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Short Communication

Agricultural intensification at local and landscape scales impairs farmland birds, but not skylarks (*Alauda arvensis*)

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Abstract

Agricultural intensification constrains the occurrences of birds from local through landscape to regional scales. Here, we tested effects of landscape configuration (comparing regions with small vs. large field size, thereby contrasting former West and East Germany), local farming practice (organic vs. conventional) and within-field position (edge vs. centre) on the abundance and species richness of farmland birds in winter wheat fields, with particular reference to skylarks (*Alauda arvensis*). We surveyed birds by point counts during breeding season within nine pairs of organic and conventional managed winter wheat fields along the Western (ca. 3 ha fields) and Eastern (ca. 20 ha fields) side of the former Iron Curtain in central Germany (n = 18 pairs). Bird abundance and species richness within arable field centres was highest in the small organic fields of the West, whereas skylarks showed a strong preference for open field conditions provided by field centres in the larger fields in East Germany. In conclusion, overall bird abundance and richness within arable fields would benefit from reducing local intensification of farming practices and field size, whereas open-land species such as skylarks benefit from large fields.

Keywords: Edge effect; field size; landscape configuration; organic farming; species richness

1. Introduction

During the last decades, European farmland birds declined rapidly in species and individual numbers including even common species such as House Sparrow (*Passer domesticus*) or skylark (*Alauda arvensis*) (Inger *et al.* 2015). A major reason is agricultural intensification leading to food shortage, lack of nesting and roosting sites at local as well as landscape scales (e.g. Newton 2004). Intensification at the landscape scale led to increase of field sizes, which is a major factor affecting farmland bird diversity as it changes configurational heterogeneity of landscapes (Fahrig *et al*. 2015, Šálek *et al.* 2018). Further, semi-natural habitats such as field edges, fallows, hedges as well as crop type diversity have been lost. Locally, bird diversity is influenced by intensification of farming practice, such as increased application of chemical pesticides and mineral fertilizers (Emmerson *et al.* 2016).

To date, a plethora of studies showed positive effects of increased landscape compositional heterogeneity with higher amount of semi-natural habitat or non-crop area on bird species richness and abundance (e.g. Wretenberg *et al*. 2010, Fischer *et al.* 2011). However, fewer studies focused on landscape configurational effects such as field size differences (but see Fahrig *et al.* 2015, Šálek *et al.* 2018). Response to landscape factors may also vary between open-land species and other bird habitat groups due to diverging attraction to woody structures (Fischer *et al.* 2011).

At a local scale organic farming is a common and still growing form of farming that can reduce farming intensification by diversification of crop rotation and omitting the use of chemical pesticides and mineral fertilizer (Reganold & Wachter 2016). Several studies show positive effects on bird diversity (e.g. Fischer *et al*. 2011), but also negative responses exist (e.g. Kragten & de Snoo 2008). However, there are also studies showing that effects of organic farming are landscape-dependent with a stronger impact of low-intensity farming in simple than complex landscapes (Wretenberg *et al.* 2010, Tuck *et al*. 2014).

Beside landscape and local management, overall species richness and abundance of birds within crop fields might be enhanced by edge effects because semi-natural habitats at the field border such as hedges and trees, provide valuable bird habitat (Heath *et al*. 2017). However, woody structures can also negatively affect ground-nesting open-land species as they typically avoid vertical structures and are expected to be disadvantaged by higher nest predation rates at the field edge (Ludwig *et al*. 2012).

In this study, we analysed the effects of landscape configuration (small vs. large field sizes), local management (organic vs. conventional farming) and within-field position (edge vs. centre) during breeding season on overall bird abundance and species richness, with particular attention to skylark abundance. We compared wheat fields on both sides of the former inner border (Iron Curtain) of Germany with small-scale agricultural landscapes (characterized by small fields) in West Germany and large-scale agricultural landscapes (characterized by large fields) in East Germany (Table S1). We predicted negative effects of larger field sizes as well as conventional farming on bird abundance and richness, which is likely to be more expressed at the field edge than centre. In contrast to overall bird richness patterns, we expected that the typical open-land species, skylark, which nest and forage in open habitats away from field edges would occur in higher densities in larger than smaller fields.

