# Tracking progress towards EU biodiversity strategy targets: EU policy effects in preserving its common farmland birds

Anna Gamero[1,*], Lluís Brotons[2,3,4,5,6], Ariel Brunner[7], Ruud Foppen[6,8,9], Lorenzo Fornasari[10], Richard D. Gregory[11], Sergi Herrando[3,4], David Hořák[12], Frédéric Jiguet[13], Primož Kmecl[14], Aleksi Lehikoinen[15], Åke Lindström[16], Jean-Yves Paquet[17], Jiří Reif[18,19], Päivi M. Sirkiä[15], Jana Škorpilová[1], Arco van Strien[20], Tibor Szép[21], Tomáš Telenský[1,18,22], Norbert Teufelbauer[23], Sven Trautmann[24], Chris A.M. van Turnhout[8,9], Zdeněk Vermouzek[1], Thomas Vikstrøm[25], Petr Voříšek[1,6, 19]

[1] Czech Society for Ornithology, 15000, Prague, Czech Republic

[2] CEMFOR - CTFC, InForest Jru, 25280, Solsona, Spain

[3] Catalan Ornithological Institute, Natural History Museum of Barcelona, 08019, Barcelona, Spain

[4] Centre de Recerca Ecològica i Aplicacions Forestals, 08193, Bellaterra, Spain

[5] CSIC, 08193, Cerdanyola del Vallès, Spain

[6] European Bird Census Council (EBCC)

[7] BirdLife Europe, 1060, Brussels, Belgium

[8] Sovon Dutch Centre for Field Ornithology, 6503, Nijmegen, The Netherlands

[9] Department of Animal Ecology and Ecophysiology, Institute for Water and Wetland Research, Radboud University, 6500, Nijmegen, The Netherlands

[10] Coordinamento Nazionale MITO2000, LIPU BirdLife Italy, 43122, Parma, Italy

[11] RSPB Centre for Conservation Science, The Lodge, SG19 2DL, Sandy, United Kingdom

[12] Department of Ecology, Charles University in Prague, 12844, Prague, Czech Republic

[13] UMR7204 CESCO, Sorbonne Universités-MNHN-CNRS-UPMC, 75005, Paris, France

[14] DOPPS BirdLife Slovenia, 1001, Ljubljana, Slovenia

[15] The Helsinki Lab of Ornithology, Finnish Museum of Natural History, University of Helsinki, 00014, Helsinki, Finland

[16] Department of Biology, Biodiversity unit, Lund University, 22362, Lund, Sweden

[17] Natagora, Département Études, 5000, Namur, Belgium

[18] Institute for Environmental Studies, Faculty of Science, Charles University in Prague, 12801, Praha, Czech Republic

[19] Department of Zoology and Laboratory of Ornithology, Faculty of Science, Palacký University, 77146, Olomouc, Czech Republic

[20] Statistics Netherlands, 2492, The Hague, The Netherlands

[21] University of Nyíregyháza, 4400, Nyíregyháza, Hungary

[22] Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, 60365, Brno, Czech Republic

[23] BirdLife Österreich, 1070, Vienna, Austria

[24] Dachverband Deutscher Avifaunisten, 48157, Münster, Germany

[25] BirdLife Denmark (DOF), 1620, Copenhagen, Denmark

Corresponding author: Anna Gamero, Czech Society for Ornithology, 15000, Prague, Czech Republic, +420 257 212 465, gamero@birdlife.cz

