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Linking agricultural policies to population trends of Swedish farmland birds in different agricultural regions

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Summary

1. The widespread declines of farmland birds have generally been linked to agricultural intensification. We tested the hypotheses that (i) changes in agricultural policy, through its effects on agricultural intensification and (ii) regional differences in agricultural intensification affect temporal and spatial population trends of farmland birds in Sweden.

2. We analysed regional bird population trends (1976–2003) for seven common farmland bird species: the migratory lapwing *Vanellus vanellus*, skylark *Alauda arvensis*, starling *Sturnus vulgaris* and linnet *Carduelis cannabina* and the resident tree sparrow *Passer montanus*, house sparrow *P. domesticus* and yellowhammer *Emberiza citrinella*. We identified three periods of agricultural policy in Sweden between 1976 and 2003: the intensification period (i.e. 1976–87; promoting increased production), the set-aside period (1987–95; promoting extensification of farming) and the Common Agricultural Policy (CAP) period (1995–2003; promoting increased production). Population trends were compared between three types of Swedish farmlands: open plains (intensive farming with a marked intensification), mosaic farmlands (i.e. farmland-dominated forest mosaics, less intensive farming, but show moderate intensification) and forest regions (i.e. forest-dominated farmlands with low intensity farming and extensification/abandonment).

3. The four migrants displayed clear significant trend switches between the policy periods, with declines in the 'intensification period' and the 'CAP period' and less negative or even positive population trends in the 'set-aside period'. The population trends of the three resident species showed no clear pattern in relation to agricultural policy periods.

4. All species except tree sparrow displayed significantly different population trends between farmland regions. Four species (lapwing, skylark, linnet and house sparrow) declined most in the open plains and the forest regions, whereas two species (starling and yellowhammer) declined most in the mosaic farmlands.

5. *Synthesis and applications.* Large-scale changes in agriculture policy have a strong potential to change the present poor state of farmland biodiversity as shown by the generally positive population trends in the 'set-aside period'. It also suggests extensification to be beneficial to farmland birds. However, in regions of low profitability and an already ongoing extensification, a further extensification will lead to loss of both farmland habitat and bird diversity. In such regions mixed farming needs to be retained and hence should be supported.

Key-words: Abandonment, agricultural intensification, Agri-environment schemes, CAP, extensification, population declines, set-aside, specialists

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Introduction

Farmland birds in western Europe have suffered severe population declines since the 1970s (Tucker & Heath 1994; Fuller *et al.* 1995; Siriwardena *et al.* 1998; Donald, Green & Heath 2001) and the declines have been linked to the rapid intensification of agriculture (Krebs *et al.* 1999; Aebischer *et al.* 2000; Chamberlain *et al.* 2000). Furthermore, many European countries have experienced extensive farmland abandonment (MacDonald *et al.*

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2000) and although less studied, abandonment affects farmland birds negatively as well (e.g. Suarez-Seoane, Osborne & Baudry 2002; Laiolo *et al*. 2004; Wretenberg *et al*. 2006).

The suggested links between agricultural changes and farmland bird declines are complex and sometimes contradictory. For example, Donald, Green & Heath (2001) showed that farmland birds declined more in western Europe than in eastern Europe, probably because the latter experienced less agricultural intensification. However, in Denmark, populations of farmland birds remained fairly stable despite rapid agricultural intensification during the 1980s (Fox 2004) and Swedish farmland birds decreased at least as much as in England, despite a lower degree of agricultural intensification than in England (Wretenberg *et al*. 2006).

Concerning the strong declines observed in Sweden, Wretenberg *et al*. (2006) suggested two possible explanations. First, several species, especially short-distance migrants, share wintering grounds with populations from England. The strong synchrony in population trends between England and Sweden could therefore be caused by shared wintering grounds with deteriorating conditions. Secondly, the declines in Sweden may have been caused by dual negative effects of intensification in the productive open plains and abandonment in the forest-dominated regions. Thus, despite the implementation of similar agricultural policy across countries (Potter 1997; Robson 1997), the effects of agricultural policy on farming practices may have differed due to regional differences in farming conditions.

