it covered the largest area of farmland, with no long-lasting continuous time-series available.

Spatial autocorrelation is a common statistical property of ecological variables observed across geographic space. Owing to the autocorrelation, values of particular variables in neighbouring sites are more (positive autocorrelation) or less (negative autocorrelation) similar than they would be in a random set of observations (Legendre 1993). Spatial autocorrelation within a response variable may explain a considerable part of the total variation, and causes a statistical problem of non-independent observations. Thus, possible effects of spatial autocorrelation have to be estimated before analyses of geographically referenced ecological data. Then, if considered necessary, spatial autocorrelation should be included in the analysis. I took spatial autocorrelation into account in **IV** by applying spatial lag models (Anselin 2002) for densities and species richnesses, and this choice to use autoregressive modelling turned out to be the correct one, since the model specification overcame the problem of residual spatial autocorrelation (**IV**). Densities and species richnesses of both bush/edge species and the two ecological groups combined were positively autocorrelated (**IV**, Table 5). The observed autocorrelation may be caused by spatial patterning of habitats or other environmental factors, or by population or community dynamical processes, for example through sociality causing spatial patterning, or by means of other species-related factors (Legendre 1993). Since the response variables were densities and species richnesses of species assemblages, I suggest that it is probable that a considerable part of the observed autocorrelations may be due to autocorrelation in habitat factors, rather than population or community processes, such as social cohesion (*cf* Legendre 1993). However, it was not possible to separate different causes behind the observed autocorrelations, and, it was also out of the scope of my study. In ecology, the fundamental causes behind observed autocorrelation is a perpetual conundrum that is not unambiguously or easily answered. It is, however, important to acknowledge the presence of autocorrelation and the possible problems that it can bring in statistical modelling. In **I** and **II** I did not include autocorrelation in the models, because this would have been unfeasible due to the study designs (dependent variables were occurrence and occupation within many-year time-periods). In investigations of the tree sparrow's colonization patterns (**III**) the presence of conspecifics was one explanatory factor, so in a way autocorrelation was included in the methods. However, the dependent variable was the colonization of a grid between two time-periods, and in this kind of study design the further inclusion of autocorrelation aspects is not meaningful.

4. Results and discussion

Table 4 summarizes the main issues that I studied and the results of **I-IV**. Table 5 describes in detail the effects of all explanatory variables on the dependent variables in **I-IV**. In the following section I will discuss my findings and relate them to previously published literature.

Table 4. Summary of the main study questions and results. For a detailed description of all the explanatory factors and their effects, see Table 5.

Study questions	Main findings	Scales used
I		
Which habitat factors explain the occurrence of the ortolan bunting (OB) in a southern Finnish agricultural landscape before, during and after the population crash?	Area of fields without vegetation cover in early May, and abundance of ditches lined by trees or bushes clearly increased occurrence. They were important at all spatial scales and during all phases of the population trend.	**Spatial:** 5 grids: 1–16 ha & patch of farmland scale: 50–310 ha. Area covered: 11.8 km^2.
Which changes in habitat factors may explain the declining trend of the OB in breeding grounds?	Loss of habitat heterogeneity, most pronounced in the loss of tree- or bush-lined ditches (subsurface drainage) and clearance of forest and bush patches, reduced breeding OBs, by decreasing availability of song-posts, and breeding and foraging habitats.	**Temporal:** 1984–2002, with special emphasis on three periods: 1984–86, 1992–94 and 2000–02.
II		
Which habitat, landscape and breeding group-related factors explain the occupation frequency of OB territory sites, which are usually located in breeding groups?	The size of the surrounding breeding group increased occupation frequency before and after the population crash that took place in the early 1990s. The abundance of tree- and bush-lined ditches also contributed beneficially, but the effect was clearly weaker than that of behaviour-related breeding groups.	**Spatial:** Territory site scale: *ca* 3 ha, breeding group effect calculated at scale of patches of farmland (70–290 ha). Area covered: 13.5 km^2.
How the significance of different factors depend on the population density in a declining population?	The effect of breeding group was strongest before the crash, when it alone explained 56 % of the variance. Ditches with high vegetation became important during and after the population crash.	**Temporal:** 1984–2003, divided into four 5-year periods.
III		
Which habitat, landscape and other factors explain the rapid colonisation of a southern Finnish rural landscape by the tree sparrow (TS)?	Human impact affected colonization favourably. Presence of HS and presence of conspecifics in the surroundings also had positive effects. No other cultivation type or other habitat factor had any statistically significant effects.	**Spatial:** 25 ha grid. Area covered: 30.3 km^2.
Do TS and the house sparrow (HS) differ in their use of different kinds of nest sites?	TS showed more diversity in nest sites than did HS, and used frequently both nest-boxes and electricity poles, whereas HS predominantly used holes in buildings.	**Temporal:** 1984–2002, of which 1986–2001 divided into four 4-year periods that were used to study the coloni-zation process.
IV		
Which habitat, landscape and spatial factors explain densities and species richnesses of true field species (F) and edge/bush species (E), and of these two groups combined (20 species)?	Diversity of crops (including set-asides) increased species richness of F, but not any densities or species richness of E. Non-cropped habitat heterogeneity, most importantly open ditches and the habitat patch richness affected positively all the dependent variables. Human impact (settlement & roads) had some negative effect on densities.	**Spatial:** 25 ha grid. Area covered: 92 km^2. **Temporal:** 2001
Does direct ordination (RDA) of species assemblage density data reveal environ-mental gradients, and what is the relative importance of environmental and spatial (geographical) variables?	The first RDA axis showed a gradient from open large arable areas to small field areas and the second axis related to habitat heterogeneity. The environmental variables explained clearly more variation in density than the spatial variables.	

