Collapse of farmland bird populations in an Eastern European country following its EU accession

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Abstract
Eastern European countries are considered a stronghold for the continent’s farmland biodiversity. The abundance of farmland birds is one important element of this biodiversity. At the end of the 20th century, member states of the European Union (EU) experienced serious population declines of farmland birds due to agricultural intensification, which was not observed in the Eastern European nonmember states. In 2004, 10 mostly Eastern European countries acceded to the EU. It is thus important to ask whether this historical step resulted in changes of agricultural production and, in turn, in farmland bird populations. Here we used annual crop yields and monitoring data on farmland bird abundance in an Eastern European new EU-member state and showed that agricultural production intensified and farmland bird populations declined steeply after country’s EU accession. These results indicate that entering EU’s Common Agricultural Policy caused significant deterioration of farmland biodiversity in a once biodiversity-rich region.

Keywords
agricultural intensification, biodiversity, birds, Common Agricultural Policy, crop yield, European Union, farmland, population trends

1 | INTRODUCTION

Farmland bird populations mirror the influence of factors shaping biodiversity at the landscape scale (Gregory et al., 2005). They are among the most important biodiversity indicators applied worldwide (Butchart et al., 2010), including the European Union (EU; Gamero et al., 2017). At the same time, populations of farmland birds have declined since the second half of the 20th century both in Europe and North America (Reif, 2013). Studying their decline in relation to some important policy changes is thus important to set the conditions for effective biodiversity conservation in farmland.

Previous studies convincingly showed that the agricultural intensification was the key driver of farmland bird decline at the pan-European level (e.g., Butler, Boccaccio, Gregory, Vorisek, & Norris, 2010), although some other factors such as land abandonment can also contribute to local declines (Wretenberg, Lindström, Svensson, Thierfelder, & Pärt, 2006). Despite the overall pattern of population decline, different European regions showed some variability in farmland bird population trends, typically reflecting differences in various aspects of intensification (Vorisek et al., 2010). For instance, introducing neonicotinoids was associated with particularly steep farmland bird declines in the Netherlands (Hallmann, Foppen, van Turnhout, de Kroon, & Jongejans, 2014), whereas Danish farmland bird populations temporarily benefited from lower amount of pesticides and fertilizers (Fox, 2004).

However, the major part of the regional variability in European farmland bird population trends can be attributed to the
East–West distinction (Donald, Green, & Heath, 2001). Eastern and Western European countries experienced markedly different histories which translated into differences in land use intensity in farmland (Reif, Böhnig-Gaese, Flade, Schwarz, & Schwager, 2011). Eastern European agriculture is less intensive and farm holdings are smaller (Tryjanowski et al., 2011). These conditions are beneficial for farmland biodiversity (Kolecek, Reif, & Weidinger, 2015; Rosin et al., 2016) and thus the Eastern Europe is considered as a stronghold for farmland bird populations (Sutcliffe et al., 2015) with a considerably slower rate of population declines in this region (Donald, Sanderson, Burfield, & van Bommel, 2006).

However, the historical heritage of land use conditions delivering biodiversity benefits may be challenged if the agricultural policy deeply changes. One example of such a change may be represented by joining the Common Agricultural Policy (CAP) following the countries’ accession to EU. Although CAP is composed from different mechanisms including those having biodiversity targets (Pe’er et al., 2017), the largest amount of funding is devoted to subsidies for farmers to increase their agricultural production (Pe’er et al., 2014). We can thus expect that joining the CAP will result in the overall population decline of farmland birds following country’s accession to EU.

The Czech Republic (hereafter called Czechia) was among 10 (mostly Eastern) European countries acceding to the EU in 2004 and its common bird populations have been monitored since 1982. Czech populations of farmland birds thus provide a unique material to test the landscape-scale consequences of joining the CAP. In this study, we compare agricultural intensity and farmland bird relative population size before and after Czechia’s accession to EU. We provide evidence that the agriculture markedly intensified after 2004 and that farmland bird populations have been depleted after country’s EU accession.

