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Overwintering of pollen beetles and their predators in oilseed rape and semi-natural habitats

Louis Sutter[a,*], Michael Amato[b], Philippe Jeanneret[a], Matthias Albrecht[a]

[a] *Agroecology and Environment, Agroscope, Reckenholzstrasse 191, CH-8046, Zürich, Switzerland*
[b] *Center for Environmental Management Military Lands, Colorado State University, 631 South Mason St., Fort Collins, CO 80523, United States*

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ABSTRACT

Semi-natural habitats (SNH) maintain high levels of biodiversity and ecosystem functioning within agroecosystems. While management recommendations for SNH to promote biodiversity and optimize natural pest control, have mostly focused on improving food resources for predators, overwintering conditions have hitherto received less attention. The success of conservation biological control is often hampered by a lack of knowledge on how different habitats and their associated traits drive the overwintering of both, crop pests and their natural enemies. Moreover, there are concerns that SNH may act as reservoirs for crop pests.

We investigated the overwintering of pollen beetles (*Meligethes* spp.) and their predators (predatory ground beetles) across 40 habitats of all major types of SNH as well as 8 winter oilseed rape (WOSR) fields, to identify the importance of type and key traits of habitats. Overwintering of pollen beetles was higher in WOSR fields (7 individuals per 0.25 m^2) and forest edges (4) compared to flower strips (2) or forest interiors (1). Similarly, overwintering of predatory ground beetles was higher in forest edges and WOSR fields (11 and 10 individuals, respectively) than in flower strips, meadows or hedgerows (4, 4 and 2 individuals). The predator-prey ratio (number of predatory ground beetles / number of pollen beetles) was higher in forest edges than in flower strips, meadows or hedgerows, and intermediate in WOSR fields. Pollen beetle numbers were negatively associated with increasing litter cover and positively with increasing bare soil, while predatory ground beetles were positively associated with soil bulk density and bare soil cover. The proportion of SNH at the landscape level (1 km radius) did not affect overwintering pollen beetles, predatory ground beetles or predator-prey ratio.

We conclude that WOSR fields, rather than SNH are the major overwintering habitat and source of spring colonisation of WOSR by pollen beetles. Forest edges promote predatory ground beetles rather than pollen beetle populations according to their disproportionally high value of overwintering individuals. Agri-environmental measures to promote predatory ground beetles rather than pollen beetles should promote overwintering habitats with compact soils and high litter cover.

1. Introduction

Agricultural landscapes are typically composed of crops and various types of uncropped, semi-natural habitats (SNH). SNH play a vital role for sustaining biodiversity in agricultural landscapes and the functioning of agroecosystems (Landis et al., 2000; Tscharntke et al., 2012). They provide essential resources for beneficial organisms, e.g. natural enemies of crop pests, such as food resources, shelter and overwintering habitat (Holland et al., 2016; Sarthou et al., 2014; Thorbek and Bilde, 2004). During the growing season of crops, SNH can enhance population densities and the diversity of natural enemies, thereby improving natural pest control services (Rusch et al., 2016; Sutter et al., 2018; Tschumi et al., 2015). Outside the crop growing season, SNH can provide valuable overwintering habitats from which natural enemies can recolonize crops (Landis et al., 2000; Pfiffner and Luka, 2000; Sarthou et al., 2014). The availability of suitable overwintering habitats in agroecosystems is therefore a key component of successful conservation biological control (Griffiths et al., 2008; Landis et al., 2000; Leather et al., 1995). In fact, the proportion and composition of SNH at the landscape scale may be an important factor shaping communities of crop pests and their natural enemies (Bianchi et al., 2006). For example, the abundance of predatory ground beetles and predation of pollen beetles in WOSR fields can be positively related to the proportion of SNH in the agricultural landscape (Sutter et al., 2018). But much less is

* Corresponding author at: Agroecology and Environment, Agroscope, Reckenholzstrasse 191, CH-8046, Zürich, Switzerland.
E-mail addresses: louis.sutter@agroscope.admin.ch (L. Sutter), mjamato@gmail.com (M. Amato), philippe.jeanneret@agroscope.admin.ch (P. Jeanneret), matthias.albrecht@agroscope.admin.ch (M. Albrecht).

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known about the role of SNH at the landscape scale affecting overwintering communities of crop pests and their natural enemies (Sarthou et al., 2014).

Moreover, different SNH types vary greatly in characteristic habitat traits including vegetation cover, plant species composition, amount of litter or soil characteristics such as soil microclimate or soil compaction and thus likely vary in their value as overwintering habitat for natural enemies and other functional groups (Sarthou et al., 2014; Sotherton, 1984; Thomas et al., 1991). Furthermore, generalist predator species may also be able to overwinter in crop fields (Pfiffner and Luka, 2000), but few studies have compared overwintering of natural enemies in crops and different SNH types.