2. Materials and methods

We surveyed birds in nine pairs of organic and conventional managed winter wheat fields (sown in autumn) along the Western (hereafter "West") and Eastern (hereafter "East") side of the former inner border of central Germany (n_{total} = 2 regions × 9 field pairs = 36 study sites; Fig. S1). We selected fields inside the agricultural matrix avoiding the vicinity of forests and built-up areas, and with typical field sizes for the region. Field size was significantly larger in East than West Germany and did not differ between management types (Table S1). Hedge and forest edge length did not significantly differ between regions or management types (Table S1). In East Germany study fields were located near the city of Mühlhausen (Thuringia, 51°13'N, 10°27'E), in West Germany close to the city of Göttingen (Lower Saxony, 51°32'N, 9°56'E). In the East, availability of organic farms was limited, therefore we selected four villages with two organic-conventional pairs and one village with one organic-conventional pair. In a similar way in the West, we selected three villages with one organic-conventional field pair and three villages with two organic-conventional field pairs. If two pairs per village were selected, those two fields of the same management type were farmed by the same farmer (this non-independence was taken into account during the statistical analysis). Management intensity was lower in organic than conventional farming, without application of pesticides, growth regulators or synthetic fertilizers in organic fields (for details see Fischer *et al.* 2018). This resulted in a much higher crop density with lower height in conventional than in in organic fields (Table S1). Straight line distance (mean ± SE) between paired organic and conventional fields was 2.8 ± 1.0 km in East and 0.5 ± 0.1 km in West.

To study potential edge effects, we surveyed birds at the edge and centre of each study field. Straight line-distance between edge and centre survey points was larger in East (200 ± 8 m) than West (100 ± 6 m) due to larger field sizes in East Germany. We measured landscape parameters in a radius of 500 m around the edge points (Table S1). We surveyed birds twice during breeding season between end of April and mid-May 2014 with 14 days break between survey rounds. Simultaneous point counts were conducted by two authors (CG and KK) standing at the field edge (including bordering hedges or trees) and centre. The two bird recorders changed their point count position (edge or centre within each study field) between fields and survey rounds in order to reduce potential bias caused by individual recorder. Point counts were done by entering the survey point, waiting for one minute and recording for five minutes all birds singing or being present within a radius of 50 m. Additionally, during the observations, the two recorders always discussed the questionable individuals immediately after the recording in order to minimize the chance of double counting. We carried out the bird surveys in the first four hours after sunrise, and only on mornings without strong winds and rain. Field pairs were always studied on the same day and directly one after another. Passing birds and aerial hunters such as swallows and raptors were excluded from the data analysis. Maximum count of the two survey rounds was used for further calculations (Bibby *et al*. 1992). Skylark was by far the most abundant species of this study, hence we analysed skylark separately (Table S2).

We analysed the effects of small-scale vs. large-scale agricultural landscapes (West vs. East regions), management type (organic vs. conventional management) and within-field position (edge vs. interior) on bird abundance (without skylark), species richness, and skylark abundance by performing generalized linear mixed-effects models based on Poisson distribution using the lme4 package (Bates *et al.* 2015) of R (R Development Core Team 2017). To take into account our partially cross-nested design, we included the factors 'farmer', and 'pair' nested in 'village' as random effects in the models (see R-syntax below). The factors 'landscape', 'management' and 'field position' were included as single and interacting fixed effects in the model. Full model in R-syntax: "`glmer(y ~ (Landscape + Management + Field Position)^3 + (1|Farmer) + (1|Village/Pair))`". We performed model diagnostics to test for normal distribution of model residuals by investigating normal quantile-quantile plots and plotting model residuals against fitted values to visualize error distribution and look for heteroscedasticity. We calculated all models nested in the global model by the command *dredge* in the package 'MuMIn' version 1.40.0 (Barton 2017) and compared them based on Akaike Information Criterion corrected for small sample size (AICc). We performed model averaging if the top model and subsequent models differed less than two units in AICc. Model-averaged parameter estimates were calculated over the subset of models including the parameter (conditional average) to avoid shrinkage towards zero. Finally, we checked for overdispersion by using the *dispersion_glmer* function of the 'blmeco' package (Korner-

Nievergelt *et al.* 2015), but there was no violation (scale parameters were under or around the value of 1.4 for all models).

