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The contribution of CAP greening measures to conservation biological control at two spatial scales

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ABSTRACT

To promote a more sustainable agricultural production, the European Commission implemented direct payments that require farmers to implement greening measures aimed at reducing negative effects of agriculture on the environment and biodiversity. These greening measures (including fallows and permanent grasslands) have been criticised for their potential inability to conserve biodiversity and promote associated ecosystem services. In this study, we investigate if the presence of old or recently established fallows and permanent grassland in the landscape are beneficial for the emergence, activity density and spillover of ground-running natural enemies and as a result aphid biological control in cereal fields. Lycosidae and Theridiidae were more numerous in fallows (emergence & activity density) compared to crop fields, while Staphylinidae and Linyphiidae showed opposite patterns. Spillover of Lycosidae was significantly higher from fallows into cereal fields, than between cereal fields. As a result of the opposite patterns in activity density in fallows between different groups of predators, a spillover from fallows did not result in a significantly higher aphid control in crop fields adjacent to them. A high proportion of permanent grassland in the landscape resulted in lower emergence of Linyphiidae and Carabidae. Our results support the assumption that a higher emergence and activity density of ground-running predators generally results in higher spillover to adjacent fields. However, patterns of emergence and activity density differed between individual natural enemy groups. Fallows, independent of age, can therefore act as source or sink depending on the focal predator group and more permanent grassland in the landscape can result in lower local emergence. Fallows at the local scale and permanent grassland at larger spatial scales therefore did not generally promote aphid biological control services provided by ground-running natural enemies.

1. Introduction

In order to reduce negative effects of farming on the environment including biodiversity, the European Commission in 2013 introduced so called greening measures to improve the common agricultural policy. To achieve parts of the direct payment, farmers are obliged to preserve permanent grasslands, create ecological focus areas (EFA), and maintain crop diversity (Regulation No. 1307/2013). However, these “greening measures” have received substantial criticism for their inability to conserve biodiversity and promote associated ecosystem services (Pe’er et al., 2014; Dicks and Benton, 2014; Matthews, 2015). In Sweden, for example, the permanent grassland measure is coordinated at the national level and while focussing on protecting permanent grasslands in agricultural landscapes requires no action by farmers (Söderberg, 2016), the crop diversity measure is in practice obsolete (Josefsson et al., 2016). Ecological focus areas, on the other hand, encompass different land-use types (e.g. fallows, uncultivated field borders, and nitrogen fixing crops) that farmers with some exceptions are obliged to implement on 5% of their land. However, there is limited knowledge about environmental and biodiversity benefits from certain EFA’s (e.g. Tzilivakis et al., 2016). Fallow land, a major type of ecological focus area, is for example known for its positive effects on bird, plant and pollinator diversity (e.g. Tscharntke et al., 2011; Toivonen et al., 2015). There is, however, very limited evidence that fallows promote populations of ground-running natural enemies and biological control services in adjacent arable fields (Holland et al., 2016). A recent

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review focusing on EFA's and their effects on ecosystem services concluded that fallows have a negative impact on biological control (Hauck et al., 2014), based on a single study with little relevance for effects on European farming (Liu et al., 2012).

Most studies about effects of fallows on natural enemies and biological control compare population sizes in fallows to other land-use types and generally support the assumption that populations are larger and more diverse in fallows compared to crop fields (reviewed in Van Buskirk and Willi, 2004; Tscharntke et al., 2011). The age of fallows additionally affects invertebrate diversity (Tscharntke et al., 2011) and natural enemies may benefit most from long-term set-aside strategies (Corbet, 1995). These results highlight the importance to consider the quality of different semi-natural habitat types that may qualify as ecological focus areas (see also Sarthou et al., 2014). However, more abundant or diverse natural enemy communities in fallows will not necessarily improve pest control services in adjacent crop fields (Holland et al., 2016). In fact, fallows may act as attractive alternative habitat for natural enemies and therefore reduce the number of predators in adjacent crop fields (Smith et al., 2014). To better understand the contribution of EFAs to populations sizes of natural enemies and the provision of biological control services in adjacent crops, field studies should ideally address the production (emergence, e.g. Hanson et al., 2016) and the activity of natural enemies in ecological focus areas and adjacent crop fields (e.g. Birkhofer et al., 2013), the spillover between adjacent habitats (e.g. Blitzer et al., 2012) and the effect on pest populations (e.g. Rusch et al., 2013) and yield in crop fields (Birkhofer et al., 2016).

Interactions between local and larger scale implementations of agri-environmental schemes affect populations of beneficial organisms and associated ecosystem services (e.g. Rundlöf and Smith, 2006; Diekötter et al., 2010). In addition to local effects of EFA's (Bianchi et al., 2006), the area of permanent grassland in the landscape for example may affect ground-running natural enemies and biological control, due to the provision of overwintering habitats (e.g. Wamser et al., 2011). Ground-running natural enemies (e.g. spiders, ground and rove beetles) are important pest control agents in European cereal farming systems (Lang et al., 1999; Rusch et al., 2013). Due to their important role as natural enemies in conservation biological control and their sensitivity to local and larger scale agricultural land use (e.g. spiders reviewed in Birkhofer et al., 2013) they are ideal model organisms to study effects and interactions between local and larger scale implementations of agri-environmental schemes.