Table 5. Statistically significant ($p < 0.05$) positive (+) and negative (–) effects of different factors on the dependent variables in **I-IV**. Grey = not included. *OB* = ortolan bunting, *TS* = tree sparrow, *D* = density, *S* = species richness, NS = not significant. The superscripts 1, 2, 3, 4 in **II** indicate the time periods 1984–88, 1989–1993, 1994–1998 and 1999–2003, respectively.

FACTOR:	**I** *Occurrence of OB*	**II** *OB territory occupancy*	**III** *TS coloni-sation*	**IV** *D, field species*	*D, edge species*	*D, field + edge spp.*	*S, field species*	*S, edge species*	*S, field + edge spp.*
Area of cultivated land	+	+ [1]							
Proportion of field without springtime vegetation *	+++ ●	+ [3–4]							
Area of rotational grasslands (incl. pastures)			NS	+	NS	NS	+	NS	+
Area of spring cereals			NS	NS	–	NS	+	NS	+
Area of potato, sugar beet & turnip rape			NS	NS	–	NS	+	NS	NS
Area of set-asides & meadows			NS	NS	NS	NS	+	NS	+
Openness of farmland		NS		+	–	NS	NS	NS	NS
Arable area in surrounding landscape				NS	NS	NS	NS	NS	NS
Area of settlement	NS		NS	–	NS	–	NS	NS	NS
Number of buildings			+						
Number of livestock farms			NS						
Length of roads	+	+ [1]	NS	NS	–	NS	NS	NS	NS
Length of open ditches	++	NS	NS	+	+	+	+	+	+
Length of ditches lined by trees or bushes	+++	+ [2–4]	NS						
Area of bush and forest islets (> 0.4 ≤ 2 ha)	+	Included in point-objects	NS	Included in small-scale habitat elements					
Number of point-like habitat objects **	++	+ [2]							
Number of small-scale habitat elements ***				NS	+	NS	NS	NS	NS
Patch richness (= N of habitats)				NS	+	+	NS	+	+
Size of the surrounding breeding group		+ [1 & 3]							
Presence of the House Sparrow			+						
Presence of the Tree Sparrow in neighbourhood			+						
Spatial autocorrelation ****				+	+	+	NS	NS	+

* Includes mainly spring cereals, root crops and turnip rape. Springtime refers to the first half of May, *i.e.* the time when ortolans arrive from migration.
** Includes small tree or bush islets (< 0.4 ha); single large trees and bushes; large rocks and rock piles; and barns with their immediate surroundings.
*** Includes bush and forest islets ≤ 2 ha; bush- and tree- growing ditch, road and field verges (not field–forest verges); wood avenues; and barns with their surroundings. **** Calculated by spatial lag models from the adjoining grid cells around the grid cell in question. ● In **I** the number of pluses indicates that the factor was significant at all spatial scales in all time-periods (+++), at most of the scales and/or time-periods(++), or at few of the scales and/or time-periods (+).

4.1. Impoverishment of the Finnish agricultural landscape

Agricultural landscapes are by default human-induced, and without cultivation many farmland bird species would not exist in Finland, or would be extremely scarce. This relates most markedly to the open field specialists, for example the skylark.

Before the era of agricultural intensification and specialization, Finnish agro-environments included various cultivated and uncultivated habitats, farms and field parcels were small and crop rotations were diverse (Tiainen 2004). At the landscape level this appeared as heterogeneous habitat mosaics, where sizes of different habitat patches were rather small, and linear landscape elements, mostly ditches, were numerous (Hietala-Koivu & Aakkula 2004). The Finnish agricultural landscape became impoverished as the intensification took place. The number of small-scale uncultivated habitats decreased drastically from the 1950s to the late 1990s, and the habitats that decreased the most dramatically were ditches and ditch margins (Hietala-Koivu *et al*. 2004). In my study area in Lammi, the decrease in the abundance of ditches contributed to the decline of ortolan bunting (**I**). Furthermore, the landscape change analysis by Luoto *et al*. (2004) revealed a decline in the heterogeneity of the Finnish agricultural landscape. Non-intensively farmed agricultural land (*e.g.* meadows, pasturages, long-term set-asides) and field and ditch margins were the habitats that decreased the most. The decrease is most evident in southern Finland, where the proportion of extensive agricultural land is at present 2–3% of the total agricultural land area. The biodiversity value of semi-natural uncultivated farmland habitats is high. For example, many threatened Finnish butterfly and plant species need different kinds of meadows, pastures and other habitats previously provided by non-intensive farming (Pitkänen 2001, Pitkänen *et al*. 2001), and also birds benefit from the presence of semi-natural uncultivated habitats (Table 2).

My results further emphasise the significance and importance of heterogeneous habitat mosaics in arable landscapes. The richness of habitat patches at the level of the farm increased the density and species richness of the bush/edge species. The same applies for the density and species richness of the true field species and the bush/edge species combined (**IV**). Hence, an increase in and maintenance of heterogeneous habitat mosaics should be promoted — at multiple spatial and temporal scales (see Benton *et al*. 2003) — in order to arrest the negative effects of the above-described impoverishment of Finnish agricultural landscapes.