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E-mail addresses: gamero@birdlife.cz, lluis.brotons@ctfc.cat, Ariel.Brunner@birdlife.org, Ruud.Foppen@sovon.nl, lorenzo.fornasari@gmail.com, richard.gregory@rspb.org.uk, ornitologia@ornitologia.org, david.horak@natur.cuni.cz, fjiguet@mnhn.fr, primoz.kmecl@dopps.si, aleksi.lehikoinen@helsinki.fi, Ake.Lindstrom@biol.lu.se, jean-yves.paquet@aves.be, jirireif@natur.cuni.cz, paivi.sirkia@helsinki.fi, skorpilova@birdlife.cz, aj.vanstrien@cbs.nl, partifecske@freemail.hu, tomas.telensky@gmail.com, norbert.teufelbauer@birdlife.at, sven.trautmann@dda-web.de, Chris.vanTurnhout@sovon.nl, verm@birdlife.cz, thomas.vikstroem@dof.dk, Euromonitoring@birdlife.cz

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## Abstract

Maximizing the area under biodiversity-related conservation measures is a main target of the European Union (EU) Biodiversity Strategy to 2020. We analyzed whether agri-environmental schemes (AES) within EU common agricultural policy (CAP), special protected areas for birds (SPAs) and Annex I designation within EU Birds Directive had an effect on bird population changes using monitoring data from 39 farmland bird species from 1981 to 2012 at EU scale. Populations of resident and short-distance migrants were larger with increasing SPAs and AES coverage, while Annex I species had higher population growth rates with increasing SPAs, indicating that SPAs may contribute to the protection of mainly target species and species spending most of their life cycle in the EU. Because farmland birds are in decline, and the negative relationship of agricultural intensification with their population growth rates was evident during the implementation of AES and SPAs, EU policies seem to generally attenuate the declines of farmland bird populations, but not to reverse them.

## Introduction

Several international actions have taken place to stop the loss of biodiversity, including international agreements (i.e. Biological Diversity’s 2010 target, Balmford et al. 2005) and conservation policies (i.e. Directive 2009/147/EC). Although some studies have investigated how successful these conservation actions are (D'Amen et al. 2013; Koleček et al. 2014), evidence-based evaluations of their effectiveness have rarely been made on a large spatial scale (but see Sanderson et al. (2016)).

In the past decades, one of the major biodiversity losses in Europe has occurred in farmland habitats, which cover about 45% of its land area (Kleijn et al. 2011). For example, birds associated with farmland habitats have experienced severe declines, as shown by a more than 50% drop on the EU farmland bird indicator since 1980 (Gregory et al. 2005; EBCC 2015). This decline of farmland bird populations has been mainly attributed to agricultural intensification favored by the European Common Agricultural Policy, CAP (Donald et al. 2001; Donald et al. 2006; Szép et al. 2012). However, to try to minimize the negative effects of agriculture practices on biodiversity, water and soil quality, the CAP also includes agri-environment schemes (AES) since 1992 (Batáry et al. 2015). AES are financial incentives for farmers, conditional to specific management requirements, which aim to improve the ecological conditions of farms. Additionally, the EU has recently adopted a Biodiversity Strategy to 2020 (European Commission 2011), which includes a target to maximize areas under agricultural use that are covered by biodiversity-related measures under the CAP in a perspective to enhance sustainable management. The evaluation of AES in protecting farmland biodiversity at the EU level is therefore critical if the 2020 biodiversity goals are to be met. So far, studies investigating the effect of AES on farmland biodiversity have involved only a subset of EU Member States and/or often assessed AES that have been implemented for a few years, and perhaps in consequence, they have shown contrasting results (Kleijn and Sutherland 2003; Donald et al. 2006; Kleijn et al. 2006; Breeuwer et al. 2009; Dicks et al. 2014).

The most important set of legislation focusing on biodiversity conservation in the EU are however the Birds Directive (Directive 2009/147/EC) and the Habitats Directive (Directive 92/43/EEC). Both establish the Natura 2000 network of protected areas to conserve Europe's most threatened species and habitats. Currently, 193 bird species and subspecies are listed on the Annex I of the Birds Directive and granted the highest protection level in the EU. Member States are required to designate the most suitable areas for Annex I bird species as Special Protection Areas (SPAs). However, designation of a given SPA does not necessarily mean that specific conservation measures are taken (Pellissier et al. 2013). Still, a positive effect of SPAs on Annex I species has been recorded (Donald et al. 2007), but their potential effect on common species has been rarely studied. Only Pellissier et al. (2013) have shown that common birds had higher abundance on sites within the Natura 2000 network in France, but found no effect on their population trends. At a European scale, however, it is still unclear whether SPAs designated in agricultural land are delivering any positive effects to farmland bird biodiversity and whether they improve the populations of Annex I species only, or of all farmland birds.