On the other hand, SNH may also promote overwintering of crop pests (Alford, 2003; Leather et al., 1995) but little is known about the potential of SNH or crop fields to support pest overwintering. However, Pywell et al. (2005) found that overwintering of several oilseed rape pests was higher in hedgerows than in field margins, yet not considering other types of SNH. The relative importance of different SNH compared to crops as spring reservoirs for pests therefore remains poorly studied and potential trade-offs between habitat management to promote overwintering of natural enemies and unintended concomitant increases of crop pests, has received little attention so far. Such potential trade-offs have been recognized with respect to the selection of plant species for floral enhancement measures as part of conservation biocontrol programmes though. Selecting plant species according to resource needs, accessibility and preferences of target natural enemies like parasitic wasps, while avoiding plants that concomitantly promote arthropod pests are crucial for the effectiveness of floral enhancements (Wäckers and van Rijn, 2012; Winkler et al., 2010). Farmers are well aware of possible trade-offs of implementing SNH and potential pest spill over into nearby crops and addressing their concerns is a key to promote the uptake and implementation of agri-environmental measures (Home et al., 2014). It is therefore crucial to improve our understanding of the importance of different SNH and crops as overwintering habitat for different natural enemies as well as crop pests. This knowledge is a prerequisite to better predict the potential contribution of SNH to pest control and to guide habitat management strategies to maximise pest control services while minimizing disservices (Gillespie and Wratten, 2017; Tscharntke et al., 2016; Zhang et al., 2007). To improve our mechanistic understanding of the factors driving the overwintering of natural enemies and crop pests, and to be able to guide habitat management, it is also important to grasp which traits of habitats favour the overwintering of natural enemies rather than pests. In addition, a better understanding of the traits driving overwintering of different functional groups and how these traits are distributed among different habitat types in agricultural systems will contribute to better informed management decisions.

Here, we address these knowledge gaps by simultaneously investigating the overwintering of a key pest of winter-sown oilseed rape (hereafter WOSR), the pollen beetles (*Meligethes* spp., Coleoptera: Nitidulidae), and its potential predators (predatory ground beetles) across a range of SNH types (forest edges, forest interiors, hedgerows, meadows and flower strips), as well as WOSR fields.

In particular, we addressed the following objectives:

a Determine the relative importance of the different types of SNH and WOSR fields as overwintering habitat for pollen beetles and their potential predators, in interaction with the SNH's available at the landscape scale.
b Compare predator-prey ratios across these habitat types to further assess their relative contribution to predators vs. pollen beetle overwintering.
c Improve our mechanistic understanding of specific habitat traits that affect overwintering of pollen beetles and their predators and how these traits are distributed among habitat types.

2. Materials and methods

2.1. Study system and sampling design

Oilseed rape, *Brassica napus* L. is amongst the most important food, fodder and biofuel crops worldwide (FAO, 2016). Several pest species impose usage of phytosanitary products in conventional WOSR production that could potentially be reduced if natural pest control is reinforced to mitigate yield loss (Alford, 2003). Thus, there is a high potential for habitat management measures to promote natural pest control services in organic, but also conventional WOSR production. The pollen beetle, is among the most important WOSR pests causing severe yield losses (Alford, 2003; Bartomeus et al., 2015; Sutter and Albrecht, 2016). After overwintering in the litter and soil layer of a variety of habitats, adult pollen beetles colonise WOSR plants and cause damage by feeding on flower buds. Adult pollen beetles lay their eggs on flower buds and open flowers where the emerging larvae feed on pollen and once fully developed drop to the ground for pupation. Two weeks later they emerge as adults and forage on a variety of plants before overwintering.

The study was conducted in the northern part of the central Swiss plateau (cantons Zurich and Aargau, N: 47°36′, S: 47°21′, W: 8°17′, E: 8°38′), in a region with agricultural landscapes characterized by a small-scaled mosaic of arable crops and SNH such as permanent grasslands, hedgerows, and flower strips (defined as ecological focus areas within the Swiss agri-environment scheme, Bundesrat, 2015). Eight different landscape sectors (1 km radius) were selected along a landscape complexity gradient based on the amount of SNH (range: 7–56%). Landscape composition was assessed based on satellite images and available land cover maps (SWISSIMAGE, swisstopo, Wabern). Each landscape contained all six habitat types to be investigated: WOSR fields and 5 of the major SNH types of the study regions: (1) sown species-rich, perennial (3–4 years old) flower strips (hereafter flower strips; see Sutter et al. (2018) and Tschumi et al. (2016) for detailed description of the species composition and management), (2) perennial meadows (hereafter meadows), (3) hedgerows associated with a 3m-wide grassy margin (hereafter hedgerows), (4) forest edges and (5) forest interiors ($>$ 12.5 m distance from forest edge; (Pfister et al., 2017)). The forest type across all sampling sites were very similar, namely: coniferous stands intermixed with a few species of deciduous trees used for the production of wood. WOSR fields were selected such that no SNH was bordering the field. All investigated WOSR fields were directly adjacent to another crop field (e.g. winter wheat). The WOSR fields were in a rotation of 4–6 years with usually 4 different crops in rotation. They were sown end of August to beginning of September 2013 into conventionally ploughed and prepared fields. All studied WOSR fields were managed according to standard agricultural management guidelines for conventional WOSR production in the region, including one or two insecticide treatments in spring. Selecting all overwintering habitats in each landscape sector ensured that the effect of local overwintering habitat type was not confounded with landscape complexity. Sampled habitats (sites) within each landscape were separated by at least 200 m and had a minimal area of 150 m^2. In WOSR fields, forest edges and forest interiors two sampling points (emergence traps, see below) were selected and four in flower strips, meadows and hedgerows. The sampling sites were placed either in the middle of the habitat or in habitats larger than 25 m at a maximum distance of 12.5 m from a randomly selected habitat border (Pfister et al., 2017).

2.2. Insect sampling

Emergence traps (photoeclectors; 144 traps = sampling points in total) were used to capture insects emerging from the soil and leaf litter layer after overwintering (Sarthou et al., 2014). Trap frames (solid metal, dug 10 cm deep into the soil) of 50 × 50 cm were covered with a dark mesh fixed on a pyramid-like metal structure. Each emergence