



## Research paper

## Positive effects of local and landscape features on predatory flies in European agricultural landscapes

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## ARTICLE INFO

## Article history:

Received 21 September 2016

Received in revised form 20 January 2017

Accepted 21 January 2017

Available online xxx

## Keywords:

Hoverflies

Dance flies

Long-legged flies

Landscape complexity

Conservation biological control

Field margin

## ABSTRACT

Provisioning of suitable habitats for predatory insects in agricultural landscapes can improve natural pest control and hence the sustainability of agriculture. Apart from Syrphidae, the spatial ecology of predatory flies remains little studied. We investigated the response of Dolichopodidae, Empididae and Syrphidae to local features of seminatural habitats and to the composition of the surrounding landscape. We sampled adult predatory flies with pan traps in 183 field-bordering seminatural habitats along gradients of landscape composition in Italy, Germany and Switzerland. Local habitat type, the composition of the surrounding landscape and proximity to watercourses affected the abundance of predatory flies. Across countries, Empididae and Syrphidae were more abundant in woody (i.e. forests and in particular hedgerows) than in herbaceous habitats, whereas Dolichopodidae had lowest abundance in forests. The abundance of Dolichopodidae in Italy and Empididae in Germany were furthermore enhanced by the proximity of watercourses. Abundance of Dolichopodidae increased with the proportion of seminatural habitats in 1 km radius. Empididae were more abundant in landscapes with higher proportion of forests. We identified hedgerows as favorable habitats for predatory flies in agricultural landscapes. Moreover, our study reveals the importance of proximity to watercourses, which has rarely been considered when studying natural enemies of pests in agroecosystems. The varying responses indicate that preserving or restoring habitat-diverse, heterogeneous landscapes guarantees high numbers of predatory flies across families.

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## 1. Introduction

Ecosystem services provided by beneficial organisms such as pollination and pest control can be supported by habitat and landscape management (Garibaldi et al., 2011; Rusch et al., 2016; Shackelford et al., 2013). In agro-ecosystems, seminatural habitats (SNH) play an important role for these beneficial organisms by providing larval habitat, refuge during disturbances, overwintering sites and alternative food resources (Holland et al., 2016). Their value for beneficials such as natural enemies of crop pests may, however, strongly depend on the type of locally present SNH, as well as their proportion and spatial distribution at the landscape

scale (Holland et al., 2016; Rusch et al., 2016; Shackelford et al., 2013). Improving our understanding of the relative importance of different SNH types across spatial scales is crucial to enhance the effectiveness of pest control management (Jonsson et al., 2008; Tschardt et al., 2012), but large-scale data across a large number of SNH and landscapes across multiple countries is scarce (Holland et al., 2016).

Most existing studies investigating the potential of SNH to promote predatory insects have focused on a relatively small number of potentially important taxa. In this context predatory flies (Diptera) have rarely been studied except of syrphid flies (Syrphidae), which are important for aphid control and additionally for pollination (Bianchi et al., 2006; Chaplin-Kramer et al., 2011; Skevington and Dang, 2002). Diptera are a diverse and common insect group, which occur in a wide range of terrestrial and freshwater habitats all over the world. They are an important part of the food chain and contribute to several ecosystem services including pest control (Skevington and Dang, 2002). Worldwide, species of at least 42 dipteran families are known to be predacious

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in their main feeding stage as larvae, especially on beetles, bugs and other flies. Some predatory flies, such as long-legged flies (Dolichopodidae), robber flies (Asilidae) and the majority of dance flies (Empididae) are predators also as adults (Skevington and Dang, 2002). They are abundant in crops (Frouz and Paoletti, 2000; Zöphel et al., 2001) and prey on soft-bodied pests of arable and horticultural crops such as aphids (Aphididae), gall midges (Cecidomyiidae) and psyllids (Psyllidae) (Bortolotto et al., 2016; Rieux et al., 1999; Stark and Wetzel, 1987). Moreover they are important predators of black flies (Simuliidae) and lake flies (Chironomidae) (Ivković et al., 2007, 2012; Ulrich, 2004; Werner and Pont, 2003). However, little is known about how and over what spatial scales SNH drive densities of predatory flies in agricultural landscapes.