The aim of this study is to analyze the potential role of EU environmental policies in conserving relatively common and widespread farmland birds. Specifically, we investigate whether the implementation of AES within CAP, the creation of SPAs in agricultural habitats, and the protection of Annex I species are associated with positive growth rates of farmland bird populations at a continental scale. We use data on population abundances for 39 farmland bird species across the EU and analyze the effects of changes in agricultural practices and EU legislation, simultaneously controlling for bird's life-history and ecological traits, to understand their relative contribution in driving changes in bird populations. Our approach, based on the different level of implementation of EU environmental policies in different countries, predicts that if the policies are effective in improving the conservation of common farmland birds, their populations will have more positive growth rates in countries with higher proportion of agricultural land designated as SPAs and under AES than in countries with lower proportion of these areas. Additionally, farmland Annex I species will have more positive growth rates as compared to non-Annex I species in areas where SPAs cover larger areas. In this study we show positive correlations of AES and SPAs with population growth rates of resident, short-distance migrant and Annex I farmland birds.

## Methods

### *Bird relative population abundances*

Data on breeding bird populations were collected annually by skilled volunteer ornithologists throughout Europe within country-based generic breeding bird monitoring schemes. This long-term dataset is coordinated by the Pan-European Common Bird Monitoring Scheme (PECBMS) and currently receives data from 28 European countries for 169 relatively common or widespread bird species. TRIM software was used to calculate country-based species-specific relative abundances (i.e. population indices) applying a Poisson model accounting for missing observations and serial autocorrelation (Pannekoek and van Strien 2001). More details on the methods used in the field and the calculation of population indices and their standard errors can be found in Gregory et al. (2005), van Strien et al. (2001) and in the European Bird Census Council (EBCC) website (http://www.ebcc.info/pecbm.html).

In this study, we used bird monitoring data ranging from 1981 to 2012 from 25 EU countries on the 39 farmland bird species selected by EBCC as common farmland birds at the European level (Table S1). These are the same species used to produce the European farmland bird indicator (Fig. S1), which is used by the European Commission as an indicator of sustainable development. We discarded all observations belonging to periods when countries were not part of EU.

*Explanatory variables*

The spatial resolution of the study was at country level and we assumed that national bird abundances are not solely shaped by events happening directly at monitoring sites, but by the changes at larger national or landscape level.

We collated annual data on landscape changes including agricultural intensification, AES and SPAs from 1980 to 2012 in the EU (Fig. S1). We used cereal yield (kg of all cereals combined/ ha of agricultural land) obtained from the World Bank (www.worldbank.org) as an indicator of agricultural intensification for each country and year. We chose cereal yield because it is highly correlated with other indicators of agricultural intensification (Appendix S1), it is the most complete data set available, and it is often used in similar studies (Donald et al. 2006).

As a measure of the differences in the implementation of the Birds Directive, we used the annual percentage of farmland habitat designated as SPAs for each country (Appendix S1). We included all farmland SPAs independently of having management plans in place or not, since this information was often unavailable. The percentage of agricultural area under AES for each country (Fig. S2) was obtained from Batáry et al. (2015), Kleijn and Sutherland (2003) and Eurostat (http://ec.europa.eu/eurostat), and it was only available for 4 years (2000, 2006, 2009 and 2012). The information on the starting year of AES within CAP was available for each country (Batáry et al. 2015) and we assumed that no EU-based AES before that particular year were in place. We delimited periods between two consecutive values available for the percentage of farmland under AES for each country. We then calculated the average between these two values as the estimation of the AES implementation for each period and country (Table S2). Likewise, we calculated mean cereal yield and mean percentage of agricultural land designated as SPA for each country and period as a measure of agricultural intensification and amount of protected areas for farmland birds respectively. We did not include Greening measures within the Pillar 1 of the CAP, because of their short and recent period of implementation (i.e. started in 2014).

