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Exploring the interactions between resource availability and the utilisation of semi-natural habitats by insect pollinators in an intensive agricultural landscape

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ABSTRACT

Intensification of agriculture and associated loss of habitat heterogeneity is a key driver of global declines in insect pollinators. Pollinators utilise different habitats to meet resource requirements throughout their life-span and it is widely accepted that their conservation requires a landscape-scale approach. Information on the mechanisms driving insect pollinators at the landscape scale is, however, lacking. To fill this knowledge gap, this novel study explores how pollinators utilise different habitats within a landscape and how utilisation changes over the season. Floral resources and insect pollinators (i.e. bumblebee, butterflies and hoverflies) were monitored during peak pollinator activity periods on a wide range of agricultural and semi-natural habitats in an intensive grassland landscape.

The availability of key foraging resources differed between semi-natural habitats and this was strongly linked to their utilisation by pollinators. Floral resources were most abundant and diverse in road verges, riparian buffer strips and open scrub. These were key habitats for butterflies, with road verges and buffer strips also being important for hoverflies and bumblebees. The relative value of semi-natural habitats in providing floral resources changed throughout the season. Pollinators appeared to respond to changes in key floral resources, dynamically using different semi-natural habitats to meet their requirements. Maintaining landscape heterogeneity and improving the quality of semi-natural habitats to ensure resource diversity and continuity is fundamental to pollinator conservation. Regionally targeting agri-environment spending could result in the simplification of agricultural landscapes with consequences on insect pollinators and biodiversity as a whole.

1. Introduction

Agricultural intensification, loss of (semi-) natural habitat and associated decline of floral resources are primary factors driving global declines in wild insect pollinators (Baude et al., 2016; Vanbergen and The Insect Pollinators Initiative, 2013). Strong links between biodiversity and ecosystem functioning exist; maintaining biodiversity is key to the delivery, stability and resilience of ecosystem services many of which are vital to agricultural production (Bai et al., 2004; Tilman et al., 2014). Insect pollination is critical in preserving terrestrial ecosystems (Ollerton et al., 2011); with insect pollinators enhancing yields in approximately 70% of crops their value to agriculture is indisputable (Klein et al., 2007). With demand for pollinator-dependant crops rising at the same time as pollinators are declining, there are concerns that this imbalance could result in a pollination deficit adversely impacting on global food security (Aizen et al., 2009). Enhancing pollinator diversity can increase pollination success due to functional and temporal complementarity between species (Blüthgen and Klein, 2011; Albrecht et al., 2012) and can increase the stability and resilience of pollination through a variety of stabilising mechanisms. Such mechanisms include inter-specific differences in response to environmental change (i.e. response diversity); increased chance that some species will adapt to change; and inter-specific differences in response to a specific environmental factor across spatial or temporal scales (i.e. cross-scale resilience) (Garibaldi et al., 2014; Winfree, 2013).

Extensive research has evaluated specific habitat components (e.g. agricultural and (semi-) natural) and the impact of habitat quality, management and agri-environment interventions on pollinators (Haaland et al., 2011; Noordijk et al., 2009; Pywell et al., 2011; Williams et al., 2012). Within agricultural landscapes such habitats do

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not exist in isolation but within a matrix of farmed and semi-natural habitats; landscape structure has been identified as a key driver of pollinator diversity (Garibaldi et al., 2011; Scheper et al., 2013). Studies investigating the impact of landscape structure on pollinators, and the delivery of pollination services, typically utilise broad scale measures of landscape complexity such as proximity to, or area of, (semi-) natural habitat (Garibaldi et al., 2011; Klein et al., 2012; Scheper et al., 2013) and indices of landscape diversity (Petersen and Nault, 2014). Such studies highlight the importance of (semi-) natural habitat components on pollinators and pollination success (Garibaldi et al., 2014; Klein et al., 2012; Petersen and Nault, 2014). Many wild pollinators are highly mobile utilising local and landscape scale cues when foraging (Jha and Kremen, 2013). Positive impacts of landscape diversity may therefore be expected as a result of different habitats supporting differences in pollinator resource requirements both spatially and temporally; enhancing resource diversity and stability (Blüthgen and Klein, 2011; Shackelford et al., 2013; Williams et al., 2012).

Insect pollinators utilise different habitats to meet resource requirements throughout the season (Mandelik et al., 2012; Williams et al., 2012). Studies that simultaneously determine the value of different habitat components for pollinators, or how utilisation changes over time, are however rare focussing on a narrow subset of habitats (Mandelik et al., 2012) or species (Williams et al., 2012). Research at large spatiotemporal scales is critical to understand the processes driving pollinator populations at the landscape scale. Such knowledge is fundamental to the development of landscape-scale pollinator conservation initiatives. Focussing on an intensive agricultural landscape, this study determines the relative value of a broad range of habitats in the provisioning of floral resources for insect pollinators (i.e. bumblebees, butterflies and hoverflies) and explores how this changes over the season. The relationship between resource availability and the utilisation of habitats by insect pollinators, and seasonal changes in this utilisation, is explored. A combination of statistical modelling and observational evidence provide insight into the mechanisms driving pollinator assemblages at the landscape scale and are used to explore the concept that pollinators move between habitats in response to resource availability (Fig. 1). Research findings will increase our understanding of how landscape structure and composition influences resource provisioning and resource stability.