2 | MATERIAL AND METHODS

2.1 | Bird data

In Czechia, bird populations are monitored at the national level using a standardized protocol since 1982 within the Breeding Bird Monitoring Programme (BBMP). BBMP is based on fieldwork of skilled volunteers conducted annually at about 100 sites (Reif et al., 2011). Each site consists of 20 points visited twice during a breeding season and the birds are counted for 5 minutes during each visit at each point (Reif et al., 2011). See Reif et al. (2011) for more details on the protocol.

As farmland birds, we considered 29 species (Table S1) based on their habitat requirements described in national literature on avian ecology (Hudec & Šťastný, 2005; Šťastný & Hudec, 2011). Our species set partly overlaps with an earlier study focused on Czech farmland birds (Reif & Hanzelka, 2016), as well as with the species used for the calculation of the national Farmland Bird Index (Hanzelka, Telenský, & Reif, 2015; Vermouzek, 2013). We thus repeated all analyses with these partly different sets of species (Table S1) to judge the robustness of our results to species selection.

Since CAP should have impacts on farmland birds and not on the bird species occurring in other habitats such as woodland, we also considered 48 woodland birds (Table S1) and repeated all analyses with this data set to test the robustness of our results to an accidental temporal coincidence between EU accession and farmland bird decline following the approach of Gamero et al. (2017). We predicted that the Czech woodland birds are not impacted by CAP and thus their populations should not decline following the country’s accession to EU.

Factors affecting bird populations are diverse (Reif, 2013) and agricultural intensification may be thus not the only driving force of the change in abundance of the focal species. Therefore, we considered the following bird traits to control for the influence of other potential drivers (Table S1): (i) migration strategy because long-distance migrants have currently been recognized as declining at higher magnitude than species with other migration strategies (Gilroy, Gill, Butchart, Jones, & Franco, 2016); (ii) life history strategy because species with faster strategies may be more resilient to recent environmental changes (Sanderson et al., 2016); and (iii) climate niche position because species facing negative climate suitability trends show severe declines (Stephens et al., 2016). Species-specific values of both life history and migration strategies were extracted from Kolecek and Reif (2011) who also provide more details on their classification and inference. According to their migration strategy, the species wintering in Czechia were classified as residents (1), the species wintering in Western Europe or in the Mediterranean region as short-distance migrants (2), and the species wintering in sub-Saharan Africa as long-distance migrants (3). The life history strategy was expressed as species’ positions along the gradient from slow (“K-selected”) to fast (“r-selected”) species revealed by a principal component analysis on six life history traits (clutch size, egg mass, body mass, number of broods per year, laying date, length of incubation). Climatic niche position was excerpted from Reif et al. (2013) and calculated as the mean temperature in species’ European breeding range over the 3 months of its peak breeding season.

2.2 | Agricultural data

We used national data on annual per-hectare yields from 1993 to 2016 of the major agricultural crops extracted from Food and Agriculture Organization website FAOSTAT (https://www.fao.org/faostat/en/#data): wheat, barley, rye, maize, and oil-seed rape (Table S2). In total, these crops cover 90% of the cropland area in Czechia and thus account for farmland bird populations before and after country’s EU accession.
for the key changes in agriculture at the national level. We selected the crop yield as a measure of the intensity of agricultural production because it directly shows the amount of goods produced per hectare, which can be reasonably equalled to the intensity of pressure upon farmland organisms in particular years (Donald et al., 2001). Some other measures such as the amount of pesticides and fertilizers are sensitive to changes in the agents applied and are thus less appropriate for comparisons over the long term.

2.3 Statistical analysis

We first tested for differences in agricultural intensity between the first (1993–2004, i.e., before EU accession) and the second (2005–2016, i.e., after EU accession) time period using the linear models having the yields of the focal crops as response variables and the time period as an explanatory variable.

For the analysis of bird data, we used species’ population indices produced by the Czech Society for Ornithology shown at https://jpsp.birds.cz/vysledky.php?menu=indices_trends. These indices were calculated using generalized estimating equations with Poisson error distribution and log link function run within the TRIM software (Pannekoek & Van Strien, 2001). For each species, TRIM models the counts as a function of site and year effects taking the overdispersion and the first-order serial correlation of counts in the time series into account (Pannekoek & Van Strien, 2001). The indices are available for each species from 1982 (start of the monitoring) to 2017 and are expressed as species’ relative abundance in percentage for each year in respect to the first year of the time series (i.e., 1982) arbitrarily set to 100% (Table S3).