4.2. Importance of uncultivated habitats

The importance of non-cropped farmland habitats for farmland birds is acknowledged in many studies (see Table 2). Habitats that are part of farmland habitat mosaics, but are not subject to intensive field management practices, provide birds with safe nest sites, shelter from predators, food and foraging habitats, perching and roosting sites, and song posts (*e.g.* Arnold 1983, Parish *et al.* 1995, Bignal & McCracken 1996, Perkins *et al.* 2002, Marshall & Moonen 2002, Fuller *et al.* 2004). By providing nest sites, food and shelter, uncultivated habitat patches may contribute to the breeding success of birds by increasing the survival of individuals.

4.2.1. Linear landscape elements

In my studies of southern Finnish farmland, ***ditches*** were shown to be the single most important habitat component increasing the abundance and diversity of farmland birds. In my habitat classification 'ditch' always includes the ditch margins. Vegetated margins (a.k.a. banks, boundaries and verges) of ditches are known to provide farmland birds with food and nest sites (Haukioja *et al*. 1985, O'Connor & Shrubb 1986, Bradbury *et al*. 2000, Morris *et al*. 2001, Perkins *et al*. 2002). Thus, it is not literally the ditch itself that is used by most farmland birds. However, the moist microclimate of ditches enhances plant growth and increases the abundance of invertebrates, and thus improves food availability for birds. The abundance of ***open ditches*** increased the density and species richness of both true field species and species of edge and bush habitats (**IV**), and the abundance of ortolan bunting (**I**). Furthermore, the abundance of ***ditches that were lined by trees or bushes*** was the most important factor explaining the abundance of ortolan bunting (**I**) and the occupation frequency of ortolans' territory sites (**II**). Ortolan buntings use tree- and bush-tops as song posts, and may use bush and tree habitats of ditches also for foraging and breeding (nest in ground; may locate in border zone of tall vegetation and field) (**I**). In my study area, the decrease in the amount of tree- and bush-lined ditches was 30% during the study period (**I**). Disappearance of these habitats can have severe effects on local populations, especially if habitat deterioration takes place in 'traditional' sites of breeding groups, which may lead to a breakdown of social structure inside the groups (**II**, see also Box 3). I argue that the disappearance of tree- and bush-lined ditches as a result of subsurface drainage or clearance of tall vegetation has contributed to the decline of the ortolan bunting population in Finland (**I**). After the disappearance of an ortolan breeding group from a patch of farmland, the reforming of a group is unlikely since the process requires the attraction of conspecific singing males (**II**). The re-establishment of a breeding group probably requires more than just a few males to settle in the same restricted area more or less simultaneously (**I, II**). The amount of tree- or bush-lined ditches also increased densities of species that use bushes and other field edge habitats for breeding (**IV**) — this group included, for example, whinchat (*Saxicola rubetra*), whitethroat (*Sylvia communis*) and scarlet rosefinch (*Carpodacus erythrinus*) (Table 1). Overall, ditches bring both structural and biological diversity to open arable landscapes, and are important components of habitat heterogeneity.

In the category of linear habitat elements belong also ***avenues of trees***. These are few in number, existing here and there in the Finnish farmland, often leading to mansions or large farms. The treetops of wood avenues are used as song posts (**I**) and trees can also offer food (mainly invertebrates) and nest sites for many species (e.g. starling, jackdaw (*Corvus monedula*), and thus bring structural and biological diversity to agricultural landscapes.

Still another linear landscape element in agro-ecosystems are ***roads*** that had a beneficial influence on the abundance (**I**) and the occupation frequency of territory sites (**II**) of ortolan buntings, but reduced the density of bush/edge species (**IV**). Roads are often lined by telephone or electricity lines and poles, and sometimes by trees, and, for example, buntings often use them as song posts (Tryjanowski 2001).

A specific kind of electricity poles have open horizontal metal tubes at the top, and these tubes are frequently used as nest sites by tree sparrows (**III**). This inventiveness and flexibility in nest site use may be one determinant explaining the recent rapid population growth of the tree sparrow in Finland (**III**, Box 4). Moreover, birds may use roads and road banks for foraging and the latter also for breeding. For example, ortolan buntings frequently search for food even on narrow farmland dirt roads (own unpublished observations). The width of roads and the intensity of their use probably matters when considering their effects on birds. Heavy traffic obviously can cause road kills and other disturbance, but in intensively cultivated monotonic agricultural landscapes all kinds of road verges can be beneficial for biodiversity (see the review by Coffin 2007). In my study areas, roads were mainly narrow dirt roads without heavy traffic, and for most response variables in **I-IV** they did not have any significant effects (Table 5).

4.2.2. Point-like landscape elements

Patches of bush and tree habitats, especially ***bush and tree islets*** that are surrounded by cultivations, but also ***single large trees and bushes*** are used by farmland bird species for foraging, breeding, perching and as song posts (*e.g.* von Haartman 1969, Tryjanowski 2001). I found this kind of habitat to increase the abundance (**I**) and territory site occupancy (**II**) of ortolan buntings, and the density of bush/edge species (**IV**). Although bush and tree habitat patches are often small and point-like habitat elements, they bring important diversity to open arable landscapes, where most of the land area is under intensive cultivation. For local ortolan bunting populations, in which the breeding group tends to be the unit of population dynamics (**II**), both linear and point-like habitat elements are extremely important, because their existence greatly determines the availability of song posts and thus also the locations where vital breeding groups may exist (**I, II**). Hence, conservation and maintenance of tree- and bush-growing habitats in open arable landscapes is important, especially in the case of ortolan bunting, whose tendency to breed in groups apparently predisposes the species to being more sensitive to habitat deterioration than are many other farmland bird species which do not breed in groups (**II**).