The agricultural policy in Sweden has changed drastically twice since the early 1970s and three distinct phases can be identified. The first phase ('the intensification period', pre-1970–87) was dominated by intensified cereal production, high inputs of pesticides and fertilizers and a rapid increase in yield per hectare (Statistics Sweden 1970–2004). Removal of non-crop habitats (e.g. ditches, stone walls and field roads) and amalgamation of small farms and fields into larger units was also a widespread phenomenon during this period (Gerell 1988; Robertson, Eknert & Ihse 1990; Ihse 1995). The second phase was caused by a huge surplus production of cereals in the European Union (EU). As a result, Sweden initiated a set-aside programme in 1987 and followed this with additional programmes in 1990 (Swedish Board of Agriculture 2006a). During this period Sweden also launched the first agri-environment schemes and the level of fertilizers and pesticides decreased (Statistics Sweden 1990). We refer to this period as the 'set-aside period', lasting from 1987 to 1995. The third phase (the 'CAP period') started in 1995 when Sweden joined the EU and the Common Agricultural Policy was implemented. Production-supporting subsidies were reintroduced and use of pesticides started to increase. Furthermore, during this period the area of farmland under agri-environment schemes increased rapidly (Swedish Board of Agriculture 1999, 2006a).

These changes in agricultural policies had a strong nation-wide impact on the use of arable land and seminatural pastures. However, the farming conditions in Sweden vary considerably between regions and this is reflected in agricultural intensity (e.g. cereal yield ha^{-1}, field sizes, proportions of fields used for cereals, leys and cultivated pastures, levels of pesticides and fertilizers and farmland abandonment; Statistics Sweden (1970–2004). These regions also vary in landscape structure from large open plains across farmland–forest mosaics to forest-dominated landscapes with infield farming (Ihse 1995; Vävare, Sjödahl & Naylor 2005). It is possible, therefore, that the effects of agricultural policy differ between these regions and as a consequence also the population trends of farmland birds.

Here, we tested the general hypothesis that changes in agricultural policy affect farmland bird population trends. This was carried out by investigating bird population trends of seven common farmland specialist species (data from the Swedish Breeding Bird Survey, three residents and four short-distance migrants). We compared agricultural statistics and farmland bird population trends based on the three agricultural policy periods defined above and three agricultural regions. We predicted population trends to be declining in the intensification period, stable or increasing in the set-aside period and declining again in the CAP period. However, because the relative effects of intensification vs. extensification (and abandonment) on bird population trends were not known a priori we could not make any predictions in terms of which region that would display the strongest response in population change.

Methods

We used data from the annual Swedish Breeding Bird Survey, which started in 1975 and consists of routes with 20 point counts (Lindström & Svensson 2005). At each point all birds heard or seen are counted during 5 min. The routes are censused once a year between mid-May and mid-June (the date and time is chosen arbitrarily and is repeated in the following years within ± 5 days and ± 30 min of that date and time, respectively). Counts are usually made the early mornings. The geographical location of the routes and the exact position of the points are chosen by the observer. A route is always surveyed by the same observer. We used the total number of birds observed at the route level as independent observations in statistical analyses. Because our aim was to study farmland birds in farmland landscapes, we selected routes that contained at least some farmland. Information on the exact location of the census points was not collected in the first census years. Therefore, we used presence of skylark *Alauda arvensis* L. in at least one year as an indicator of occurrence of farmland habitats. The skylark is widespread and common in all farmland areas larger than 11·5 ha in Fennoscandia (Piha, Pakkala & Tiainen 2003). The first year of the bird survey, 1975, was omitted because disproportionately fewer routes were censused that year. Moreover, we excluded routes that had been censused in only one or two years.

Because of differences in soil, bedrock type, topography and climate, the conditions for farming differ between regions in Sweden. This is reflected in, for example, amount of forest in the landscape, sizes of farms and fields and productivity, which in turn affect agricultural intensity and production (cereal or cattle production). Based on these differences, we divided southern Sweden into three agricultural regions, which in the text will be referred to as (1) open plains, (2) mosaic farmlands and (3) forest regions (Fig. 1). In total we used data collected from 369 different bird census routes south of latitude 61° N (i.e. including approximately 90% of all Swedish farmland; Statistics Sweden 2002) between 1976 and 2003. Of these routes 55, 168 and 146 were located in open plains, mosaic farmlands and forest regions, respectively.

We analysed seven common farmland specialist species (for a list of specialists, see Wretenberg *et al.* 2006). Common species were chosen because sample sizes decreased rapidly when the bird data were separated into three regions and three time periods. Farmland specialists were chosen because these species are assumed to be most sensitive to changes in agriculture practices (Siriwardena *et al.* 1998; Shultz *et al.* 2005; Wretenberg *et al.* 2006). The species were four short-distance migrants (lapwing *Vanellus vanellus* L., skylark, starling *Sturnus vulgaris* L. and linnet *Carduelis cannabina* L.) and three resident species (tree sparrow *Passer montanus* L., house sparrow *P. domesticus* L. and yellowhammer *Emberiza citrinella* L.).

