



Both woody and herbaceous semi-natural habitats are essential for spider overwintering in European farmland



Laia Mestre^{a,*}, Jens Schirmel^a, Johanna Hetz^a, Sebastian Kolb^a, Sonja C. Pfister^a, Michael Amato^{b,c}, Louis Sutter^b, Philippe Jeanneret^b, Matthias Albrecht^b, Martin H. Entling^a

^a Institute for Environmental Sciences, University of Koblenz-Landau, Fortstraße 7, 76829 Landau, Germany

^b Agroscope, Reckenholzstrasse 191, 8046 Zurich, Switzerland

^c Department of Evolutionary Biology and Environmental Studies, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland

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ABSTRACT

Semi-natural habitats (SNH) support biodiversity and associated ecosystem services on farmland, thereby contributing to sustainable agriculture. However, little is known about the specific suitability of different types of SNH as overwintering habitat for predatory arthropods, despite the crucial role of such knowledge for conservation biological control. We used ground photoelectors to sample spiders in 65 habitats comprising crop fields and four major SNH types (herbaceous areal, herbaceous linear, woody areal, woody linear) across two study regions in Switzerland and Germany to identify the most important overwintering habitats for spiders. Spider emergence started in February and over half of the individuals of the most common spiders had already emerged by late April. SNH supported on average 146% higher species richness and 194% higher densities of spiders than crop fields. Woody and herbaceous SNH supported distinct spider communities, with individual species exhibiting marked preferences for either woody or herbaceous SNH. Habitat shape (areal or linear) had no significant effects on spider overwintering. Woody SNH hosted more species, whereas herbaceous SNH had higher densities of agrobiont species (i.e. species known to reach high densities in crops in the growing season). Given the higher number of overwintering agrobionts in herbaceous SNH, this habitat type has potential to promote pest control by spill-over of spiders into nearby crops early in the season. In contrast, woody SNH seem to be more important for the conservation of diverse spider communities that are highly distinct from those inhabiting open land. Hence, creating and preserving a variety of SNH is key to provide suitable overwintering sites for species in agricultural landscapes.

1. Introduction

After decades of expansion and intensification of cropland and pastures, agriculture is now the largest land use of the planet and covers almost 40% of the ice-free land surface (Foley et al., 2011). Agricultural expansion is one of the main causes of habitat and biodiversity loss worldwide (Foley et al., 2005; Power, 2010), thereby compromising the delivery of ecosystem services to crops, like animal-mediated pollination and natural pest control (hereafter pest control; (Holzschuh et al. (2016); Tschamtko et al. (2008)).

Generalist predators such as spiders provide pest control services on farmland (Riechert and Bishop, 1990; Symondson et al., 2002). Unlike specialists, generalist predators do not depend on the presence of the target pest for survival, so their pest control potential relies on their ability to build high population densities before pest colonization and

limit early-stage pest population growth (Birkhofer et al., 2008; Riechert, 1999). Ensuring early high densities of generalist predators in crops is therefore crucial for effective pest control (Östman et al., 2001; Riechert and Bishop, 1990).

Semi-natural habitats (SNH) are defined by the dominance of native vegetation and reduced management relative to crops (Holland et al., 2016). SNH provide generalist predators with alternative prey and refuges from the regular disturbances of fields (Thomas and Jepson, 1997; Thorbek and Bilde, 2004). The presence of SNH during the crop growing season increases population densities and biodiversity of arthropod predators (hereafter predators), sometimes improving pest control services (Rusch et al., 2016; Tschumi et al., 2015, 2016b). Outside the growing season, most SNH are left less disturbed than fields and offer potentially favorable overwintering conditions to predators in the form of litter or tussocky grasses and undisturbed soil (Sotherton,

* Corresponding author.

E-mail address: mestre@uni-landau.de (L. Mestre).

1984; Thomas et al., 1991). Instead, arable fields are likely to be low-quality overwintering habitats for predators due to regular disturbances and sparse vegetation cover (Andersen, 1997; Pfiffner and Luka, 2000). Therefore, SNH are potentially important sources for recolonisation of crops by generalist predators after winter and their presence is expected to benefit the populations in crops in early spring, when they are most needed to control crop pests (MacLeod et al., 2004; Öberg et al., 2008).

Agrobiont spiders are distinguished from other spiders by their numerical dominance in agricultural fields and are therefore especially relevant for pest control (Samu and Szinetár, 2002). Non-crop habitats hold high population densities of both agrobiont and non-agrobiont spiders during spring (Schmidt and Tscharnke, 2005), but evidence for the relative importance of crops and SNH as overwintering habitat has been mostly indirectly inferred or based on local case studies (Pfiffner and Luka, 2000; Schmidt et al., 2008). Lifestyles and habitat requirements of spiders are often strongly dependent on species identity, with sometimes marked differences among closely-related species (Wise, 1993). Therefore, in order to enhance spider densities for pest control, it is crucial to consider the influence of different SNH on the entire overwintering spider community, and especially on agrobiont species. Indeed, vegetation type (e.g. woody or herbaceous) is a key determinant of the composition of spider communities (Entling et al., 2007). Regarding shape, SNH can be classified as “linear” (e.g. hedgerows and herbaceous strips) or “areal” (e.g. meadows and forests), which cover a larger surface (Fusser et al., 2017; Holland et al., 2016; Pfister et al., 2017). Since edge-to-area ratios decrease with patch surface, assuming immigration to be the main driver of overwintering populations, theory on patch area-density relationships predicts a negative influence of SNH area on population densities for actively dispersing organisms, like spiders, that use edges to orient towards new habitat (Hambäck and Englund, 2005).

