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The benefits of hedgerows for pollinators and natural enemies depends on hedge quality and landscape context

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ABSTRACT

Ecological intensification advocates the harnessing of regulating and supporting ecosystem services to promote more sustainable food production, and this relies on effective management of non-cropped habitats. Hedgerows are an important component of the landscape in many farming systems across the world, management of which provides a potential mechanism to enhance ecological intensification. Here we investigate the value of hedgerows in Southern England as a source of functionally important taxa, and how hedgerow quality and local landscape composition impact on their potential contribution to sustainable agriculture in arable landscapes. We show that hedgerows are a source habitat for many natural enemies which spill over into neighbouring fields, and that hedgerows provide a valuable forage resource and corridor for movement of pollinators. Hedgerow quality affects these benefits and continuous unbroken hedgerows, with a high diversity of woody species, are more valuable for the provision of bumblebees and Linyphiid spiders, while the presence of trees within the hedgerow supports Lycosid spiders. Floral resources, beyond the woody hedgerow species themselves, are also a key forage resource for hoverflies. The impact of these hedgerows on invertebrate abundance is moderated by local landscape, and hedgerows are a more valuable forage resource for pollinators in more intensely managed landscapes. Our study shows that in order to support abundant and a broad range of natural enemies and pollinators in agricultural landscapes, both hedgerows and local semi-natural habitats need to be protected and managed. The benefit of hedgerows, as a habitat for functionally important taxa depends on hedgerow quality and management practices such as avoiding gaps, high hedge species diversity and maintaining an abundant understory of plants, can improve their value for ecological intensification.

1. Introduction

In order to address the increasing demand for food while simultaneously reducing the environmental impacts of agriculture, ecological intensification advocates the replacement of anthropogenic inputs and/or enhancement of crop productivity, by including regulating and supporting ecosystem service management in agricultural production (Bommarco et al., 2013). Agricultural production itself, however, has been a key driver of declining biodiversity in the wider landscape (Matson et al., 1997) simultaneously reducing the capacity of this biodiversity to provide ecosystems services such as crop pollination and pest regulation. Non-cropped land and semi-natural habitat within agricultural landscapes have been shown to be reservoirs of biodiversity, including functionally important taxa that provide services underpinning crop production at local and landscape scales (Bianchi et al., 2006; Chaplin-Kramer et al., 2011; Kennedy et al., 2013; Shackelford et al., 2013), with spill over from these natural areas into cropped habitats in evidence (Garibaldi et al., 2011; Blitzer et al., 2012; Macfadyen and Muller, 2013; Woodcock et al., 2016). The spatial makeup of landscapes is also important and it is not simply the area of valuable habitat components that supports abundant biodiversity but also the high heterogeneity and connectivity within the landscape promotes flow, stability and delivery of biodiversity based ecosystems services (Mitchell et al., 2013; Rusch et al., 2013), and hedgerows can make an important contribution to this. Maximising the positive impacts of semi-natural habitats on key service providing taxa, and their capacity to deliver ecosystem services, is therefore an important component of sustainable agricultural management and a corner stone of ecological intensification.

Hedgerows are common linear semi-natural features in lowland agricultural landscapes across the world (Hannon and Sisk, 2009; Morandin and Kremen, 2013; Dainese et al., 2016; Dondina et al., 2016; Lacoeuilhe et al., 2016; Ponisio et al., 2016). They are a particularly ubiquitous feature of the UK countryside, with more than 450,000 km of hedgerows in England alone (Norton et al., 2012). Hedgerows provide a valuable habitat and food resource for biodiversity including

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invertebrates (Amy et al., 2015; Staley et al., 2016), plants (Critchley et al., 2013) and other wildlife (Staley et al., 2012; Dondina et al., 2016) and may provide an important mechanism for increasing the abundance of functionally important taxa and improving the permeability of agricultural landscapes allowing more access to crop fields (Haenke et al., 2014). In light of this, hedgerows are a priority habitat across Europe and support for their management is provided to land managers through agri-environment schemes (Natural England, 2013).

Hedgerows can provide a valuable habitat for functionally important taxa including pollinators (Hanley and Wilkins, 2015; Sardiñas and Kremen, 2015; Ponisio et al., 2016) and natural enemies (Amy et al., 2015). There is some emerging evidence that these taxa spill over into adjacent crop fields (Morandin and Kremen, 2013; Haenke et al., 2014; Morandin et al., 2014, 2016) where they may provide services. The manner in which hedgerows are managed has significant implications on their value as a habitat resource (Maudsley, 2000; Staley et al., 2012, 2016; Amy et al., 2015) and this presents an opportunity for farmers to optimise the management of hedgerows to increase the benefits they provide to food production, as well as a habitat for wildlife.

To develop the potential contribution of hedgerows towards ecological intensification, it is important to understand which taxa they enhance and whether this benefit translates into improved ecosystem services for farmers. Identifying the optimal management of hedgerows to support taxa underpinning crop production, and understanding how hedgerows function within a wider context could enable the development of management practices to support sustainable food production. The aims of the present study were to: 1) measure the effect hedgerows have on the spill-over of functionally important taxa into cropped fields; 2) understand how hedgerow management and quality (based on structure and plant diversity) affects the composition and spill-over of pollinators and natural enemies; and, 3) determine how hedgerows and surrounding semi-natural landscape components interact to influence the abundance of functionally important taxa found in crop fields.