In this study, we address the question if fallows and the area of permanent grassland in the landscape are beneficial for the emergence, activity and spillover of natural enemies and if these effects promote natural enemy numbers, biological control services and yields in adjacent cereal fields. We used a number of established sampling techniques (emergence tents, pitfall traps, drift fence pitfall trapping and predator exclusion barriers) in a common design that includes recently established and old fallows. We hypothesize that fallows have higher emergence of natural enemies compared to cereal fields, with maximum numbers in old fallows (small scale). Large areas of permanent grassland (large scale) are hypothesized to lead to higher numbers of active natural enemies in cereal fields and fallows. Spillover of natural enemies is hypothesized to be highest from fallows into cereal fields. Biological control services would then consequently be highest in cereal fields with an adjacent fallow and rather large areas of permanent grassland in the surrounding landscapes.

2. Material & methods

2.1. Study site and sampling

We selected six study locations per treatment, with each location featuring two adjacent fields. The two fallow treatments either included a "new" (0–3 years after establishment) or "old" (at least 8 years after establishment) fallow with an adjacent cereal field. The "control" treatment consisted of two adjacent cereal fields. Cereal field, old and new fallows are referred to as "field types". In total, we had six pairs of each treatment level (18 total paired sites): 1.) 6 cereal fields next to 6 cereal fields, 2.) 6 cereal field next to 6 old fallow, 3.) 6 cereal field next to 6 new fallow. Cereal fields were 14 spring barley, 8 autumn wheat, 1 rye and 1 oat field under conventional management. Fields were under conventional (non-organic) management, but only 3 out of 24 cereal fields received insecticides and the study areas in cereal fields were always located in an insecticide-free strip of 10 × 40 m. The six locations per treatment were selected along a continuous landscape gradient covering landscapes (radius 1 km) with very little semi-natural grassland to landscapes with larger areas of grassland (range of semi-natural grassland area for each treatment level: "new": 12.0–71.8 ha, mean = 48.6 ha; "old: 15.9–136.5 ha, mean = 72.1 ha; 'control': 2.8–139.3 ha, mean = 56.3 ha). The radius size was selected prior to field site selection to identify sites along an appropriate landscape gradient and because aspects of predator communities in the study region were previously affected at this spatial scale (Rusch et al., 2014; Birkhofer et al., 2016). Semi-natural grasslands were unimproved grasslands not receiving synthetic fertilizers. We used land-use cover data from the Swedish Board of Agriculture's Integrated Administrative and Control System database (IACS, 'Blockdatabasen') to calculate area sizes.

Each field was sampled every 14 days to quantify emergence rates, activity densities and spillover activity of ground-running natural enemies over four sampling periods during the cereal growing season in Southern Sweden (province Scania, sampling periods: 18–22 May, 1–5 June, 15–19 June and 29 June–3 July 2015). Basic structural properties of fallow vegetation (total vegetation cover and maximum vegetation height) were visually estimated (cover) or measured (height) in three randomly placed 1 m^2 quadrates per visit. The plant species composition, cover of bare soil, graminoids and herbs in each fallow was quantified in four randomly placed 1 m^2 quadrates between 22 and 26 June 2015.

To study emergence rates of ground-running natural enemies, study plots with 20 m distance to the adjacent field and 20 m minimum distance to any other field edge were established in all 24 cereal and 12 fallow fields. A single closed emergence tent was established in each plot and was kept in the same position during the sampling period to obtain a measure of the total productivity of the sampled habitat over time (e.g. Idinger et al., 1996; Hanson et al., 2016). Commercially available emergence tents (MegaView ScienceTM) that covered a surface area of 0.6 × 0.6 m, were 0.6 m high and were built from a synthetic fabric with a mesh opening of 0.5 mm were used. To constrain emerging arthropods from escaping or entering the tent, the tent had flaps around the base that were inserted into the soil to a depth of 10 cm. A single bottle attached to the top and one pitfall trap (11.5 cm diameter, 12 cm depth) were used to collect arthropods in each tent. All traps were partially filled with propylene glycol (70%) and some odour-free detergent to reduce surface tension.

To study the density of ground-running natural enemies in all 24 cereal and 12 fallow fields, a single pitfall trap was established 10 m away from the emergence tent and 20 m away from the interface between the two fields in each location. Since pitfall traps do not provide unbiased estimates of the number of ground-running natural enemies, as they for example catch more active species more frequently, we use the term activity density instead of abundance. Pitfall traps to assess activity densities were identical to the traps installed in the tents. In addition, all pitfall traps had a grid made of wire (12.7 mm mesh size) inserted to prevent catching vertebrates and pitfall traps outside the tents had a roof to protect trap content from rainfall (Woodcock, 2005).

To study spillover between the two adjacent fields in each of the 18 paired locations, a single Z-shaped plastic fence was established at the field interface in each location. The fence consisted of a 1.5 m long central plastic barrier and two shorter end pieces of 1 m length. The