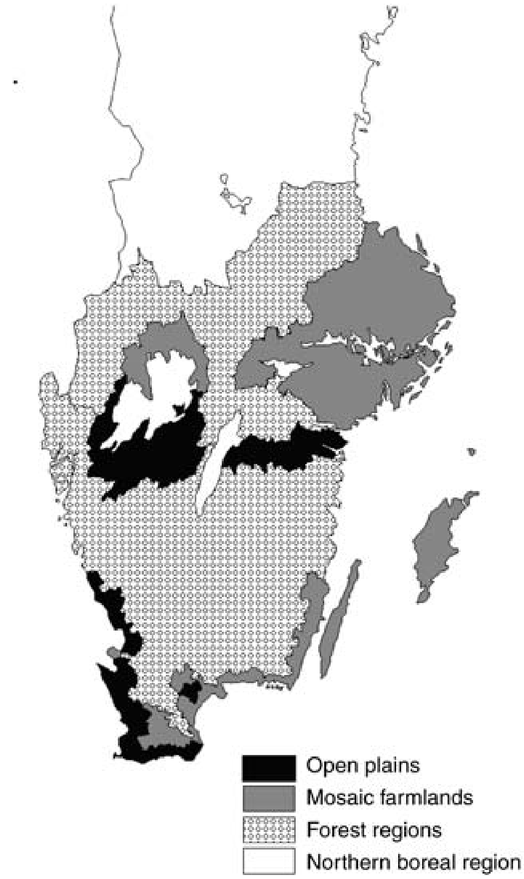

Fig. 1. Agricultural regions of Sweden. The northern boreal region was not included in the analyses.

BIRD TREND ANALYSIS

Population trends were calculated using TRIM (TRends and Indices for Monitoring data; Pannekoek & van Strien 2001). TRIM analyses time-series of counts with missing observations using Poisson regression (log-linear models; McCullagh & Nelder 1989). Several models were used in the analyses. To test whether regional population trends differed among periods with different agricultural policies we divided the bird data into the same three periods and three geographical regions as the agricultural statistics (i.e. 1976–87, 'the intensification period'; 1987–95, 'the set-aside period'; and 1995–2003, 'the CAP period'). Thus, the years 1976, 1987 and 1995 were used as change points in linear (switching) trend models. The yearly number of routes censused in each time period varied between 65 and 116, 116–160 and 132–175 for the intensification period, the set-aside period and the CAP period, respectively.

We used a model with effects for each site and year (time–effect model) to estimate the overall trends and standard errors of the whole study period for each region. This resulted in 21 regional population trends (i.e. three population trends for each species). These regional population trends were measures of an average yearly change between 1976 and 2003. To test whether regional population trends differed, we used a model with site–effect and a linear effect of time. For more information about the different models used, see Pannekoek & van Strien (2001).

DEFINITIONS AND ANALYSES OF AGRICULTURE STATISTICS

There are two major categories of farmland, namely non-ploughed seminatural grasslands (mainly used as pastures) and ploughed arable land. Seminatural pasture is non-ploughed land with grazing regimes that have been maintained for centuries. Arable land includes all fields ploughed repeatedly (e.g. annually as for most crops, or with longer time intervals such as leys or other types of cultivated grasslands). In the open plains leys and cultivated pastures are often part of crop rotation systems and may persist only for a few years, whereas in the forest regions ploughing may occur at longer time intervals (e.g. 5–10 years). When we refer to abandonment of arable land or seminatural pastures, we mean fields or seminatural pastures that have been permanently taken out of agricultural production. Abandoned arable lands have normally been planted with trees, whereas abandoned seminatural pastures have often been left to secondary succession of bushes and trees.

We analysed and compared regional trends and temporal patterns of several agricultural variables. We focused on changes in total area of arable land, proportion of mixed farms, wheat yield per hectare and area of the most common land-use types (i.e. winter wheat, spring-sown cereals, cultivated pastures, leys and set-aside). However, we lacked detailed regional statistics on several potentially important variables, for example use of pesticides and fertilizers, rate of removal of non-crop habitats, amount of secondary succession of trees and shrubs and changes in area of seminatural pastures.