For several biological reasons, predatory flies may respond differently to diverse SNH types and to their abundance in the wider landscape. First, larvae of Empididae and of many Dolichopodidae live in the soil, in rotting vegetation, under bark or in freshwater habitats (Bickel and Dyte, 2013; Smith, 2012; Ulrich, 2004). They are usually associated with moist conditions and therefore are often more abundant in shaded habitats, such as hedgerows and forests (Cauwer et al., 2006; Gelbič and Olejníček, 2011; Pollet and Grootaert, 1996). Secondly, some Empididae (especially Empidinae), Dolichopodidae and almost all Syrphidae use flower resources as adults and may therefore prefer flower-rich habitats (Smith, 2012; Ulrich, 2004). Finally, many predatory flies require multiple habitats to complete their life cycle and therefore are quite mobile. For example, Empididae use different habitats (herbaceous habitats, water bodies, hedgerows) for larval development, feeding, swarming and mating (Delettre et al., 1992, 1997; Frouz and Paoletti, 2000). Thus, abundance and species richness of Empididae may be highest in heterogenous and complex landscapes with high amounts of different types of SNH (Burel et al., 2004; Delettre et al., 1997). Indeed, it could be hypothesized that most predatory flies may respond to SNH at a larger (landscape) scale compared to other beneficials due to their relatively high mobility and because they are not central place foragers such as

bees, for example (Jauker et al., 2009; Rader et al., 2016; Sommaggio, 1999).

In the present study, we studied Dolichopodidae, Empididae and Syrphidae across different types of SNH along gradients of landscape composition in 50 agricultural landscapes from three European countries. We addressed the following research questions:

1. Do woody habitats harbor more predatory flies than herbaceous habitats?
2. Does the proximity of watercourses enhance predatory fly densities?
3. Does proportion of SNH at the landscape scale enhance predatory fly densities and shape effects of the local SNH type?
4. How do the responses to local and landscape features differ between predatory fly families?

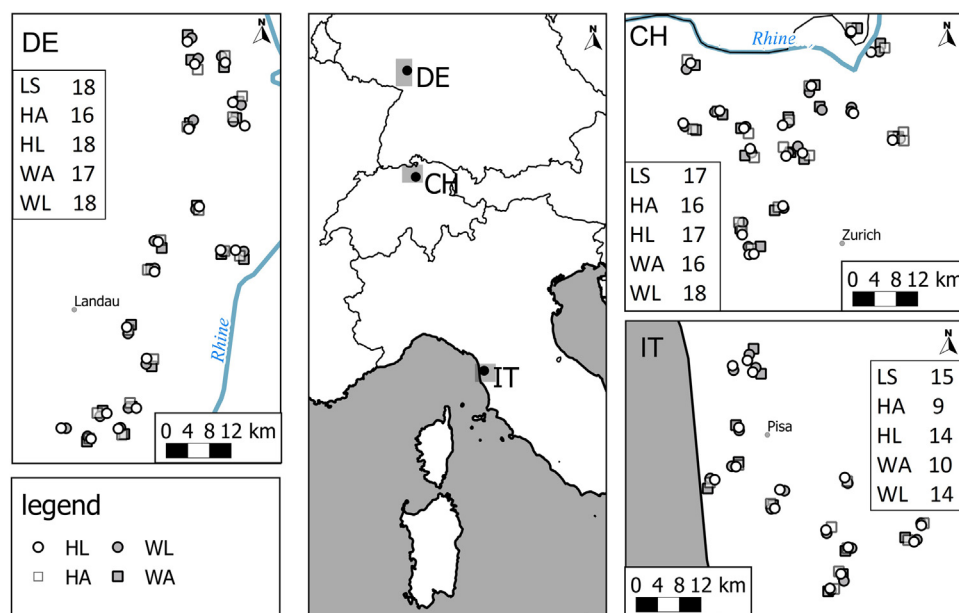
## 2. Methods

### 2.1. Study areas and site selection

The study was conducted in 183 seminatural habitats (local scale) in 50 agricultural landscapes (landscape scale) in three European Countries: Germany, Switzerland and Italy (Fig. 1).

In Germany, SNH were located in the Upper Rhine Valley between Kandel and Ludwigshafen (N: 49°4' to 49°27', E: 8°28' to 8°6'). The region is characterized by intensive agriculture with only few grassland and forest fragments. Elevation ranges from 90 to 160 m a.s.l. The climate is warm temperate with warm summers and fully humid (Kottek et al., 2006). The annual mean temperatures are around 10.5°C and annual precipitation is 667 mm on average.

In Italy, SNH were located in the Pisa Plain, around the city of Pisa (N: 43°50' to 43°31', E: 10°17' to 10°40'). The Pisa plain is an alluvial plain characterized by intensive agriculture established mainly on reclamation area. Hedgerows are often present around



**Fig. 1.** The three study sites in Germany (DE), Switzerland (CH) and Italy (IT) (overview in the map in the centre): The location of the sampled SNH (38 HA = grasslands/fallows, 48 HL = grass margins, 43 WA = forests/shrubland, 49 WL = hedgerows) is shown for each country in an inset.

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