The category of farmland's point-like habitat elements encompasses also ***barns with their immediate surroundings***, ***rock piles***, and ***individual large rocks***. Barn tops are frequently used by birds as song posts (**I**) or for perching, and species like white wagtail (*Motacilla alba*), wheatear and barn swallow also use barns for breeding (von Haartman 1969). In the

Box 3. Where Have All the Ortolans Gone?

Two decades ago the size of the Finnish ortolan bunting population was estimated to be 150 000–250 000 breeding pairs (Väisänen *et al.* 1998), *i.e.* the second biggest population in Europe after the population in Spain (Stolt 1997). Rapid decline in the Finnish population took place during the 1990s, and the present estimation of the breeding population size of ortolans in Finland is 30 000–50 000 pairs (Väisänen 2001). To understand the causes behind this sudden decline, one has to consider the conditions and threats that ortolan buntings face during migration, in wintering areas and in their boreal breeding grounds.

The ortolan bunting is a long-distance migrant that winters in sub-Saharan Africa. In autumn Finnish ortolans migrate along the south-western route, *i.e.* to France, Spain, and then via Gibraltar to Africa. Ortolans are hunted and eaten during migration in France, especially in south-western parts of the country. Although hunting of ortolan buntings is strictly forbidden by EU legislation, some local French authorities silently accept hunting (O. Claessens, pers. comm.), and the whole activity is often justified as "important tradition" and "sophisticated epicurism". As ortolans are not *officially* hunted in France, it is impossible to know the exact numbers killed annually. In the mid-1990s Claessens (1994) estimated the annual numbers at 50 000, and current estimates are between 5 000 and 30 000 ortolans killed annually (O. Claessens, pers. comm.). During spring migration, ortolans return to the European breeding areas not only via France, but also via the Middle East and also over the Mediterranean Sea (Yosef & Tryjanowski 2002). Hence, in springtime ortolans may face Maltese and Italian bird hunters killing or catching all kinds of birds, mainly for fun or to cage.

Unfortunately, little is known about the ortolan bunting in its wintering areas in sub-Saharan Africa (Cramp & Perrins 1994, Stolt 1997). In sub-Saharan Africa there has been a 15-fold increase in the total import of pesticides and a five-fold increase in the use of fertilizers between the early 1960s and the early 2000s (**I**). The use of agrochemicals in wintering and migrating areas may have an impact on ortolan populations through direct toxic or indirect effects. However, it is not well known how much ortolans use farmland habitats outside the breeding season. The toxic effects of alkyl mercury (used for seed coating) caused decreased reproduction in Sweden in the 1960s and 1970s and were attributed to the population decline of ortolan buntings (Otterlind & Lennerstedt 1964, Swanberg 1976). Alkyl mercury was never used in agriculture in Finland. Brood losses due to precipitation have also been suggested (Durango 1948, Conrads 1977) as a factor contributing to the decline. In the extremely small (less than 200 pairs) Norwegian ortolan bunting population, the breeding population has became male-biased, because fewer females than males return from migration to Norway, which has an accelerating effect on the ongoing population decline (Dale 2001).

In Finnish breeding grounds, I have attributed the decline of the ortolan bunting population to the decrease in the abundance of bush- and tree-growing habitats in farmland, and to the breakdown of the social structure of breeding groups, which is induced by habitat deterioration in 'traditional' central places of local ortolan populations (**I, II**). Furthermore, I have found out that Finnish ortolans seem to prefer bare ground (*e.g.* spring cereals, root crops) over vegetation-covered (*e.g.* grasslands, set-asides) fields at the onset of the breeding season (**I**). Thus, changes in this habitat may have contributed to the declines in areas of some local populations. I suggest, however, that the changes in fields' vegetation cover cannot be a very important factor contributing to the decline. In Finnish farmland springtime bare ground has for decades dominated, even during the national set-aside schemes (Fig. 3). The main distributional area of the ortolan bunting is mainly in dry and open landscapes in the south-east of Europe (Cramp & Perrins 1994). Thus, the adaptation of the species to these environments may influence its habitat preferences in the north.

All in all, most probably the decline of the Finnish ortolan bunting population is caused by various factors operating both in breeding grounds and in migrating and wintering areas. The decline cannot be attributed to some single major or at least visible environmental change. Quite small environmental or other changes may accumulate, and then have a major effect on the dynamics of the species, often in complex and non-linear ways (see *e.g.* Lorenz 1963, May 1976). This could apply to the population dynamics of the ortolan bunting too.

Finnish farmland the number of barns has decreased drastically during the past five decades (Hietala-Koivu *et al.* 2004). The original purpose of the barns was to store hay, but as cattle breeding has been discontinued in most farms, barns are not needed for that purpose anymore. By pulling down useless barns, farmers obtain more field for cultivation. Additionally, in some areas of Finland abandonment of farming has left barns unused. Rocks and rock piles are nowadays minor curiosities in the Finnish farmland, but yet they are used as song posts by *e.g.* ortolan buntings (**I**) and as nest sites by wheatears (von Haartman 1969).