The following procedure was used in all tests of agricultural variables. First, we used PROC REG in SAS to make preliminary model trends and to test for serial correlations (Brockwell & Davis 2002). Secondly, we continued by using the MIXED procedure to model trends and by specifying an AR(1) dependence structure (autoregression of order 1). However, in three cases (set-aside, total area of arable land and 'leys and cultivated pastures') the serial correlations were close to 1, indicating non-stationary models. In those cases we used differences between subsequent years to obtain stationary series (cf. Brockwell & Davis 2002). We always started with the most complex models, incorporating possible different trend slopes among the regions and quadratic terms (to test for non-linear relationship). However, in all cases we could use simple models (i.e. quadratic terms were never significant and only a few interaction terms between time and region were found to be significant).

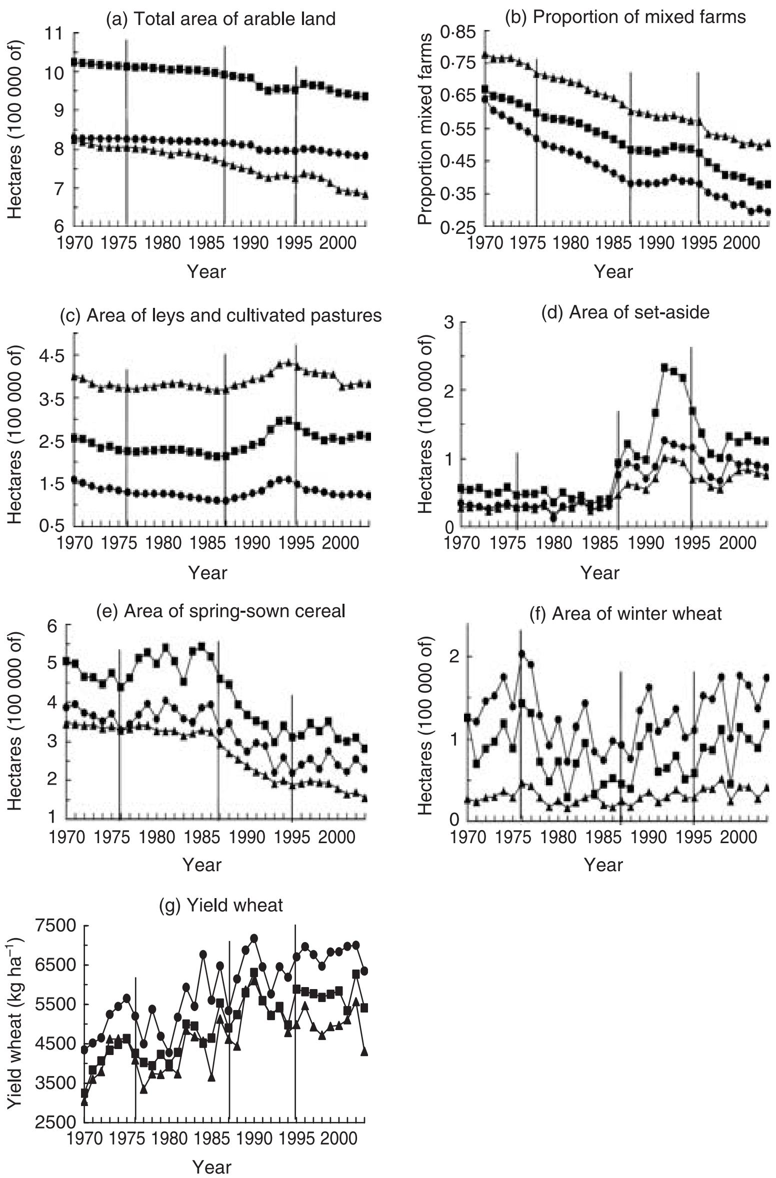

Fig. 2. (a–g) Agricultural variables for three regions in Sweden. ● = Open plains, ■ = mosaic farmlands and ▲ = forest regions. Vertical bars denote the three time periods: intensification period (1976–87), set-aside period (1987–95) and CAP period 1995–2003.

Results

REGIONAL AND TEMPORAL TRENDS IN AGRICULTURE

Figure 2a–g shows regional trends in agricultural variables during the three time periods. Below we present a summary of the results (see Supplementary tables S1–S7 for all statistical tests of agricultural variables). Annual changes in total area of arable land differed significantly between regions. The most rapid decline was found in forest regions followed by that observed in mosaic farmlands, whereas there was a non-significant decline in open plains (Fig. 2a).