Migration strategy (long-distance migrant vs. short-distance migrant/ resident) and species average body mass (g) in Europe were obtained from Cramp et al. (2004). We used migration strategy as a two level factor because both short-distance migrants and resident species spend their life cycle mainly in Europe, while long-distance migrants (i.e. wintering south of the Sahara or India) are in Europe during the breeding season only. Body mass was included to control for life-history strategy, as it correlates with many other life-history traits (Blueweiss et al. 1978). EU conservation status was obtained from the Annex I of the Birds Directive (Directive 2009/147/EC) (Table S1). The detailed description of all variables used in the study and data sources is listed in Table S3 & S4.

### *Population growth rates*

For most of the species used in the analyses, individuals start breeding in their second calendar year, so we assumed that changes in EU policy and land use change would affect current year reproduction, but the next year’s population growth. Therefore, we calculated population growth rate for each species belonging to each time period and country as the log transformed ratio between the relative abundance (x) in the second year of the period and one year after the period ended, log $(x_{b+1}/x_{a+1})$, with “a” corresponding to the first year of the period and “b” to the last year. For the period 2009-2012, we used relative abundances from 2012 instead of 2013 because of missing data from 2013. This calculation of population growth rate allows the use of population indices instead of raw data and it is analogous to the additive slope produced by TRIM software, which requires raw data (Appendix S2). We used population growth rate for each species-country-period combination (N=1372) as the response variable for the statistical analyses.

*Statistical analyses*

We used linear mixed modelling (LMM) to analyze the effects of average agricultural intensification, percentage of agricultural land under AES, percentage of agricultural land designated as SPA, and Annex I status on population growth rates, controlling for migration strategy and body mass, as fixed effects. We included the interaction between Annex I status and the percentage of farmland area as SPAs because SPAs are mainly designed to protect Annex I species. We included the interactions of migration strategy with percentage of agricultural land under AES, percentage of agricultural land as SPAs, and agricultural intensification because conditions in the EU should affect more strongly species spending their whole life cycle in the EU (i.e. residents and short-distance migrants) than long-distance migrants. Because time periods differed in duration, we controlled the model for the length of the period population growth rates were calculated for. Country identities and species nested in taxonomic family were both included as random intercepts to account for non-independence of observations corresponding to the same species and country, and potential phylogenetic effects (Jiguet et al. 2010). All continuous variables were standardized ($(x_i$-mean(x))/SD(x)) before including them in the model to obtain parameter estimates of the same scale.

We weighted the model by the inverse of the average standard error of the two population indices used to calculate growth rates to correct for the degree of uncertainty in the response variable (Jørgensen et al. 2016). The results of the model with the weights were qualitatively the same as of the same model without weighting, and here only the results of the weighted model are shown. For details on model validation tests see Appendix S3.

Due to the correlative nature of the study and to minimize the possibility that the results of the model were related to other drivers affecting common birds more generally, we re-fitted the same model structure to population indices of the 33 European forest species collated by PECBMS during the same time periods (Table S5), since their populations should not be affected by changes in EU farmland.

We used R 3.1.0 (R Development Core Team 2014) to conduct all the statistical analyses. Package “lme4” (Bates et al. 2014) was used to fit LMMs, and “lmerTest” (Kuznetsova et al. 2014) to obtain P-values for the fixed effects. Package “plyr” (Wickham 2011) was used to calculate log transformed population growth rates and package “ggplot2” (Wickham 2009) to produce the figures.