3. Results

Overall, we recorded 532 bird individuals belonging to 45 species (details see Table S2). Skylark accounted for 36.3% of all bird records, with 193 individual records. Bird abundance (without skylark) and species richness was higher at the field edge than centre, but in both cases edge effects were weaker expressed for small fields of West compared to the large fields of East due to missing edge-centre differences in organic fields in West (Table S3; Fig. 1a,b). The positive effect of organic field centres in West for bird abundance was also reflected in the significant three-way interaction between region, management, and within-field position. Skylarks were more abundant in large fields of East than in small fields of West as well as at the field centre compared to field edge (Table S3, Fig. 1c). Management type did not significantly affect presence of skylarks.

4. Discussion

Our study revealed that bird abundance (without skylark) and species richness within arable fields benefit from a cumulative effect of smaller field sizes (in former West Germany) and organic farming, whereas neither small-scale agriculture nor organic farming alone could compensate decreased individual and species numbers from field edge to centre. In contrast, skylark, a true open-land species originally evolved in steppes, preferred open-land habitats at a local and landscape scale irrespectively of farming intensity. Decline of bird abundance and richness from field edge to centre can be most likely explained by the presence of hedges and trees at the edge providing breeding, feeding, roosting and sheltering sites for most recorded bird species except ground-nesting open-land species. Skylark, as by far the most abundant ground-nesting farmland bird in our study, avoided edge structures probably due to their general avoidance behaviour towards higher vertical structures (Koleček *et al*. 2015) as well as the increased nest predation risk at habitat edges (Erdős *et al*. 2009). Edge structures decrease with increasing field sizes, thereby causing higher skylark abundance in the large fields of East. Further, less overall edge structures due to larger field sizes are likely to cause a concentration of birds restricted to such habitats, which might explain the higher amount of bird species and individuals in Eastern than Western field edges.

Contrary to some previous findings and our own prediction, decreasing field size or organic farming did not favour bird abundance or richness (e.g. Fischer *et al.* 2011, Fahrig *et al.* 2015, Šálek *et al.* 2018). However, for field centres we could identify that the effectiveness of organic farming was landscape dependent, which is in line with other studies (Wretenberg *et al.* 2010, Tuck *et al.* 2014), but our findings emphasises the importance of organic farming in the small fields of the West. For most species the centre of fields was probably used as a feeding habitat, while hedges or trees at the field edge were used as breeding habitat. These birds fly into crop fields for feeding, but their foraging flights depend on the distance and quality of the foraging site (Bruun & Smith 2003). Potential flight distance between field edges and centres was smaller in West due to smaller field sizes and food supply is expected to be better in small organic fields, where insect and weed seed abundance is higher (shown by Batáry *et al.* 2017 within the same study area). Thus birds might balance their flying costs and quality of foraging site, making it likely that birds prefer to fly into small organic fields where flying distance is short and food supply is enhanced. Nevertheless effects of field size and farming practice are also species-dependent and open-land species such as skylarks might respond differently than other bird habitat groups (e.g. Donald 2002, Fischer *et al.* 2011).

In conclusion, bird abundance and species richness within arable fields profits from an (positive) interaction effect of organic farming and small field sizes, except for skylarks. Hence, local reduction of farming intensity combined by field size reduction at a landscape level might be appropriate to promote farmland bird abundance and richness within arable fields. However, skylarks also need a number of large open fields within agricultural landscapes. I.e. the biological legacy effect of the past management determines the current bird diversity in arable ecosystems with a higher conservation potential of skylarks in the Eastern large, but organic fields, and higher diversity of bird species in edge habitats more common in the West t regional scale.