4.2.3. Settlements

Farmyards, farm buildings, small villages and other kinds of ***scattered rural settlement***, are an integral part of Finnish farmland habitat diversity. Farm house surroundings and yard areas often include bushes and trees, vegetable, fruit and ornamental gardens and other such small-scale habitat specifics that spice up the structural and biological diversity of farmlands. Cattle-breeding farms provide invertebrate food that birds need to feed their chicks with, since where there are animals, cowsheds and pastures, there is also dung attracting insects and other invertebrates (*e.g.* Curry 1994, Roslin 1999), as long as domestic animals are not kept indoors permanently. The attractiveness of rural settlement surroundings may be affected by the cleanliness of farmyard and farm buildings, and also by age and type of buildings. Modern, closed buildings do not provide as many nest sites as do old-fashioned, more open buildings where birds may fly in and nest (Ambrosini *et al.* 2002). Furthermore, the tendency to build bird-proof grain silos and other farm storage buildings has decreased the availability of spilled grain that birds feed on (Robinson & Sutherland 2002). All these actions that aim to sanitize farm surroundings decrease the availability of organic matter for food, and thus may contribute to the decline of farmyard species.

House sparrows predominantly use buildings for nesting, and tree sparrows also utilize them (**III**). In Finland, tree sparrows more frequently use nest-boxes that people often have in their yards. Although quantitative data on changes in the number and abundance of nest-boxes in Finland do not exist, my results suggest that nest-box use by tree sparrows may be one factor behind the population increase, which again reflects the adaptability of the species in its breeding habits (as did electricity poles, above) (**III**, Box 4). Another human-dependent activity that improves birds' survival chances is the winter-feeding that has increased in Finland during recent decades (Väisänen & Solonen 1997). Winter-feeding has most probably contributed to the increase of the Finnish tree sparrow population (Box 3). In my studies, the amount of winter-feeding or nest-boxes could not be directly measured, but the significance of the number of buildings probably indirectly reflects these two human-attributed factors (**III**).

Otherwise in my studies the effect of the area of settlement was either non-significant or negative. Non-significant effects of settlement in **I**, **II** and **IV** are probably simply due to the fact that farmyard species were not included in those studies. Nevertheless, settlement decreased the density of true field species (**IV**). True field species need large areas of open farmland (Piha *et al.* 2003, **IV**), thus the negative effects of any other habitats than cultivations are understandable.

Similarly, bush/edge species require first and foremost bush and tree patches on fields, and the suitability of settlements for breeding or foraging depends on the presence of suitable vegetation and the amount of food (**IV**).

4.3. Importance of diversity of crops

The important role of diverse field mosaics for the diversity and abundance of farmland birds is acknowledged by numerous European studies (Table 2). In farmland where traditional mixed farming is practiced, spatially and temporally heterogeneous cultivation mosaics are continuously present owing to diverse crop rotation. Especially set-asides are important in enhancing farmland biodiversity (Table 2). In a diverse environment there is an abundant plant and invertebrate assemblage which birds feed on. Intensively managed cereal or grassland monocultures, on the other hand, are naturally more homogeneous and less diverse in their fauna and flora, and thus less suitable for breeding and foraging by birds (Table 2).

I found the diversity of crops (including set-asides) to increase the number of true field species (**IV**). This means that in southern Finnish arable landscapes dominated by spring cereal, a patchy mixture of grasslands, set-asides, cereals and broad-leaved crops benefits the species richness of farmland birds. Thus, if Finnish agri-environmental policy wanted to promote diverse avian communities in farmland, rotational cultivation and cattle farming should be supported, instead of augmenting the specialization of farms and thus the homogenization of cultivations.

The amount of spring cereals, root crops and turnip rape decreased the density of bush/edge species (**IV**), which accurately reflects the effect of open arable areas on species that do not use fields for breeding. Because spring cereals are the dominating cultivation type, their area naturally correlates strongly with the total arable area. Thus, mere open arable fields, where, on the average, the number of small-scale non-cropped habitat elements have decreased in recent decades (**I**, Luoto *et al*. 2004, Hietala-Koivu *et al*. 2004), are not a suitable habitat for species that are dependent on bushes, trees and other edge habitats. For the true field species the situation is different by default, since they need open field area *per se* (**IV**, Table 2). The most numerous Finnish farmland bird species of purely arable habitats, the skylark, needs open fields (Piha *et al.* 2003), and I found it to be the only species that in direct ordination related to spring cereals; in other words, to the arable area (Figure 4 in **IV**). In the Baltic States (Estonia, Latvia and Lithuania) Herzon *et al.* (2006) found the abundance of true field species to be highest when the proportion of field covered by cereals was *ca* 50%; the same pattern was also found in Poland by Tryjanowski (2000). In my study, however, the true field species group did not benefit from spring cereals, but instead from the amount of grasslands, which increased abundance (**IV**). This was most probably only due to the preference of skylark for springtime vegetation-covered habitats in breeding (Piha *et al*. 2003), since the skylark was by far the most numerous species in **IV** (accounting for *ca* one third of all territories). Similarly, open field specialists curlew and lapwing associated with grasslands, as revealed by direct ordination analysis (Figure 4 in **IV**).

The non-significant effect of diversity of crops on abundances in **IV** indicates probably that in agro-ecosystems the

Box 4. Where Did All the Tree Sparrows Come From?