2. Methods

2.1. Study sites

The study was conducted in the Cessnock Water catchment Ayrshire, Scotland (N55°32′50″, W4°22′00″). This 75.9 km^2 catchment is dominated by productive ryegrass, *Lolium perenne* L., swards primarily grazed by livestock and/or cut for silage. Twelve habitats that were either dominant within the catchment, or considered to be potentially important for insect pollinators were investigated: Arable, Intensive Grassland, Rough Grassland, Open Scrub, Riparian Buffer Strips, Coniferous Woods, Coniferous Wood Edges, Deciduous Woods, Deciduous Wood Edges, Intact Hedges (hedges with no gaps over 2 m), Sparse Hedges (hedges with gaps over 4 m) and Road Verges (Table 1, Fig. A.1). To minimise the impact of adjacent habitats, woodland edges, hedges, and buffer strips were selected adjacent to intensive grassland or arable fields.

In 2013, a total of 60 sites were surveyed (i.e. five sites per habitat class). In 2014, 24 of these sites (i.e. two per habitat class) were resurveyed and 24 sites (i.e. two per habitat class) new to the study were also surveyed (i.e. 48 sites in total). This gave a total of 84 sites (i.e. seven unique sites per habitat) over the two year period. Sites occurred on 35 farms and were selected to maximise spatial spread within a habitat class (i.e. minimum distance between sites in a habitat class was 904.2 m in a specific year: Fig. 2). This helped ensure independence between replicates within a habitat class (i.e. limited overlap of pollinator foraging area). As this study intended to explore the idea that pollinators move between habitats in response to their relative profitability it was not necessary to ensure that different habitats were independent. The minimum distance between different habitats was therefore approximately 25 m (i.e. for woodlands and their adjacent woodland edge).

2.2. Insect pollinator and botanical sampling

Three taxa of pollinators that all depend strongly on floral resources as adults were surveyed: butterflies, bumblebees and hoverflies. Additional resource requirements, however, differ due to differences in ecology and life-history. Most bumblebees observed were social species and therefore central placed foragers that return to their nests between foraging visits. Butterflies require shelter as adults and larval food plants that show considerable interspecific variation. Hoverfly larvae have extensive interspecific variation in resource requirements with insectivorous, phytophagous, saprophagous and coprophagous larvae all being represented (Stubbs and Falk, 2002).

Insect pollinators and flowering plants were monitored by standardised transect walks under conditions stipulated by the Butterfly Monitoring Scheme Standards (i.e. temperature 13–17 °C with at least 60% clear sky, or over 17 °C if cloudy, not raining, maximum wind speed of Beaufort Scale 5: Polland and Yates, 1993). To standardise sampling effort all transects were walked at a constant rate of approximately 10 m min^{-1}. Monitoring was conducted over four sampling periods annually: June (12th–20th June), July (9th–13th July), early August (28th July–4th August) and late August (18th–23rd August).

All butterflies, foraging bumblebees, foraging hoverflies and plants observed in flower within the transect area were identified to species level and quantified. Flower abundance was quantified using the Domin Scale converted to percentage cover prior to statistical analyses (Currall, 1987). Plant-pollinator interactions were recorded by documenting the plant species pollinators were observed foraging on. Hoverflies observed foraging in the transect area were netted and identified in the laboratory following Stubbs and Falk (2002) and Speight and Sarthou (2012). A total of nine bumblebee species were observed consisting of the six most common UK social bumblebees and three cuckoo bumblebees (Table A.1). Due to difficulties in differentiating between workers of *Bombus lucorum senso lato* (i.e. species complex of *Bombus lucorum, Bombus cryptarum* and *Bombus magnus*) and workers of *Bombus terrestris* based on morphological features, analyses were conducted on the aggregated data for these species (Wolf et al., 2010). Most bumblebees were thus readily identifiable in the field (Potts et al., 2009) with difficult specimens being brought back to the laboratory (Prys-Jones and Corbet, 1991).

Permanent transects were established at all sites to ensure consistency in survey area between sampling dates (and sampling year for sites sampled in both years). Transects in nonlinear habitats (i.e. Arable, Intensive Grassland, Rough Grassland, Open Scrub, Coniferous Woods and Deciduous Woods) were 100 m in length and established in the habitat centre to avoid edge effects. Pollinators and flowering plants were monitored 2 m (1 m for hoverflies) on either side, and 2 m (1 m for hoverflies) in front, of the observer. Transects adjacent to linear features (i.e. Riparian Buffer Strips, Coniferous Wood Edges, Deciduous Wood Edges, Intact Hedges, Sparse Hedges and Road Verges) were established at a distance of two meters from the linear feature for bumblebees and one meter from the linear feature for hoverflies. Linear feature transects were 200 m long and 2 m (1 m for hoverflies) to one side, and 2 m (1 m for hoverflies) in front of the observer. The transect area for both linear and non-linear habitats was thus standardised (i.e. 400 m^2 for bumblebees, butterflies and plants in flower and 200 m^2 for hoverflies).