The proportion of mixed farms (i.e. cereal and husbandry) declined rapidly between 1976 and 2003 in all three regions (Fig. 2b). However, the changes depended on both region and time period. In the open plains and mosaic farmlands, the proportion of mixed farms decreased significantly in the intensification period and the CAP period, whereas it remained stable during the set-aside period. In contrast, in the forest regions mixed farming decreased significantly during all three time periods. The trends in area of leys and cultivated pastures did not differ between regions (Fig. 2c). However, the trends differed significantly between time periods. During the intensification period the area of leys and cultivated pasture was stable, whereas it increased during the set-aside period and decreased during the CAP period. Changes in area of set-aside (Fig. 2d) depended on region and time period. The main change occurred during the set-aside period when the area of set-aside increased (with the most rapid increase in the mosaic farmlands), whereas the area of set-aside was more stable during the intensification and the CAP periods.

The areas of spring-sown cereals were stable during the intensification period and the CAP period. However, during the set-aside period spring-sown cereals decreased significantly in all three regions (with the most rapid decrease in the mosaic farmlands; Fig. 2e).

The area of winter wheat varied considerably across years due to variation in weather (Fig. 2f). The trends were similar between regions and decreased during the intensification period and increased during the set-aside period, whereas it was stable during the CAP period. However, although changes in the two first periods were significant, the actual changes were small compared with, for example, changes in spring-sown cereals and set-aside.

Wheat yield per hectare increased significantly in all three regions. However, the rate of increase differed between regions, with the most marked increase in the open plains and the lowest in the forest regions (Fig. 2g). Furthermore, in the intensification period wheat yield increased dramatically, whereas it was more stable during the set-aside and CAP period.

POPULATION TRENDS IN FARMLAND BIRDS

The four short-distance migrants (lapwing, skylark, starling and linnet) displayed relatively similar population trends, with declining populations in all three regions during the intensification period (Table 1). In the following set-aside period, all these four species switched to less negative or positive population trends in all three regions (67% of the trend switches being statistically significant). During the final CAP period regional population trends in skylarks and linnets again switched to negative trends (yearly declines between 4% and 13%) in all regions, whereas the lapwing and starling demonstrated regionally different and mainly non-significant trend shifts.

The resident species (tree sparrow, house sparrow and yellowhammer) displayed more heterogeneous regional population trends among all time periods. During the intensification period, the house sparrow declined as much as the four short-distance migrants, whereas the population trends of yellowhammer and tree sparrow were non-significant in all but one case (Table 1). In the set-aside period, although all trends were negative and some significant, the trend shifts were diverse and mainly non-significant. Finally, in the CAP period, all trend shifts were non-significant, but tended to be in a positive direction (seven of nine were positive).

Table 1. Annual population changes (in percentage) of seven farmland bird species in three time periods and three regions with 95% confidence intervals (CI) of seven common farmland bird species. The symbols –, – –, – – – and +, + +, and + + + equal *P*-values of < 0·05, < 0·01 and < 0·001, respectively. *P*-values > 0·05 are in brackets. For trends with *P*-values close to 0·05, the actual values are given behind the symbol