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Figure captions

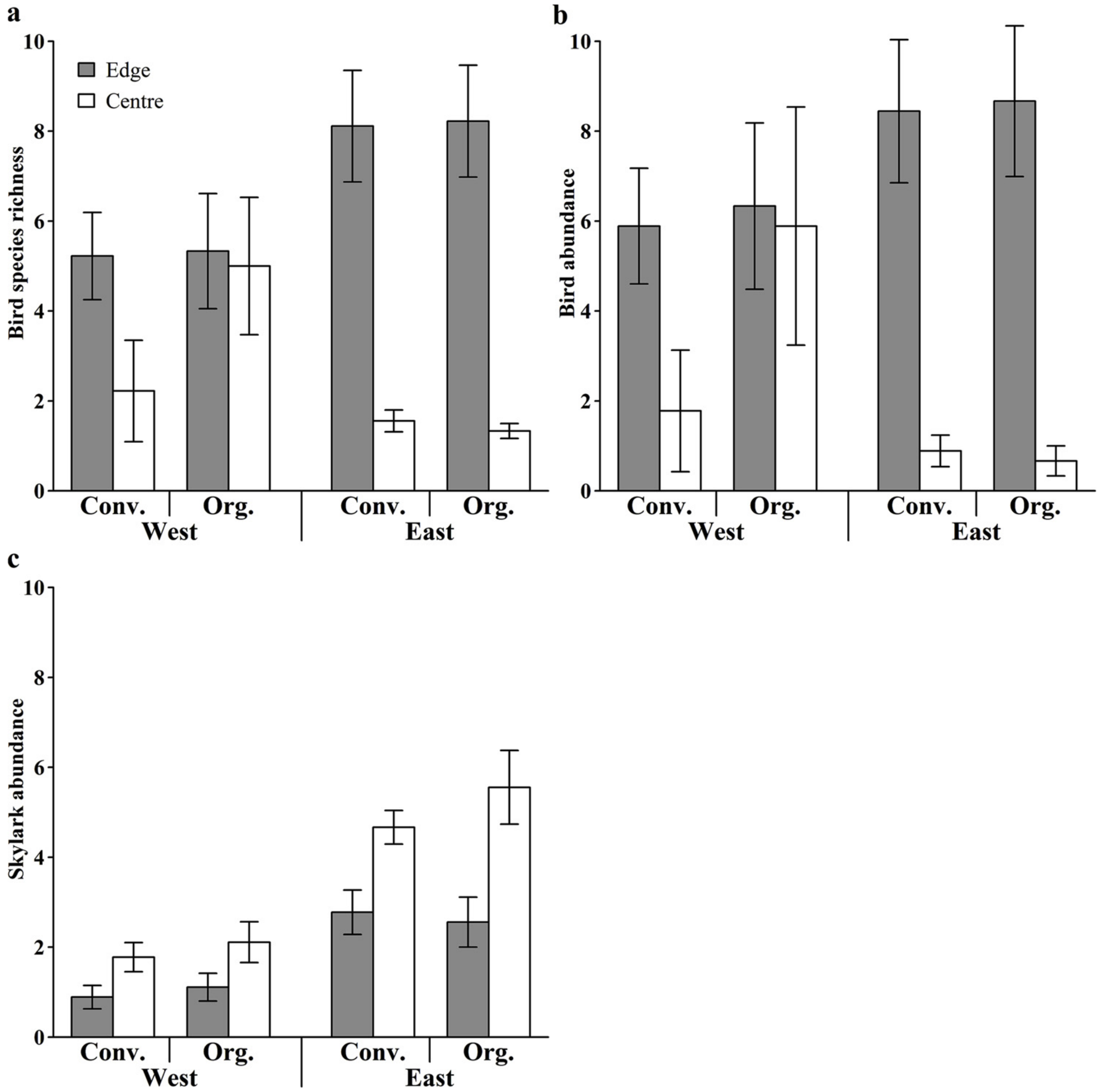

Figure 1. Bird species richness (a), bird abundance without skylark (b) and abundance of skylarks (c) at the edge and centre of conventional (Conv.) and organic (Org.) winter wheat fields in West and East Germany (mean ± SE).