## Results

The full model was highly significant when compared to the null model (LRT; $\chi^2$=78.82; df=11; P< 0.001), suggesting a strong influence of the predictors on farmland population changes. Specifically, populations of protected species (Annex I) performed better with the creation of farmland SPAs than non-Annex I species (Table1; Fig. 1a). Short-distance migratory and resident species showed more positive population growth rates with increases in percentage of SPAs and AES than long-distance migrants (Table1; Fig. 1b & 1c). Migration strategy had no effect on how population growth rates were affected by agricultural intensification (Table 1). Therefore, to get an estimate of the main effect of agricultural intensification on farmland population growth rates, we ran the same model without this interaction. This revealed that agricultural intensification had a negative overall effect on population growth rates (estimate±SE=-0.034±0.011; t=-3.172; P=0.002; Fig. 1d).

The same model fitted to data on common forest species showed that except period duration, none of the rest of variables explained the variation in population growth rates of forest birds (Table S6).

## Discussion

The decrease of European farmland bird species over the last decades has been attributed to an increase in agricultural intensification (Donald et al. 2001; Donald et al. 2006). Our results, using data extending an additional decade, indicate that this association is still strong and that the negative effects of agricultural intensification on common farmland bird populations persist even if countries are implementing AES and SPAs. On the other hand, we found a lower population decrease of resident and short-distance migratory common farmland birds in countries where agricultural areas under AES were more abundant, even though AES are usually not designed to protect bird species, but rather to generally improve farmland environmental quality (Batáry et al. 2015). This suggests that the non-targeted environmental measures within CAP could be beneficial to some common farmland birds at the EU level and be moderating their decrease. Interestingly, a previous study focused on farmland bird population changes between 1990 and 2000, when AES had only been implemented for a few years, did not find any positive effect (Donald et al. 2006). Possibly, these general measures need longer time to start delivering biodiversity benefits, at least for short-distance and resident birds. The stabilizing and positive effects of AES on biodiversity found in this study and others (Batáry et al. 2015) may be compromised in the future because in the new CAP (2013-2020), the funding for Pillar 2, which includes AES, has been reduced by 18% and the new Greening measures under Pillar 1 seem unlikely to provide biodiversity benefits (Pe'er et al. 2014).

In this study, we investigated AES regardless of the differences between countries or specific agri-environmental measures (i.e. focus on improving biodiversity, soil quality, water quality, the reduction of chemical use, or a mixture of them). Therefore, we were not able to estimate which agri-environmental measures or country-specific schemes were associated with more positive trends of common farmland birds, but this could be analyzed in follow-up research.

Furthermore, we found that a higher proportion of land designated as SPAs had a more positive effect on population growth rates of the species listed on the Annex I of the Birds Directive suggesting that SPAs had an effect in protecting the most threatened species and generally fulfilling the main role they were designed for. This is in accordance with a recent study in Portugal investigating the effect of conservation areas on farmland bird species which concluded that only protected species benefited from conservation areas, but no positive effect was found for the whole farmland bird community (Santana et al. 2014). Similarly, Donald et al. (2007) found a more positive trend for all Annex I European birds relative to the area of SPAs in 15 EU Member States compared to non-Annex I species. However, SPAs network could improve more generally bird species if current spatial mismatches between high bird species richness areas and protected sites (Albuquerque et al. 2013) were addressed in future site designations.

Short-distance and resident species had higher population growth rates compared to long-distance migrants when areas of SPAs and AES increased. This suggests that different EU conservation measures in agricultural land may be more relevant for species that spend more time in the European breeding areas. Particularly, some AES have measures that improve food availability for wintering farmland birds, which in the UK have been shown to improve population trends of these species (Gillings et al. 2005), and this could partly explain the divergent responses to AES related to the species' migration strategy. Therefore, the conservation measures analyzed in this study, corresponding only to the conditions on the breeding grounds of long-distance migrants, are not likely to be sufficient to improve population decline, which is often attributed to changes on their staging grounds or wintering areas (Sanderson et al. 2006; Vickery et al. 2014). Additionally, beneficial changes in habitat and management practices on SPAs and AES for resident and short-distance migrant bird populations might increase competition with late breeding species, such as long-distance migrants (Ahola et al. 2007). This could explain why environmentally favourable areas were negatively correlated with population growth rates of long-distance migrants. These hypotheses remain to be tested at a more detailed ecological community level.