	Intensification period 1976–87				Set-aside period 1987–95				CAP period 1995–2003			
Species	% annual population change	95% CI		Trend[1]	% annual population change	95% CI		Trend switch[2]	% annual population change	95% CI		Trend switch[2]
Lapwing												
Open plains	–11·4	–15·7	–7·1	– – –	4·4	0·4	8·4	+ + +	–5·8	–9·8	–1·8	– –
Mosaic farmlands	–4·5	–7·0	–1·9	– – –	1·9	–0·9	4·7	+ +	1·5	–1·1	4·1	(–)
Forest regions	–7·2	–12·3	–2·0	– – –	–1·5	–5·3	2·3	(+)	0·6	–3·3	4·5	(+)
Skylark												
Open plains	–5·6	–7·4	–3·9	– – –	–0·2	–2·0	1·5	+ + +	–9·2	–11·2	–7·2	– – –
Mosaic farmlands	–5·9	–6·8	–5·0	– – –	1·4	0·1	2·6	+ + +	–4·0	–5·4	–2·7	– – –
Forest regions	–8·3	–10·3	–6·4	– – –	2·2	0·2	4·3	+ + +	–8·7	–10·7	–6·7	– – –
Starling												
Open plains	–1·4	–5·1	2·3	(–)	–0·2	–3·7	3·4	(+)	–1·0	–5·0	3·1	(–)
Mosaic farmlands	–5·7	–7·7	–3·7	– – –	–2·5	–4·6	–0·4	(+) 0·08	0·5	–1·9	3·0	(+)
Forest regions	–3·7	–6·7	–0·7	–	0·4	–2·1	2·8	(+) 0·07	–1·0	–3·5	1·5	(–)
Linnet												
Open plains	–10·0	–13·7	–6·4	– – –	7·5	3·1	12·0	+ + +	–13·3	–18·3	–8·2	– – –
Mosaic farmlands	–7·8	–11·5	–4·2	– – –	10·2	6·2	14·1	+ + +	–9·8	–12·8	–6·7	– – –
Forest regions	–12·8	–18·2	–7·4	– – –	–1·9	–7·7	4·0	+	–5·7	–10·4	–1·0	(–)
Tree sparrow												
Open plains	–3·0	–7·5	1·5	(–)	–2·4	–6·7	1·8	(+)	6·6	1·2	12·0	+
Mosaic farmlands	–1·6	–4·3	1·2	(–)	–3·3	–6·2	–0·4	(–)	2·0	–1·4	5·4	(+) 0·056
Forest regions	4·6	–0·6	9·7	(–)	–3·0	–6·0	0·0	–	–0·8	–4·2	2·5	(+)
House sparrow												
Open plains	–7·2	–11·2	–3·2	– – –	–9·8	–14·5	–5·1	(–)	–6·2	–14·2	1·8	(+)
Mosaic farmlands	–6·6	–9·0	–4·2	– – –	–3·1	–6·0	–0·1	(+)	–0·2	–4·2	3·8	(+)
Forest regions	–8·1	–12·7	–3·4	– –	–4·2	–7·8	–0·7	(+)	–3·4	–7·8	0·9	(+)
Yellowhammer												
Open plains	2·8	0·6	5·0	+	–1·9	–4·0	0·1	–	–3·9	–6·5	–1·4	(–)
Mosaic farmlands	–0·4	–1·6	0·8	(–)	–5·3	–6·5	–4·0	– – –	–3·3	–4·8	–1·8	(+)
Forest regions	–1·4	–3·3	0·5	(–)	–0·2	–1·9	1·5	(+)	–2·7	–4·4	–1·1	(–)

[1]Symbols and *P*-values describe a test of H_0 = 0% annual change. [2]Signs and *P*-values describe a test of H_0 = annual change of the preceding time period (i.e. a test of trend switches).

Table 2. Annual population changes (in percentage) between 1976 and 2003 in three regions (OP = Open plains, MF = Mosaic farmlands, FR = Forest regions) with 95% confidence intervals (CI) of seven common farmland bird species. Populations that have declined significantly in bold type. Significant *P*-value shows that trends differ among regions. The last column shows the results from pairwise tests which were made in order to investigate between which regions population trends differed, e.g. OP; FR < MF means that populations in OP and FR have declined significantly ($P < 0{\cdot}05$) more than in MF, but there was no significant difference between OP and FR

	Open plains			Mosaic farmlands			Forest regions				
Species	% annual population change	95% CI		% annual population change	95% CI		% annual population change	95% CI		*P*-value different trends	Regional comparisons
Lapwing	**−2·5**	**−4·6**	**−0·3**	−0·3	−1·3	0·7	**−3·0**	**−5·3**	**−0·7**	0·014	OP; FR < MF
Skylark	**−4·2**	**−5·0**	**−3·4**	**−2·5**	**−2·9**	**−2·1**	**−4·3**	**−5·2**	**−3·4**	0·001	OP; FR < MF
Starling	−0·9	−2·3	0·6	**−3·1**	**−3·9**	**−2·4**	**−1·4**	**−2·7**	**−0·2**	0·006	MF < OP; FR
Linnet	**−4·2**	**−5·8**	**−2·5**	−1·0	−2·4	0·3	**−8·3**	**−11·0**	**−5·6**	0·007	FR < OP; MF[1]
Tree sparrow	−1·0	−2·9	1·0	**−1·5**	**−2·6**	**−0·4**	0·5	−1·3	2·4	0·630	OP; MF; FR
House sparrow	**−7·9**	**−10·3**	**−5·4**	**−3·7**	**−4·9**	**−2·4**	**−5·4**	**−7·2**	**−3·5**	< 0·001	OP < FR; MF
Yellowhammer	−0·5	−1·5	0·4	**−3·1**	**−3·5**	**−2·6**	**−1·3**	**−2·0**	**−0·5**	< 0·001	MF < OP; FR

[1]*P*-value = 0·068 for the comparison between OP and MF.