2. Materials and methods

2.1. Study sites

In 2014, sixteen field sites were selected in four, 25 km × 25 km landscape blocks in Southern England (Fig. 1a). The climate in this region is maritime temperate and agriculture is predominantly conventional arable production with cereals in rotation with oilseed rape and field beans. Field sites for this study included a hedgerow adjacent to a crop of winter wheat (Fig. 1b.). These hedgerows had been previously classified as “Good” or “Poor” quality based on data collected as part of a Department for the Environment and Rural Affairs (Defra) condition assessment (Defra, 2007) carried out during a previous study, the Chiltern Conservation Board, Hedgerow Survey 2006 and 2007. Good quality hedges were defined as those containing more than three woody species within the 75 m study section, with a solid structure with no gaps bigger than 2 m. Poor quality hedges had fewer than three woody species, had poor overall structure with variable height and width with gaps greater than 2m, and showed little evidence of maintenance. The local landscape surrounding these hedgerows was characterized at a 500 m radius considering the percentage (%) area of semi-natural habitat based on the UK Government’s Priority Habitat Inventory (Natural England, 2014) which includes deciduous woodland, good quality semi-improved grassland, lowland calcareous grassland and lowland meadow. A 500 m radius was chosen because it is likely to capture responses for the diverse groups of both natural enemies and pollinators being considered, and is generally relevant for management at the farm scale. Within each study region there were four hedgerows, two good quality and two poor quality, with one located in an area of high semi-natural habitat (> 5% with a range of 9.89–41.97% across sites) and one in an area of low semi-natural habitat (< 5% with a range of 0.0–4.71% across sites). Initial selection of sites was carried out using ArcGIS10.1 (ESRI, 2012) followed by ground-truthing to determine final study sites.

2.2. Invertebrate sampling

At each study hedge, three 50 m transects, running perpendicular to the field edge and hedgerow, 25 m apart and at least 50 m from other field boundaries were marked out. Invertebrates were sampled using pitfall traps placed at 0, 10, 25 and 50 m along each transect into the wheat field to assess abundance (activity density) of ground active natural enemies. Pitfall traps, with a 95 mm diameter containing dilute anti-freeze solution, with a rain cover were placed out for a period of 10 days. In order to capture spring and summer activity of natural enemies, two rounds of pitfall sampling was carried out, the first in late April/early May 2014 and the second in mid-June 2014. After collection, pitfall trap contents were stored at −20 °C and then natural enemies were counted and identified to broad functional groups including Carabids, Staphylinids, Linyphiid spiders, Lycosid spiders, Coccinellids, Centipedes and Opiliones.

Aphid population density was sampled in the wheat crop three times during the season, at stem elongation in early May, flowering in early June and dough development in early July 2014. As with pitfall trapping, aphid populations were estimated at sampling locations located at 0, 10, 25 and 50 m along each transect. At each sampling location, 25 tillers were examined and the number and species of aphids recorded. The number of parasitoid mummies was also counted.

The abundance of bumblebees, hoverflies, honeybees and solitary bees was recorded along transects running parallel to the hedgerow, at 0 m,10 m and 50 m into the field. Each transect was 75 m long and divided into three, 25 m sub sections. On the day of pollinator surveys, each sub-section was walked slowly for a period of 5 min and all bees and hoverflies 2 m either side of the observer were recorded. For the transect immediately adjacent to the hedgerow, whether pollinators were observed visiting flowers on the hedgerow itself or flowers which were part of the non woody understorey of the hedge bank was also noted. All surveys were carried out in low wind conditions and in temperatures in excess of 15 °C. Three rounds of pollinator surveys were carried out at each field site, the first in mid-May, the second in mid-June and the final survey in mid-July 2014.

2.3. Hedgerow characterisation

At the time of pollinator surveys a floral resource survey was carried out along each of the hedgerows. At the base of each transect a 0.5 m by 0.5 m quadrat was held up to the hedge. Based on height, the hedge was divided into thirds and a quadrat was held up to the lower section, mid-section and upper section of the hedge. A photograph was taken of each quadrat and back at the laboratory the percentage coverage of each quadrat with open flowers was visually estimated to the nearest 2%. This was done three times during the season at the same time as pollinator surveys.

In October 2014, a visit was made to all experimental hedgerows to collect further data on hedgerow characteristics. On the 25 m hedge section at the base of each transect, hedge height and width were estimated to the nearest 25 cm based on three independent measures per section. Then, to assess hedge continuity, the percentage extent of gaps in woody species was noted (% coverage); and whether there were any gaps greater than 5 m present (yes/no) was recorded. The number of species of woody hedgerow plants were recorded and an assessment made of how recently the hedge was cut (< 2yrs, 2–10yrs). Hedgerow type was characterised for each section as ‘bank’, ‘shrub’, ‘tree’ or ‘tree and shrub’ in line with Defra’s condition assessment (Defra, 2007). In addition, two 1 m by 1 m quadrats were placed on the ground on either side and towards the centre of each hedge section to assess understory plant composition. The number of non-grass plant species within the