We used linear mixed-effect models to relate the species’ yearly relative abundances (the response variable, log-transformed) to the explanatory variables. The explanatory variables with fixed effects were: time period (1993–2004, i.e., before EU accession, and 2005–2017, i.e., after EU accession), migration strategy, life history strategy, and climatic niche position. We assumed 1-year time lag in birds’ population responses. As the real-time lags are unknown and may be species-specific, we used the lag values from 0 to 2 years and repeated the analysis with the start of the second time period in 2004 and 2006, respectively, to judge the robustness of our results to the different time lags in bird responses. We also included year and species nested within genus and family as variables with random intercepts into all models. We first ran the model with the time period as the only explanatory variable to reveal whether the farmland birds’ relative abundance declined after the country’s accession to EU. In the next step, we also included the remaining explanatory variables in the model to test whether the pattern holds even after accounting for their effects. Finally, we ran these models with different settings for species’ lists and time lags (see above) to reveal the robustness of the observed patterns. To visualize the difference in species’ relative abundance between the focal time periods a concise way for all farmland bird species’ together, we calculated the geometric mean of species’ population indices across all species in a given year following the approach of Gregory et al. (2005).

Finally, we tested for a direct link between agricultural intensity and farmland bird abundance to provide a mechanistic explanation for the expected temporal changes in both measures. We expressed bird annual population growth rates as a logarithm of the ratio between population indices for each pair of consecutive years (i.e., $N_{t+1}/N_t$) over our time series and related them to the agricultural intensity using linear mixed-effects models following Gamero et al. (2017) controlling for the effects of density dependence, species’ traits (i.e., migration strategy, life history strategy and climatic niche position) and climatic variables. Agricultural intensity was expressed as the mean yield across the focal crops in the year $N_t$. To account for differences in absolute yield values between crops when, for example, maize yield is generally two times higher than oil-seed rape yield and thus has disproportionally higher influence on the average values, we standardized yield of each crop to zero mean and unit variance across the years. Density dependence was controlled for by including species’ population index in the year $N_t$ into the model. Climatic variables accounted for possible climatic drivers of bird population growth rate: early spring temperature and precipitation (mean temperature and precipitation in March and April in the year $N_t$), late spring temperature (mean temperature and precipitation in May and June $N_t$), and mean temperature of the coldest month (mean temperature in December in the year $N_t$ or mean temperature in January or February in the year $N_{t+1}$ whatever is lower). By including the random effects of species nested within genus and family, we were able to calculate the mean parameter estimates of the focal fixed effects variables across species. Consistently with the previous analyses, we run the models using different species selections of farmland birds and for woodland birds as a control.

We visually checked the normality of residuals of all models using qq-plots.

3 RESULTS

Agricultural intensity, measured as a per hectare yield of five major crops, significantly increased between the first (1993–2004) and the second (2005–2016) time period in Czechia (Table 1). The pattern was consistent across all crops considered and ranged from 19% increase for barley to 29% increase for maize (Table 1, Figure 1).

Relative abundance of farmland birds significantly declined between the same time periods according to the linear mixed-effect models run at the species level (Table 2, panel a).
TABLE 1 Changes in per hectare yield of the main agricultural crops between the time periods before (1993–2004) and after (2005–2016) accession of Czechia to the EU. The values are the least-square means for respective time periods estimated by linear models testing for the difference between the time periods.

| Time period | Barley (kg × 1,000/ha) | Wheat (kg × 1,000/ha) | Rye (kg × 1,000/ha) | Maize (kg × 1,000/ha) | Oil seed rape (kg × 1,000/ha) |
|-------------|-------------------------|-----------------------|--------------------|-----------------------|-------------------------------|
| Mean        | 3.85                    | 10.41                 | 4.57               | 5.89                  | 2.51                          |
| SE          | 0.16                    | 0.004                 | 0.15               | 0.003                 | 0.004                         |
| F            | 17.13                   | 10.24                 | 17.69              | 13.69                 | 13.69                         |
| P            | 0.001                   | 0.004                 | 0.001              | 0.004                 | 0.004                         |

FIGURE 1 Example of the increase of agricultural intensity in Czechia expressed as the mean per hectare yield of wheat (with ±95% confidence interval, CI) between the periods before (1993–2004) and after (2005–2016) EU accession.