The aim of this study was to analyse overwintering spider communities in crop fields and four different major SNH types to compare the suitability of each habitat type for spider overwintering in Central Europe. We selected 14 landscapes across Switzerland and Germany where we installed ground photoelectors in one crop and in one replicate of each SNH type that was located close to the crop. We had the following expectations: (1) each habitat type hosts a distinct spider assemblage, owing to the variation in species-specific habitat preferences in the community. (2) SNH harbour a higher diversity and density of overwintering spiders than crop fields. (3) SNH vegetation type (woody vs. herbaceous) is the main driver of community composition, diversity, and density, whereas SNH shape (areal vs. linear) is only driving densities, which will be higher in linear habitats.

2. Materials and methods

2.1. Study regions

We conducted the study in the northern part of the central Swiss plateau (cantons Zürich and Aargau, N: 47°36', S: 47°21', W: 8°17', E: 8°38') and the Upper Rhine Plain in Germany (Palatinate region, N: 49°16', S: 49°3', W: 8°8', E: 8°23'). The regions are a mosaic of arable and horticultural crops, grasslands, herbaceous field margins, hedgerows and forest remnants. Both regions have a temperate climate, Germany having warmer temperatures (annual mean: 10.2 °C vs. 9.4 °C in Switzerland) and less precipitation (annual mean: 668 mm vs. 1053 mm).

2.2. Sampling design

We focused on five habitat types: an arable crop (oilseed rape in Switzerland, winter cereal in Germany) and four types of SNH defined by their vegetation type (herbaceous, woody) and shape (areal, linear). This resulted in the following combinations: herbaceous-areal (HA; permanent grassland), herbaceous-linear (HL; herbaceous field borders,

grassy strips or flower strips), woody-linear (WL; hedgerows and tree lines) and woody-areal (WA; forests and woodlots) (Pfister et al., 2017). Linear SNH were 1.5–25 m wide (mean: 9.65 m in Germany, 13.83 m in Switzerland), whereas areal ones were > 25 m wide. Woody SNH had at least 30% cover of shrubs and trees (mean: 58% in Germany, 59% in Switzerland). All HL habitats in Switzerland were perennial flower strips: these were over 2 years old and were sown with certified seed mixtures developed for the Swiss agri-environment scheme (Tschumi et al. (2016a); see Supplementary material Table A1 for species used in the seed mixture and Supplementary material Table A2 for detailed information about the ground cover of each habitat type). All SNH had a minimum area of 150 m² and were ≥ 50 m long. Oil seed rape fields in Switzerland were sown end August to beginning of September of the previous year and were managed according to standard agricultural management guidelines for conventional oil seed rape production in the region, including one or two insecticide treatments in spring. Winter cereal fields in Germany were sown in October of the previous year. Management in the region includes one herbicide application in autumn and then again at the onset of the vegetation period until spikes come out, whereas pesticides are applied only in case of high levels of aphid infestation.

In order to replicate the five habitat types with a balanced spatial distribution across the two regions, we selected 14 non-overlapping landscapes with 1-km radius (8 in Switzerland, 6 in Germany) and in each of them we looked for one crop field replicate and one replicate of each of the four SNH types (see Supplementary material Table A3). Not all habitat types were present in all landscapes, so we ended up with 13 crop fields and 13 replicates of each SNH type between the two regions, 65 replicates in total. Crop fields in Germany had one of their sides directly adjacent to one SNH replicate, whereas Swiss ones were bordering other fields or small tracks or roads with crop fields on the other side. All studied SNH replicates within one landscape were ≥ 200 m apart from one another (see Supplementary material Fig. A1).

We established four sampling points in each habitat replicate, two at the edge and two at the interior. However, Swiss crop fields had only two sampling points. Sampling points at the edge were 20 m apart from each other, within the first 2 m from the habitat border (from the side adjacent to the crop in the case of all SNH). In linear SNH replicates, sampling points at the interior were ≤ 12.5 m away from the border and placed in the middle of the SNH, whereas in areal SNH habitats they were 12.5 m away from the border. There were 244 sampling points in total.

2.3. Sampling methodology

We sampled overwintering spiders with ground photoelectors, one at each sampling point. Photoelectors consisted of a rigid frame dug 5–10 cm deep into the soil and covering a surface of 0.25 m², with a mesh tent mounted on a metal support above the frame. Each photoelector had one pitfall and one top bottle. The pitfall was a plastic cup adjacent to the inner border of the photoelector that collected spiders running on the ground. The top bottle was fitted into the tip of the mesh tent to collect spiders crawling upwards. We filled both devices 2/3 with a 30% propanediol solution and some drops of detergent to reduce surface tension. By enclosing an area of ground, photoelectors have important advantages over the more commonly used pitfall traps: first, samples are not biased by the mobility of the individuals and so they yield true density estimates instead of activity-densities like pitfalls. Moreover, catching efficiency is not biased by the habitat ground cover. Finally, the ecological meaning of samples is straightforward, inasmuch as all collected individuals have overwintered in the enclosed area, whereas pitfall traps also capture individuals migrating between habitats.

We set up photoelectors before first emergence according to the weather conditions of each region and collected samples every 2 weeks until June, seven times in Germany (February 24th–June 4th) and six

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