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High degree of philopatry is required for mobile insects used as local indicators in biodiversity studies

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ABSTRACT

Local changes in land use and climatic conditions provoke transformations of habitats and therefore, distribution changes of species in the landscape. Different insect groups are repeatedly used as indicators of local ecological conditions in biodiversity research. Here we suggest that only highly philopatric groups can be relevant indicators pointing to differences in ecological conditions among spatially close habitats. For our study in open agriculture landscape, we chose aculeate Hymenoptera and hoverflies as two insect, mostly pollinator groups differing in their degree of philopatry within the registered pool of our survey where hoverflies were represented by common generalist species showing high mobility. We tested if these groups appeared in significantly different species numbers in two most contrasting habitats typical for the European open agriculture landscape: patches of flower-rich, semi-natural habitats around fields with a variety of nesting sites and wheat fields in proximity that represented a non-viable agricultural habitat with no nesting and foraging opportunities. For this purpose, comparison of results from attractant based (pan traps) and observational (transect walks) methods were used. Philopatric species were detected in significantly different species numbers in the two habitat types using both methods. In contrast, highly mobile non-philopatric species showed a mixed pattern. We assume that these species can be attracted at any place if containing a suitable attractant (flowers or pan traps in this case) what may not indicate their actual living in the habitat.

1. Introduction

Recently, local changes in climate or land use have been causing transformations of habitats and therefore, new repartition of species in the landscape (Parmesan et al., 1999; Falcucci et al., 2007). This trend is expected to continue (Bellard et al., 2012).

Several insect groups are commonly used as indicators of ecological conditions to describe recent habitat transformation. They are usually insect orders or families that are numerous and widespread and can be identified with a reasonable effort, e.g. wild bees (Papanikolaou et al., 2017) and butterflies (Parmesan et al., 1999). For the same reasons, hoverflies are also included in many studies (Sommaggio, 1999; Billeter et al., 2008). Duelli and Obrist (2003) suggest that biodiversity indicators must be chosen according to the specific goal of a biodiversity study, and its value system. We propose that the degree of philopatry is a key ecological characteristic in biodiversity research as it determines the scale an indicator tells us about. Here, philopatry is considered as a fidelity of an individual to the habitat providing reproduction sites (and also, nesting sites in case of nesting animals) as well as food resources. It is a trait that derives from the biology of the species. We suggest that only groups with high degree of philopatry are suitable indicators of local ecological conditions for surveys on a small scale as within this study where tiny portions (approximately 100 m^2) of two different habitats placed only several hundred meters apart were investigated.

In this survey, we focused on two mainly pollinator groups of open agriculture landscape differing in their degree of philopatry within the species pool of our study. Aculeate Hymenoptera are mostly strongly attached to their nest and look for floral resources, or invertebrate prey as close to it as possible (Westrich, 1996). Their flight distance derives from their body size with typical homing distance varying from 100 m to more than 10 km (Greenleaf et al., 2007). However, even in the largest solitary bees, vegetation of only 300 m around the nest is crucial for survival of more than 50% of the population (Zurbuchen et al., 2010). Aculeate Hymenoptera have species-specific habitat preferences

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and, within the life of an individual, they show a strong site fidelity to a very limited area of only a few hundred square meters around the nest where most of them return daily. In contrast, hoverflies do not have any nest. Sexually mature females lay eggs in an environment conducive to the development of larvae e.g. close to aphid colonies, in mud, etc., depending on ecology of the species (Sommaggio, 1999) and do not need to return to that area as they do not feed their offspring. Even though hoverflies are not nesting insects, they also show a habitat fidelity with the range of habitat preferences and general mobility differing among species. There are many mostly spring to mid-summer species requiring specific habitat conditions e.g. alluvial forest or open ground in wetland and moreover, some showing even strong site fidelity (Speight, 2016). These narrow habitat preferences can make them good indicators of local ecological conditions in biodiversity studies (Ssymank, 2002). Nevertheless, most common summer generalist species typically inhabiting open agricultural landscapes, what was actually the pool of our study, are highly mobile and even migrant species (Speight, 2016) that can be found in wide range of habitats within this landscape type (Marshall and West, 2006). Therefore, what may differentiate the philopatric and non-philopatric group within this study is the scale that is referred to as its habitat. While philopatric behavior is here considered as a fidelity to a specific habitat within the open culture landscape (e.g. wheat field, open herbaceous uncultivated semi-natural habitat around fields), non-philopatric behavior is actually a fidelity to the whole open culture landscape comprising a variety of smaller distinct habitats.