The decline was consistent across all species selection approaches (Tables S4 and S5) and was not affected by the length of the time lag between the accession to EU and the start of the second time period, that is, the decline was always large and significant irrespective of whether it was measured 0, 1, or 2 years after the accession to EU (Table 2, panel a). The pattern was also not affected by ecological traits of the farmland bird species considered (Table 2, panel b). Indeed, the change in relative abundance of farmland birds was unrelated to migration strategy, life history strategy and climatic niche position, respectively, and thus the time period was its only significant predictor (Table 2, panel b). Annual changes of the geometric mean of species’ population indices, expressing the overall change in farmland bird populations for all species together, showed the same pattern of decline after the accession to EU (Figure 2).

After controlling for significantly negative density dependent effects, annual population growth rates of farmland birds were significantly negatively related to agricultural intensity, and not to species traits and climatic variables (Table 3). This pattern was robust to the farmland bird species selection (Tables S7, panels a and b).

Repeating the analyses with woodland birds showed that their relative abundance remained unchanged between the two time periods indicating no relationship to the country’s accession to the EU (Table S6). Similarly, their population growth rates were unrelated to agricultural intensity (Table S7, panel c).

4 | DISCUSSION

Our results showed that accession to the EU by Czechia in 2004 was associated with both marked increase in agricultural...
TABLE 2  Results of linear mixed-effects models relating the relative population abundance of farmland birds in particular years from 1993 to 2017 in Czechia to respective predictor variables: the time periods before (1993–2004) and after (2005–2017) accession of Czechia to EU, migration strategy, life history strategy, and climatic niche position. Due to uncertainty associated with bird response to change in agricultural intensity, the start of the second time period varied according to the time lag after EU accession (2004: lag = 0, 2005: lag = 1, 2006: lag = 2). (a) Models with the time period as a single predictor, (b) Full models with all predictors tested in concert. Significant results are in bold.

| Model term                  | Lag = 0 Estimate | SE  | DF  | t    | P    | Lag = 1 Estimate | SE  | DF  | t    | P    | Lag = 2 Estimate | SE  | DF  | t    | P    |
|-----------------------------|-------------------|-----|-----|------|------|-------------------|-----|-----|------|------|-------------------|-----|-----|------|------|
| Intercept                   | −0.06             | 0.21| 695 | −0.27| 0.788| −0.06             | 0.21| 695 | −0.29| 0.772| −0.07             | 0.21| 695 | −0.35| 0.727|
| Time period                 | −0.30             | 0.03| 695 | −8.73| <0.001| −0.31             | 0.03| 695 | −9.27| <0.001| −0.31             | 0.03| 695 | −9.26| <0.001|
| Migration strategy          | 0.04              | 0.30| 4   | 0.15 | 0.889| 0.04              | 0.30| 4   | 0.15 | 0.889| 0.04              | 0.30| 4   | 0.15 | 0.889|
| Life history strategy       | 0.09              | 0.37| 4   | 0.24 | 0.822| 0.09              | 0.37| 4   | 0.24 | 0.822| 0.09              | 0.37| 4   | 0.24 | 0.822|
| Climatic Niche Position     | 0.14              | 0.24| 4   | 0.59 | 0.585| 0.14              | 0.24| 4   | 0.59 | 0.585| 0.14              | 0.24| 4   | 0.59 | 0.585|

(a) Intercept
(b) Full models

*Difference in the farmland bird relative abundance between the time periods before and after accession of Czechia to the EU.

FIGURE 2  Decline of farmland bird populations in Czechia expressed as the change in the mean relative abundance (±95% confidence interval, CI) of all species considered in respect to the year 1982 (0 value) between the periods before (1993–2004) and after (2005–2017) EU accession.

intensity, as well as with conspicuous declines of farmland bird populations. These declines were independent of species selection, time lag after the accession to EU and the factors potentially shaping bird populations in addition to agricultural intensity. Moreover, woodland birds experienced a strikingly different population trajectory. Finally, we showed that agricultural intensity in a given year was negatively related to farmland bird abundance in the subsequent year indicating a mechanistic link between agricultural intensification and farmland bird decline. Taken all these results together, they provide strong evidence that agricultural intensification following Czechia’s accession to EU impacted populations of farmland bird species irrespective of the natural variability in their ecological traits.