The Finnish tree sparrow population has shown an exceptionally rapid and strong increase during the last two decades. The Finnish population was estimated to be *ca* 8 000 breeding pairs in the mid-1990s (Väisänen et al. 1998), but current estimates are 30 000–50 000 breeding pairs (BirdLife International 2004). The number may already be even higher, as estimating the population size is extremely difficult owing to the speed and magnitude of the increase (R. A. Väisänen, pers. comm.); however, the order of magnitude of the Finnish breeding population is currently tens of thousands. The Finnish population trend is exceptional, when compared to most other European countries. Elsewhere in Europe, tree sparrow populations are in decline or stable (BirdLife International 2004).

Before the onset of the recent population increase, the small Finnish tree sparrow population inhabited the Åland Islands (situated between Finland and Sweden), and, on the other hand, rather small areas in south-eastern Finland near the Russian border. From the 1960s onwards, the south-eastern Finnish tree sparrow population started to expand its range westwards — this range expansion can be conveniently traced back from observation reports of local ornithological societies that exist in various areas of Finland. By the 1980s, the range expansion and the population increase accelerated notably, and currently tree sparrows already inhabit rural and urban areas in south-western Finland. It seems that during the range expansion of eastern populations, the tree sparrow population of the Åland Islands has not expanded its range eastwards nor colonized the south-western coast — the conquest over Finland has proceeded from east to west, and it is still continuing, now northwards.

In my study area Lammi, southern Finland, the first reported tree sparrow appeared in the main village of Lammi (small rural settlement centre) in the late 1970s or early 1980s, and the first breeding was confirmed there in 1983 (**III**). From the 1990s onwards, the tree sparrow population of Lammi has increased rapidly and currently the species has colonized thoroughly both rural and semi-urban environments in the study area (**III**). I did not find any connections between the colonization and different land-use types or other habitat factors (**III**). Thus, it seems that agricultural practices – either intensive or less intensive – do not have any effect on the tree sparrow in Finland. At least, detrimental effects of intensive farming presently cannot be attributed to the species. Instead, the tree sparrow most probably benefits from human influence, especially from winter-feeding and nest-boxes that are often used by the species (**III**). The adaptive flexibility of the species can also be seen in the habit of using certain kinds of electricity poles for breeding. Diversity in nest-use has probably benefited tree sparrows and partly made possible the population increase and range expansion (**III**).

However, since the tree sparrow is expanding its range, it is likely that its increase is connected to environmental factors that operate on a much larger spatial scale than the one I used in my study (**III**). Reliable information would be needed on population development of the tree sparrow in Russian Carelia in order to study the range expansion on large geographical scales. Unfortunately, no good-quality survey data currently is available from there.

densities are determined by different factors than is species richness of farmland birds. In Finland, the location and configuration of sufficiently large patches of farmland primarily define where abundant farmland bird communities can exist, *i.e.* where abundant species from the true field species group are able to “fit in” in high numbers (Heikkinen *et al*. 2004). In the study by Piha *et al*. (2003), the threshold area of farmland patch for the skylark was found to be 11.5 ha — in patches larger than that, skylarks were always breeding, whereas in smaller patches they bred only sporadically and mainly in years of high population density. In agro-ecosystems, species richness, on the other hand, increases with habitat diversity (Bengtsson *et al*. 2005). This is because the presence of different habitat types in a patch of farmland enables more species of different ecological groups to be present. In the Baltic States, farmland bird species richness decreased when field coverage by cereals exceeded *ca* 30% (Herzon et al. 2006).

Uncultivated or cultivated — which one matters more?

On the basis of my results (see Tables 4 and 5), I argue that heterogeneity of both non-cropped and cultivated habitats increases abundance and species richness among farmland birds, but in this respect the amount and diversity of “marginal” (often small-scale) uncultivated habitats are essential (*cf.* Table 2; see also Herzon 2007). Ditches in particular seem to be a keystone structure (Tews *et al.* 2004) for farmland birds in boreal landscapes. Although I consider uncultivated habitats to be generally more beneficial for farmland birds than cultivations, we should also remember the importance of cultivation heterogeneity too. Various kinds of crops are needed, and homogeneous cultivations of the single crop type should be avoided.

4.4. Are measures under the Finnish AES sufficient for biodiversity preservation?

The Finnish national AES include several measures, which could benefit farmland biodiversity (Table 3). Most of these are voluntary special measures, and hence practiced by an extremely small proportion of farmers (Table 3). The measures of the first scheme period 1995–1999 focused strongly on the prevention of water eutrophication and pollution, and biodiversity issues were of minor importance (Kuussaari *et al.* 2004b). However, some biodiversity considerations were included in the measures of the second subsidy period 2000–2006 (Table 3), and in Finland’s environmental policy there is a goal to emphasise biodiversity issues even more in the future (Kuussaari *et al.* 2004b). At the moment (May 10th 2007) the Finnish government’s proposal for the Rural Development Programme of Continental Finland for the subsidy period 2007–2013 (Anon. 2007) is still under consideration in the European Commission. That programme also includes the AES for 2007–2013, and the measures included in the AES are already accepted at the national level by the degree of Finnish Council of State (Valtioneuvosto 2007). Compared with the previous AES (Table 3), some changes are proposed regarding the biodiversity-related measures (Anon. 2007). **Vegetation-covered set-aside** (with a minimum duration of two years) is a new measure included in the basic measures (*i.e.* those that each farmer committed to the scheme must implement). In additional measures **diversification of cultivation** is introduced, which allows an annual maximum of 40% of a farm's cultivated area to be allotted to one single crop species, and the cultivation of one particular crop species is allowed in the same field parcel for a maximum of two sequential years (three years for ley or silage). The new AES divides **wintertime vegetation cover and lightened tilling** into several classes and action combinations. For example, a farmer may choose whether it is appropriate to leave 30% or 50% (a new option) of cultivated area covered by vegetation or stubble in the winter. Otherwise, the biodiversity-related measures of AES are basically the same as in the previous subsidy period (Table 3, Anon. 2007).