Regional long-term population trends (1976–2003) were in most cases (15 of 21, 71%) declining significantly (Table 2). No regional populations increased significantly (but see tree sparrow in forest regions; Table 2). Although for all species, except tree sparrow, population trends differed significantly between regions, no region performed consistently better or worse. However, lapwing, skylark, linnet and house sparrow tended to decline most in open plains and forest regions (Table 2).

Discussion

TEMPORAL POPULATION TRENDS AND AGRICULTURAL POLICY

Our study partly corroborates the prediction that farmland bird trends are linked to agricultural policy. The four short-distance migrants (lapwing, skylark, starling and linnet) in particular displayed significantly different population trends in the intensification period (strongly declining), the set-aside period (more stable or increasing) and the CAP period (again declining, especially skylark and linnet; see Table 1). Chamberlain *et al*. (2000) showed a similar temporal link between agricultural intensification during the 1970s and the 1980s and the decline of farmland birds in Britain. On a larger spatial scale, Gregory *et al*. (2005) found that farmland birds in eastern Europe began to recover around 1990, when the break-up of the former Eastern Bloc made farming there less intensive.

However, the links between agricultural policy and population trends of the three resident species (tree sparrow, house sparrow and yellowhammer) were more diverse (Table 1). One explanation for the differences between the short-distance migrants and the resident species may be that the migratory species are confined more closely to farmland habitats. Skylarks and lapwings are true field species and use farmland almost exclusively both for foraging and nesting, and linnets and starlings use farmland fields and pastures for foraging (Cramp, Simmons & Perrins 1977–94). In contrast, parts of the populations of the three resident species also breed in non-farmland habitats (e.g. tree sparrow and house sparrow in urban areas and yellowhammer in forest clear-cuts; Svensson, Svensson & Tjernberg 1999), thus being less sensitive to changes in agricultural policy. Another explanation may be that short-distance migrants are affected by agricultural changes at the wintering grounds in western and south-western Europe. This is because agricultural change in theses parts of Europe has been similar to that observed in Sweden (Potter 1997; Robson 1997), and winter survival may be a key factor for the observed trends (Siriwardena, Baillie & Wilson 1998, 1999). However, common wintering grounds cannot explain why all four short-distance migrants showed significantly different trends in the three farmland regions. Thus, at least a part of the explanation for the observed population trend shifts is probably found in the changes at their Swedish breeding grounds.

A range of farmland bird species prefer set-aside fields to neighbouring crops (Berg & Pärt 1994; Wilson *et al*. 1997; Buckingham *et al*. 1999; Henderson *et al*. 2000; Henderson, Vickery & Fuller 2000), probably because of a higher abundance of weeds and insects (see review by Henderson & Evans 2000). The positive response of lapwing, starling, skylark and linnet during the set-aside period may therefore be linked to the rapid increase of set-aside fields. During the CAP period the area of set-aside remained relatively high, but apparently without any positive effects on skylark and linnet populations. However, during the set-aside period, vegetation on most set-aside fields was composed of self-regenerating weeds. These fields had sparse vegetation and patches with bare ground, thus constituting suitable habitats for ground foraging and nesting birds such as skylark (Green 1978; Henderson *et al*. 2001) and lapwing (Berg, Lindberg & Kallebrink 1992; Hudson, Tucker & Fuller 1994). In contrast, during the CAP period, only 1-year rotational set-aside fields were allowed to self-regenerate, whereas non-rotational set-aside fields were sown with grasses and clover, thereby making vegetation in these fields more dense with low abundance of weeds.

REGIONAL POPULATION TRENDS

Although several populations in this study declined less, and even increased, during the set-aside period, most regional populations showed long-term declines. Four species (lapwing, skylark, linnet and house sparrow) showed the strongest declines in numbers in the open plains and the forest regions (Table 2). The open plains were characterized by the most marked agricultural intensification and the forest regions by extensification and abandonment of farming. Thus, our results suggest that at least for these species the overall negative population trends in Sweden may have been caused by the dual negative effects of a simultaneous agricultural intensification and extensification/abandonment in different regions (see also Wretenberg *et al*. 2006).