These results show that joining the CAP resulted in deterioration of farmland biodiversity (as measured by changes of farmland bird abundance), at least in one of the new EU-member states. The possibility of such negative impacts...
was anticipated even though a CAP reform introducing some greening measures recently came into effect due to dilution of the environmental prescriptions implemented in CAP and leaving the responsibility for their exact design and realization to the individual countries (Pe’er et al., 2014). As EU’s new member states had generally lower income levels than the old member states (for instance, according to the OECD data for 2004, per capita gross domestic product was by 66% lower in Czechia compared to Germany and the average wage was 71% lower), the main target of their inhabitants and representatives was rapid economic growth after the accession to EU, aiming to reach the level of the old member states as fast as possible (Hajek, 2008). It is therefore not particularly surprising that the implementation of the greening measures was not very strong in these countries (Pe’er et al., 2017). Indeed, a recent assessment of the country-level performance of the CAP reform in terms of development of the Ecological Focus Areas discovered that Czechia ranked particularly low within the countries considered (Pe’er et al., 2017). Our study shows that this poor performance in CAP reform in Czechia had most likely adverse impacts on biodiversity represented by farmland birds.

New EU-member states (and the Eastern European countries in general) are considered as a stronghold of EU’s (and generally European) farmland biodiversity (Sutcliffe et al., 2015). For example, even a small country such as Czechia covering less than 0.78% of Europe’s surface hosts 10% of European breeding population of Emberiza citrinella L. and 3% of Carduelis chloris L. (BirdLife International, 2015). It is also well known that the agricultural intensification caused the collapse of farmland bird populations in the old member states (Donald et al., 2001, 2006). For some time, it seemed that the Eastern European countries, experiencing a different land use history (Kolecek et al., 2015), would not join the trajectory of the biodiversity deterioration reported from the Western Europe (Gregory et al., 2005; Vorisek et al., 2010). For instance, the decline of farmland birds slowed down in Czechia in 1990s (Reif, Voršek, Šťastný, Bejček, & Petr, 2008) and the species associated with grasslands even increased toward the beginning of the 21st century (Reif & Hanzelka, 2016). However, it seems that the farmland bird populations in Czechia face the same challenges, which were responsible for the farmland bird collapse in the Western Europe. It is thus possible that the traditional view of the Eastern Europe as a refugee for farmland birds and habitats will be no longer applicable.

Indeed, agricultural land use applied in Czechia was more intensive than in the other Eastern European countries even before the accession to EU (Tryjanowski et al., 2011). Therefore, it is possible that the deterioration of farmland biodiversity following EU accession is even sharper in the other Eastern European countries where the baseline level before their accession was lower in terms of agricultural intensity and higher in terms of farmland biodiversity value than we report here for Czechia. Studies testing whether the patterns reported here also apply to other countries of similar histories are thus urgently needed because some indications of similar patterns have recently been reported from Hungary (Szép, Nagy, Nagy, & Halmos, 2012) and Bulgaria (Spasov, Hristov, Eaton, & Nikolov, 2017).

It is interesting that EU fails on farmland biodiversity, but its nature conservation policy is successful in various other aspects. For example, populations of species listed within the Annex I of the EU’s Birds Directive markedly increased (Donald et al., 2007; Sanderson et al., 2016) and this improvement is even detectable in the new member states (Koschova, Rivas Salvador, & Reif, 2018). Moreover, agri-environment schemes, despite their initially reported mixed biodiversity benefits (Kleijn et al., 2006), are effective in supporting farmland biodiversity locally (Batary, Dicks, Kleijn, & Sutherland, 2015). However, the problem is that these conservation measures are unable to reverse the general trend of farmland biodiversity deterioration (Gamero et al., 2017). To reverse this trend, we suggest that it is necessary to reconsider the CAP in terms of (i) setting clear aims for delivering biodiversity benefits, (ii) increasing the proportion of the budget allocated to biodiversity support, (iii) making the environmental prescriptions more addressed and less diluted, and (iv) setting some basic and strict rules common for all member states involved in CAP.

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**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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