The above mentioned relationships between the agricultural variables and population fluctuations were only apparent for farmland species, but not for forest birds. This indicates that although this is a correlative study, the factors we suggest as potential drivers most likely mirror causal mechanisms underpinning farmland bird population changes and do not reflect accidental temporal coincidence.

In summary, we found higher population growths of Annex I, and short distance and resident species with increasing SPAs, indicating the value of the Birds Directive in improving some farmland bird populations. The implementation of AES within CAP were related with a moderation of the declines of mainly common farmland bird populations spending all their life cycle in Europe, although it did not seem to fully compensate for the negative effects of agricultural intensification overall, nor reversed the trend. The relationships of farmland bird trends and EU environmental policies reported in this study are relevant at the EU level. This does not necessary mean that AES and the Birds Directive show the same relationships with bird trends in each Member state, since it is known that AES and the implementation of managing plans in SPAs differ largely among countries. Still, we suggest that the creation of more SPAs in agricultural areas in combination with a more widespread application of agri-environmental schemes could contribute to improve the negative trend of farmland birds at the EU level and help reaching EU and global biodiversity conservation goals.

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**Table 1.** Summary of the linear mixed-model investigating the effects of Annex I designation, agricultural intensification, percentage of agricultural land under agri-environmental schemes (% AES), and percentage of agricultural land as special protected areas for birds (% SPA) on population growth rates of common farmland birds. Period duration, body mass and migration strategy are included as controlling effects. The model includes species identity nested in family, and country identity as random intercepts and it is based on 1372 population growth rates from 39 farmland species from 25 EU countries. Reference levels for migration strategy and Annex I designation are “short-distance and resident” and “no” respectively. Significant effects are shown in bold.

| | Estimate | SE | t value | P |
|---|---:|---:|---:|---:|
| Intercept | -0.088 | 0.022 | -4.050 | **<0.001** |
| Agricultural intensification | -0.043 | 0.013 | -3.382 | **<0.001** |
| % AES | 0.017 | 0.012 | 1.482 | 0.138 |
| % SPA | 0.015 | 0.016 | 0.969 | 0.333 |
| Period duration | -0.060 | 0.010 | -5.819 | **<0.001** |
| Body mass | 0.005 | 0.019 | 0.284 | 0.777 |
| Migration | -0.043 | 0.056 | -1.202 | 0.237 |
| Annex I | -0.053 | 0.053 | -0.990 | 0.325 |
| Annex I * % SPA | 0.092 | 0.044 | 2.122 | **0.034** |
| Migration * % AES | -0.074 | 0.020 | -3.756 | **<0.001** |
| Migration * % SPA | -0.055 | 0.026 | -2.135 | **0.033** |

| | | | | |
|---|---|---|---|---|
| Migration * agricultural intensification | 0.031 | 0.023 | 1.333 | 0.183 |

**Figure 1.** Population growth rates of common farmland birds in relation to the (a) percentage of agricultural land designated as SPA (Annex I species in blue and non-Annex I species in red), (b) percentage of agricultural land designated as SPA (long-distance migrants in blue and resident and short-distance migrants in red), (c) percentage of AES (long-distance migrants in blue and resident and short-distance migrants in red), and (d) agricultural intensification (Kg/ha of cereal). Dots represent the raw data of each species in each country, lines represent the model predictions based on the corresponding estimates of main effects and interactions of the LMM presented in Table 1, and bands represent the 95% confidence intervals.