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Grass buffer strips benefit invertebrate and breeding skylark numbers in a heterogeneous agricultural landscape

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ABSTRACT

The loss of non-crop habitat is often suggested to be a key driver of biodiversity decline on arable land. Grass buffer strips on cereal field edges, to reduce erosion and agro-chemical runoff into surface water, could be useful to mitigate this diversity loss as they are often assumed to provide refuge and food for invertebrates, small mammals and birds. Evidence for this idea is, however, scarce and it remains unclear whether densely vegetated buffer strips benefit biodiversity in structurally complex landscapes of Northern Europe. Here, we examined whether buffer strips affected breeding skylark *Alauda avensis* numbers and its main food supply (i.e. beetles *Coleoptera* and spiders *Arachnida*) on cereal fields in a heterogeneous agricultural landscape of south-central Sweden. We also examined whether buffer strip effects on skylark density depended on seasonal sward height differences between sowing regimes (spring- vs. autumn-sown) as they presumably influence seasonal invertebrate accessibility. Fields with buffer strips supported on average 0.51 ± 0.26 more skylark territories per hectare up to 100 m into the field and boosted invertebrate activity densities compared to fields without buffer strips. These effects were most apparent early in spring, but persisted throughout the sampling period, and were similar among spring and autumn sown fields. Thus, our results provide evidence to suggest that buffer strips target multiple environmental objectives on cereal fields in heterogeneous farmland. Future research should work to identify buffer strip management practices that further increase their value to biodiversity at the local scale, and investigate how they affect farmland biodiversity in different landscape types at larger spatial scales for more efficient implementation across Europe.

1. Introduction

Across Europe and North America, increased size of arable fields together with simplified crop rotation has resulted in loss of non-crop habitat and a simplification of agricultural landscapes (Smith et al., 1993; Stoate et al., 2001, 2009). Increased pesticide and fertilizer use has further boosted agricultural productivity, but also imposes a negative impact on surface water quality (Watson, 2004), biodiversity (Fuller et al., 1995; Chamberlain et al., 2000a,b; Donald et al., 2001; Power, 2010), and biological control potential (Straub et al., 2008; Geiger et al., 2010).

Multi-purpose buffer strips have been established on a large scale to mitigate these negative effects of intensified agriculture (Muscutt et al., 1993; Marshall and Moonen, 2002). These densely vegetated strips are typically established on field edges by sowing a mixture of perennial grass species adjacent to streams and larger ditches to avoid soil erosion (Vought et al., 1995), reduce leaching of agro-chemicals from agricultural land (Uusi-Kämppä and Jauhiainen, 2010), benefit invertebrates for pest suppression (Bianchi et al., 2006), and provide habitat for ground-foraging farmland birds (Vickery et al., 2002). However, evidence for positive effects of buffer strips on farmland birds is scarce, as studies on biodiversity effects of field margins often comprise of a variety of margin types that are managed mainly for the conservation of arable plants and pollinators, or provision of food and protection for birds and small mammals (Perkins et al., 2002; Vickery et al., 2002; Marshall et al., 2006; Conover et al., 2009; Douglas et al., 2009).

Without active management buffer strips form tall, dense and species-poor swards throughout the year that limit food accessibility (Blake et al., 2013) for ground-foraging farmland birds such as skylarks *Alauda arvensis* (Weibel, 1998), wheatears *Oenanthe oenanthe* (Low et al., 2010), and yellowhammers *Emberiza citrinella* (Douglas et al., 2009). In the same way that has been shown for field edges, buffer strips may also attract predators and increase nest predation risk (Morris and Gilroy, 2008; Schneider et al., 2012), and may thus be avoided by farmland birds (Vickery et al., 2002; Piha et al., 2003; see also Lima and Dill, 2013; Eggers et al., 2006). Compared to cereal fields, however, buffer strips can provide refuges

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and overwintering habitat for invertebrates (Thomas and Marshall, 1999; Barker and Reynolds, 1999), and relatively more shelter against nest predators (Morris and Gilroy, 2008). Hence, crop fields with buffer strips could still be a preferred option on intensively farmed land (Kuiper et al., 2013).

We assessed how buffer strips affect breeding skylark numbers and activity densities of their invertebrate food in a heterogeneous agricultural landscape of south-central Sweden. Explicitly, we examined whether (1) breeding skylark densities are higher in fields adjacent to buffer strips compared to control fields without buffer strips and if (2) this difference is associated with increased activity densities of their main food supply; namely ground-living beetles *Coleoptera* and spiders *Arachnida* spreading from buffer strips into adjacent cereal fields. Further, as grass strips on spring-sown fields can be assumed to provide relatively more shelter against predators and bad weather in early spring compared to strips on autumn-sown fields (Eggers et al., 2011), we examined if (3) the anticipated positive effect of buffer strips is more pronounced in spring- than in autumn-sown fields.