I shall now discuss, in the light of my results (**I-IV**), how well certain measures of the Finnish AES meet the habitat needs of farmland birds. Even though I have not compared the effects of any individual AES measures "before *versus* after", the extensive spatial and temporal coverage of my data allows me to present information on the habitat needs of farmland bird species. And, by knowing which habitats birds do need in farmland, it is justified and reasonable to explore whether protection, or even an increase, of such habitats is included in the AES measures.

The most rarely practised measures (Table 3), for example wetland management and management of traditional habitats, surely increase habitat heterogeneity in the landscape and are thus beneficial for biodiversity. Owing to the small coverage of these measures, their effects will, however, be mostly local. I therefore consider widely applied basic measures as a more important conservation tool. **The formation of margins along main ditches (a minimum width 1 m) and border strips (a minimum width 3 m) along larger water systems** is a basic measure that I suggest has good potential to increase abundance and diversity among farmland birds, although the area covered by margins is not large. Ditches and their non-cropped vegetation-growing margins are important habitats for birds (**I**, **II**, **IV**, Table 2), hence any action that makes margins and banks wider constitutes positive development. Before the EU era, Finnish field and ditch margins used to be narrower, often "so narrow that it was difficult to avoid stepping on cultivations when walking along ditch margins in a territory mapping census" (J. Tiainen, pers. comm.).

Another basic measure, called **the maintenance of biodiversity**, could be a powerful tool in biodiversity protection if farmers could understand and apply it more easily, which during the previous subsidy period unfortunately was not the case (Kuussaari *et al.* 2004a). The measure includes the maintenance of large single trees, tree avenues, small tree and bush islets, streams, springs, and small wetland habitats. Farmers may have difficulties in identifying suitable conservation targets if expert support is not available.

The new basic measure of **vegetation-covered set-aside** will possibly increase fallowing and appears to be a promising addition to the AES, since positive effects of set-asides on birds and other organisms are evident (Table 2, **IV**). However, it is impossible to predict the real impact of this measure on biodiversity, since farmers are free to choose how many hectares they will leave as set-aside, *i.e.* no minimum obligatory areas or proportions of field area are defined.

The new measure of **diversification of cultivation** may basically increase species richness and abundance among farmland birds (**IV**, Table 2). How much practical effect it will have remains to be seen —

much depends on how large a proportion of farmers decide to choose the measure.

Of the voluntarily selectable special measures, **organic farming** is the most important one. Organic farming aims to reduce the impact of agriculture on the environment by operating without pesticides and artificial fertilizers, and usually with a more diverse crop rotation. My results (**IV**) support the diversification of cultivation through diverse crop rotations. Organic farming increases the species richness and abundance of many taxa, including birds (Hole *et al*. 2005, Bengtsson *et al*. 2005, Christensen *et al*. 1996, Wilson *et al*. 1997, Lokemoen and Beiser 1997, Chamberlain *et al*. 1999b, Freemark and Kirk 2001, Beecher *et al*. 2002). Organic management also increases weed abundance and species richness (Hyvönen *et al*. 2003), which directly benefits granivorous birds and indirectly insectivores, because the abundances of invertebrates and weeds tend to correlate positively (Wilson *et al*. 1999). Furthermore, insectivorous birds may benefit directly from the absence of insecticides (Boatman *et al*. 2004). At present in Finland all the advantages of organic farming may not yet have been identified because of the rather small area of fields under organic treatment (*cf.* Bengtsson *et al.* 2005) — organic production covers still less than 10% of the total field area (Table 3).

5. Conclusions and recommendations for conservation

Modern intensive farming has caused loss of habitats and habitat heterogeneity, and thus contributed to the decline of many farmland bird species and to the impoverishment of farmland biodiversity in general. As this negative development is predicted to continue within the EU, conservation actions are needed to arrest biodiversity loss, or even to increase the diversity of farmland organisms and agricultural landscape.

I shall now present the implications for conservation, based on my own and previously published studies.

First of all, homogenization of cultivation, with its consequential detrimental effects on biodiversity, is in Finland fundamentally caused by a problem amply summarized in three words: *lack of cattle*. A striking decrease in cattle farming has led to simplified crop rotations without grasslands, especially in southern and western parts of Finland. Alarmingly, the remaining Finnish animal husbandry is expected to further decline in the near future, and also in eastern and northern Finland, *i.e.* in the areas where cattle breeding is currently chiefly concentrated (Lehtonen & Pyykkönen 2005). The ongoing trend will most probably cause many livestock farms to combine or stop production completely, or change to cereal or root crop cultivation. Consequently, grassland habitats will become concentrated in fewer and more isolated areas, whereas spring cereal cultivation will dominate even more than before. With regard to farmland biodiversity, the most ideal development in Finnish farming would be a return to the traditional mixed farming. Because economical, social and political realities make that unlikely, I suggest that agricultural policy should be changed so that a new expansion of cattle farming would be possible. Support should perhaps be targeted at areas of homogeneous cereal cultivation, *i.e.* at southern and western Finland where cattle farming is rare. More efficient targeting is also needed in other actions aiming to maintain particular habitat types or landscape structures, and differences in landscape structure (most importantly field sizes) in different parts of Finland have to be taken into account. Tscharntke *et al.* (2005) have suggested that landscape complexity and heterogeneity may compensate for biodiversity losses that are caused by intensive management. Hence, maintenance of non-cropped habitat elements within large open fields is essential. Similarly, the existing abundance and diversity of farmland organisms has to be taken into account to find biodiversity "hotspots" that require special conservation attention. Tools and knowledge for detailed farmland conservation planning exists — the question is one of political will and attitude.