The objective of this study was to determine whether both insect groups with low and high degree of philopatry are suitable for indicating inter-habitat differences in ecological conditions within a very restricted territory. More specifically, we test if there exists any difference in aculeate Hymenoptera and mainly common generalist hoverfly species richness obtained by pan trap and transect walk sampling between a rather rich and a non-viable habitat in terms of foraging and nesting opportunities.

We suppose that philopatric species will point to a significant difference between a rich and a non-viable habitat while, based on the occurrence of non-philopatric species, the two contrasting habitat types should appear as identical.

2. Materials and methods

2.1. Study site and design

The experiment was carried out in 2016 at 7 localities in the Czech Republic (50.0360, 14.6192; 50.0878, 14.2990; 50.1187, 14.2311; 49.5496, 14.9579; 49.6029, 14.2545; 49.5478, 14.3584; 50.0086, 14.8779). At each locality, we chose two sites representing two habitat types that contrasted in foraging and nesting opportunities for pollinators: a flower-rich, semi-natural habitat and a winter wheat field as an example of nearly non-viable agricultural habitat typical for Central European landscape. Only strictly weedless wheat fields with no presence of aphids observed were chosen for the study in order to avoid additional food resources for the insect groups studied. The selected semi-natural habitats were non-cultivated areas providing both relatively high species-richness of dicotyledonous plants and a variety of different nesting opportunities. More specifically, they were patches of open uncultivated herbaceous areas around fields with occasional shrubs or trees that are not managed and are left unmown. We selected the closest semi-natural habitat meeting our criteria that was above the minimal distance of 350 m from the sampling area in wheat field – just above the distance of 300 m from the nest that is considered as vital for most individuals within bee populations (Zurbuchen et al., 2010) – in order to minimize any interference between the habitat types within one locality but by maintaining the same general character of the surrounding landscape.

2.2. Insect sampling

We analyzed the performance of two commonly used sampling methods: (1) yellow pan traps, (2) standardized transect walks. Pan traps are considered as the most efficient sampling method for bees and wasps with the highest species coverage in agricultural and semi-natural habitats and transect walks were determined as the second most powerful sampling method showing complementarity to pan traps in species coverage (Westphal et al., 2008). Yellow pan traps showed to be convenient also for sampling hoverflies (Bowie, 1999; Laubertie et al., 2006). Transect walks are likewise a commonly used method for assessing local species richness of both groups also because of the possibility to detect plant-pollinator interactions (Dicks et al., 2002; Jauker et al., 2009).

The sampling took place at monthly interval three times during the summer from the end of June (mostly milk stage of wheat) to the beginning of September (harvested wheat). At each site, the sampling methods were used on the same days.

In the wheat fields, the corridor where the sampling took place was 90–130 m far from any field edge in order to minimize the effect of the surrounding vegetation on sampling. While in the semi-natural habitats, we focused on spots with the highest plant diversity providing most floral resources. The sampling was carried out during suitable weather conditions for studied insects: minimum of 18 °C, low wind, no rain, and dry vegetation.

The standardized transect walks took place in a corridor of 100 m × 1 m. All transect walks were done by one surveyor in order to have uniform collector bias throughout the study. Species that could not be identified in the field were collected with a sweep net for later identification.

At the same corridor where standardized transect walks were done, 8 non UV-bright yellow pan traps were placed 3 m apart, with eventual higher distance in semi-natural habitats where spots with flowering plants were preferred. Pan traps were mounted on a plastic pole and placed at the vegetation level, filled with water and detergent, and left active for 48 h.

All collected specimens were identified to species except for individuals from *Syrphus* spp. In transect walks, individuals of *Bombus terrestris* and *B. lucorum* were not differentiated. As only about 0.2% specimens sampled were identified as *Bombus lucorum*, all observed individuals from the *Bombus terrestris/lucorum* group during transect walks that were not collected and identified were considered as *Bombus terrestris* for data analysis.

2.3. Data analysis

For each site (7 localities, 2 sites on each), numbers of species were counted for four studied groups: Syrphidae from pan traps, Syrphidae from transects, aculeate Hymenoptera from pan traps and aculeate Hymenoptera from transects. These data were analyzed with Redundancy Analysis (RDA) in R software, package "vegan" (Oksanen et al., 2015). Data were standardized by groups so each of four groups has the same weight in the analysis. Type of habitat was used as a predictor for the RDA analysis. Further, differences in species richness between two habitat types were tested by Mann-Whitney U test for each group.

3. Results

In total, collections from both habitats using both sampling methodologies, 179 and 26 species of aculeate Hymenoptera and Syrphidae, respectively, were identified from 3966 and 2071 specimens detected in this study.

For aculeate Hymenoptera sampled by pan traps and by standardized transect walk significantly higher species richness was found in semi-natural habitats as compared to wheat fields. For Syrphidae this