In the forest regions, the rapid decrease in area of spring-sown cereals since the mid-1980s has created a landscape dominated by grassland (leys, cultivated pastures and non-rotational set-aside fields; see Fig. 2c–d). Today, it is possible that cereal has become in shortage as a farmland habitat in the forest regions of Sweden. This possibility has also been discussed in Britain, where the importance of cereal habitats in grassland-dominated landscape has been emphasized (Robinson, Wilson & Crick 2001). For example, lapwings prefer to put their nests on harrowed fields and avoid high and dense vegetation (Hudson, Tucker & Fuller 1994; Wilson, Whittingham & Bradbury 2005). Furthermore, cereal grains are important food resources for many granivorous species (e.g. yellowhammer; Fuller, Trevelyan & Hudson 1997; Kyrkos, Wilson & Fuller 1998; Stoate, Moreby & Szczur 1998) and there may be a critical threshold of cereal cultivation in farmland landscapes, below which some species cannot persist (Kyrkos, Wilson & Fuller 1998). This hypothesis is emphasized by the fact that the response of linnet and lapwing during the set-aside period was much weaker in forest regions compared with the open plains and the mosaic farmland (Table 1).

The increased farming intensity at the fertile soils in the open plains, together with the conversion from annual crops to leys, cultivated pastures, non-rotational set-aside and abandoned fields in the forest regions, have all decreased farmland habitat heterogeneity in each region. Effectively, this means that mixed farming has declined in both regions. It is therefore possible that reduction of habitat heterogeneity at both the landscape and local scale may explain why the declines were most pronounced in the open plains and the forest regions for lapwing, skylark, linnet and house sparrow (see Benton, Vickery & Wilson 2003). However, the population trends of the three other species (starling, tree sparrow and yellowhammer) are less clear and yellowhammer and starling declined most in mosaic farmland, which experienced an intermediate level of agricultural intensification and the highest level of increase in area of set-aside. This suggests that there is no single broad habitat change that affects all farmland bird species similarly (see also Vickery *et al*. 2004).

Differences in long-term population trends within a country (Chamberlain & Crick 1999; Chamberlain & Fuller 2001; this study) as well as between countries or larger geographical regions (Schifferli 2000; Donald, Green & Heath 2001; Van Strien, Pannekoek & Gibbons 2001; Fox 2004; Gregory *et al*. 2005; Wretenberg *et al*. 2006) imply that conservation measures to counteract the negative effects of farming must consider all geographical scales and landscape structures (Kleijn & Baldi 2005). The most recent reform of the CAP has decoupled payments from production and thus since 2005 has encouraged especially small-scale farmers in Sweden to use their land in an extensive way (EU Commission 2003; Statistics Sweden 2006). Between 2004 and 2005 the area of set-aside increased by 20% and the area of leys and cultivated pastures by 10% (Statistics Sweden 2006). Since the start (about 200 years ago) of agricultural statistics, the smallest area of cereal production in Sweden was recorded in 2006 (Swedish Board of Agriculture 2006b). It is therefore probable that the extensification trend among small farms in the forest regions will continue, and even accelerate, in the future. Our results suggest that this will lead to further population declines of farmland birds in these already extensively farmed regions and even more so if farming is completely abandoned. However, it is important to note that in more intensively farmed regions extensification probably improves the conditions for farmland birds (e.g. Gregory *et al*. 2005).

Conclusions and management implications

This study supports the general idea of negative effects of agricultural intensification and positive effects of extensification on farmland birds. Furthermore, it shows that changes in agricultural policy, resulting in less intensive agriculture with more set-aside, can be highly effective in reversing negative farmland bird population trends. However, the effects of extensification on farmland birds may differ markedly depending on region and landscape structure. Consequently, conservation measures need to be spatially flexible and take into account the regional differences in farming practices and landscape structure. For example, a general agricultural policy towards more extensive farming may be favourable in intensively managed regions. However, in regions with low profitability, small-scale farming and ongoing extensification and abandonment, policies that further encourage this development will lead to loss of both farmland habitat and bird diversity.

In such regions mixed farming with some cereal production is important for farmland birds, needs to be maintained and therefore should be supported.

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Supplementary material

The following supplementary material is available for this article.

Tables S1–S7. Statistical tests of agricultural variables

This material is available as part of the online article from: http://www.blackwell-synergy.com/doi/full/10.1111/j.1365-2664.2007.01349.x
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