At the moment Finnish agri-environmental policy does not support biodiversity conservation sufficiently. Improvements are needed.

5.1. Suggestions for improvement of the Finnish AES

The Finnish agri-environmental programme or any other agricultural policy have not fully met the requirements to conserve farmland ditches as a habitat type. The formation of vegetated margins along main ditches is indeed included in the Finnish AES, but this action does not relate to narrow open ditches within field parcels ('sarkaoja' in Finnish). On the basis of the evidence presented in my thesis, I argue that ignoring the essential role of ditches as part of farmland habitat heterogeneity is a major fault in Finnish agri-environmental policy. Clearly, the maintenance of open ditches should be promoted with economical incentives, and so should the maintenance of tree- and bush-lined ditches. Unfortunately, this objective is in conflict with the sub-surface drainage agenda included in the Horizontal Rural Development Programme, which aims to underdrain by the year 2020 one half of the Finnish arable area still drained by open ditches (Anon. 2004). Moreover, it is cost-effective to unite fields and hence increase parcel size (Myyrä & Pietola 2002). Consequently, at present, farmers are paid for removing ditches, instead of leaving them untouched. In socio-economic value assessments on sub-surface drainage activity, biodiversity values are typically not taken into consideration (*e.g.* Haataja & Peltola 2001). This is a fatal mistake as far as farmland biodiversity is concerned. Thus, I suggest a thorough discussion be carried out on all the socio-economically important aspects of sub-surface drainage and parcel fusion activities, including targets of biodiversity preservation.

The AES measures should more clearly than previously include maintenance of <u>tree and bush islets, large individual trees and bushes, and other bush- or tree-covered habitat patches</u>. These habitats are in a way included in the basic measure "Maintenance of biodiversity", and because basic measures are obligatory for each farmer participating in AES, this particular action has a potential to conserve biodiversity. Thus, practical actions needed to fulfil the objectives of this measure have to be made sufficiently clear for farmers to be able to apply them easily. Finnish farmers are interested in and willing to conduct actions that benefit farmland wildlife and biodiversity (Herzon & Mikk 2007). Consequently, explicit guidelines are needed. In practice, in most cases farmers would be paid for not clearing patches of tall vegetation from their fields, or for managing habitats in agreed ways. More farm-level advice and training on this issue is needed, and preferably given by ecologists or other trained experts.

Farmers should be encouraged to select the additional measure "<u>Diversification of cultivations</u>" that is included in the AES in 2007–2013. The best solution would be to upgrade this measure to a basic one in the near future.

Establishment of <u>set-asides</u> of different durations should be encouraged and financially promoted within the limits of the AES budget more than is done currently. The set-aside obligation in the AES is a promising development, but it would be even more promising and effective if the AES clearly defined the proportion or area of fields that has to be left as set-asides. Alternatives to one-season CAP-set-asides are needed in Finnish farmland.

<u>Organic farming</u> should also be promoted by the AES in future and probable even more than is currently done. Organic farming gives an incentive to undertake rich crop rotation, and thus to promote heterogeneity of cultivations. Especially those organic farms that raise cattle should get financial support to make their production sustainable. Organic farming also promotes diversity of farmland organisms. From an economical point of view, it is suggested that organic milk and

rye production consumes less energy than conventional production (Grönroos *et al.* 2006).

Overall, great challenges lie ahead in conserving of farmland biodiversity and in minimizing the detrimental effects of agricultural intensification and specialization. To tackle and overcome these challenges, steering agricultural policy in a more biodiversity-oriented direction is required, since CAP-driven loss of habitats and habitat heterogeneity is likely to continue. When the present development of agricultural intensification is seen in conjunction with future scenarios of climate change (IPCC 2007) and its partly unpredictable consequences, biodiversity conservation becomes even a more challenging task. For example, in Finland a warming of 0.3°C per decade until 2050 is predicted to expand the area suitable for wheat cultivation northwards by several hundreds of kilometres (Carter & Saarikko 1996). Such large-scale changes will notably affect farmland biodiversity and farming. To model and predict in detail the consequences of interactions between intensive farming and climate change, research is needed. As a member of the EU, Finland is committed to arrest biodiversity decline by the year 2010. This aim seems, on the basis of present agricultural policy, extremely difficult to achieve on schedule. Biodiversity issues clearly merit increased financial support, both for research and for carrying out practical measures in the field.

6. Acknowledgements

Early May in year 1995, at 5 am. Snow falls quietly on the legendary field bird census area "Pappila Northern" in Lammi, near the biological station. Birds do not sing. Snow falls also on me, a young biology student who thinks: "at the moment I could — and probably should — be in some other place than here".

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