2. Methods

2.1. Survey area and field selection

The fieldwork was carried out in Uppsala county in the south-central Swedish plain (59°40′ N; 17°15′ E), where the landscape is dominated by crop fields interspersed by forests, small areas of semi-natural grasslands and wetlands (see Fig. S1, Supplementary data). We selected cereal crop fields with ($N = 12$; treatment) and without ($N = 12$; control) buffer strips in 2011 ($N = 6$) and 2012 ($N = 18$). Of the 24 cereal fields, 10 were sown with spring barley *Hordeum vulgare* and 14 with winter wheat *Triticum aestivum*. Fields with and without buffer strips were matched pairwise across multiple criteria to account for potentially confounding effects of year, sowing regime (spring/autumn-sown), field size, ditch size and other landscape elements (see below) affecting skylark breeding numbers and invertebrate abundance. Field pairs consisted of the same crop and were always inventoried the same year. Field size and the distance between landscape elements (i.e. forest edge, semi-natural grassland and farmstead) and the center point of each study plot (see below) did not differ between fields with and without buffer strips (paired *t*-tests, all p-values > 0.4).

To avoid potentially confounding effects of buffer strips and crop management on skylark numbers and invertebrate activity we selected only fields under conventional management. All fields were treated with both fertilisers and herbicides (once), and were accessed through tramlines (i.e. tracks where the tractors drive through the crop parallel to buffer strips). To the best of our knowledge insecticides and fungicides were not applied during the study period. Wheat and barley are sown with a row space of 12 cm with no difference in seed density. Thus, the only difference between crop types (during May–June) was a difference in sward height and leaf density caused by different sowing time.

2.2. Inventory methods

2.2.1. Skylark counts

We counted skylarks with point counts (five visits) in intervals of one week between May 22nd and June 21st. Study plots extended into fields as an arc with a radius of 100 m (approx. 1.57 ha). To define the border of study plots and estimate the location of skylarks we used landmarks (e.g. fence posts, bushes and other structures) and bamboo sticks as reference points. Visits were made in good weather between 8 a.m. and 3 p.m. and the timing of visits to different fields was randomized to avoid biases due to temporal variation in bird activity. To minimize observer effects on skylark activity we waited 5 min after arrival at the study plot before the 5-min bird counts were conducted (Bonthoux and Balent, 2011). The location of all singing skylarks observed within the study plot was recorded on field observation maps.

2.2.2. Invertebrate sampling

In 2012, we placed three pitfall traps (diameter 9 cm) each in the 18 cereal fields: one in the field border, and at 15 and 30 m into the field. Traps were placed in the ground with the rim at the ground level. The pitfall traps were filled with water, and detergent added to reduce surface tension. Plastic roofs prevented rain from filling the traps. Traps were set at the date of the first skylark count (May 22nd) and were emptied each week concurrent with skylark counts. After each bird count we approached traps using tramlines and row spaces (see above) to avoid irreversible changes of crop swards through trampling that could influence invertebrate sampling. After collection, all samples were kept in 70% ethanol until further analysis. From the samples, we counted the number of all beetle and spider individuals larger than 0.5 cm (>approx. 90% of the spider sample). We focused on beetles and spiders since these two orders constitute the majority of the diet of skylark chicks (Holland et al., 2006).

2.3. Statistical analyses

The effect of buffer strips on skylark and invertebrate abundance was assessed with Generalized Linear Mixed Models (GLMMs) using the lme4 package in R (R Development Core Team, 2011). Explanatory variables included presence of buffer strip (presence/absence), sowing regime (spring/autumn-sown) and time (visit number), which were included as fixed effects together with the two-way interactions sowing regime × buffer strip, sowing regime × time and buffer strip × time and the three way interaction buffer strip × sowing regime × time. We also included a squared term for time in season to account for possible non-linearity in seasonal trends, but this parameter was only found to improve the invertebrate models (i.e. lower AIC_c) and was hence dropped from the skylark models. The invertebrate models also included distance to trap from field border and the interaction term trap distance × buffer strip as fixed effects to test whether the within-field distribution of individuals differed between margin types. To account for effects of geographic location of field pairs, we included field identity nested in pairs as random effect. We used an observation-level random effect in our models to account for overdispersion (Poisson-lognormal model).

To compare candidate models, we used an information theoretical approach based on Akaike's Information Criterion with a second-order correction for small sample size (AIC_c) to prevent overfitting. Candidate models were derived using the dredge function in the MuMIn package for multimodel inference (Barton, 2010). Parameter estimates were compiled using model averaging with AIC_c relative importance weights to rank variable importance (Burnham and Andersson, 2002), and included models that had ΔAIC_c values of <4.

3. Results

In total, we made 154 observations of territorial skylarks (including repeated visits from the same field) from 24 fields and we collected 8400 beetle individuals and 2318 spider individuals from 18 fields.