Biological Conservation 184 (2015) 51–58

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Sown flower strips in southern Sweden increase abundances of wild bees and hoverflies in the wider landscape

Annelie M. Jönsson [a,*], Johan Ekroos [b], Juliana Dänhardt [b], Georg K.S. Andersson [b], Ola Olsson [a], Henrik G. Smith [a,b]

[a] Department of Biology, Lund University, Ecology Building, S-223 62 Lund, Sweden
[b] Centre of Environmental and Climate Research, Lund University, Ecology Building, S-223 62 Lund, Sweden

ARTICLE INFO

Article history:
Received 11 August 2014
Received in revised form 28 December 2014
Accepted 31 December 2014

Keywords:
Agro-ecosystem
Attraction effect
Distance decay
Habitat quality
Landscape heterogeneity

ABSTRACT

Pollinator populations have suffered severe declines in many industrialised countries due to reduced floral and nesting resources, brought on by agricultural intensification. One potential method of mitigating these effects is creating flower strips. Most previous studies have shown higher pollinator abundances in flower strips, but none have been able to demonstrate increased pollinator abundances at larger spatial scales, in the surrounding agricultural landscapes. We assessed local and landscape-wide effects of flower strips on pollinator abundances, using 18 carefully selected study landscapes in southern Sweden, distributed along independent gradients of landscape heterogeneity and farming intensity. We found that flower strips were more attractive than field borders in general to bumblebees, whereas hoverflies were only attracted to flower strips from nearby field borders. Solitary bees declined with increasing distance from flower strips, but only in complex landscapes. As one of the first studies investigating effects of flower strips on pollinators across the wider landscape, we found increased abundance of bumblebees, but not solitary bees, in field borders outside the flower strips in floristically enhanced landscapes as compared with control landscapes. However, we found that higher quality and/or larger total area of flower strips within a farm was important for both bumblebees and solitary bees. Hoverfly abundance was enhanced on farms with flower strips in simple landscapes. Our results demonstrate that flower strips with rewarding plants do not only attract pollinators locally, but in addition have the potential to increase pollinator abundances across entire landscapes, and particularly in landscapes dominated by farmland.

1. Introduction

Pollinator declines have been attributed to removal and deterioration of interstitial and semi-natural habitats rich in pollen and nectar (Carvell et al., 2006; Goulson et al., 2005), as well as nest sites (Kells and Goulson, 2003). Intensive farming practices, such as the use of competitive crops, herbicides, inorganic fertilizers and switch from hay to silage, have not only reduced floral resources, both outside and within fields (Marshall et al., 2001; Wallis de Vries et al., 2012), but also restricted them seasonally (Carvell et al., 2006; Goulson et al., 2005). For pollinators, such as bumblebees, this causes problems since they require a continuous supply of forage throughout the season for successful population growth and reproduction (Bowers, 1986). Mass-flowering crops, such as *Brassica napus* and *Trifolium pratense*, can to some extent compensate loss of floral resources by providing an abundance of food for a relatively short period of time. However, any effect on pollinator fitness may critically depend on whether mass-flowering crops seasonally complement other flower resources (Rundlöf et al., 2014; Westphal et al., 2009).

Flower strips, i.e. patches or strips sown with a flowery seed mixture, has been suggested as a means to mitigate the decline of pollinators (Haaland et al., 2011), as they have the potential to provide a mix of plants rich in pollen and nectar (e.g. Campbell et al., 2012; Denys and Tscharntke, 2002) that lasts through the season (Carreck and Williams, 2002). This makes them an attractive tool in pollinator conservation (Haaland et al., 2011). To enhance pollinator diversity and abundance, creation of flower strips has therefore become part of agri-environment schemes or

* Corresponding author at: Unit of Biodiversity, Department of Biology, Lund University, Ecology Building, S-223 62 Lund, Sweden. Tel.: +46 (0) 46 2223822.

E-mail addresses: annelie.jonsson@biol.lu.se (A.M. Jönsson), johan.ekroos@cec.lu.se (J. Ekroos), juliana.danhardt@cec.lu.se (J. Dänhardt), georg.andersson@biol.lu.se (G.K.S. Andersson), ola.olsson@biol.lu.se (O. Olsson), henrik.smith@biol.lu.se (H.G. Smith).

http://dx.doi.org/10.1016/j.biocon.2014.12.027
0006-3207/

management advice in some European countries (Haaland et al., 2011).

The suggested benefit of flower strips is that they may boost the growth of pollinator populations in the landscape. However, the evidence for this is inconclusive. Whilst many studies show that pollinators prefer to forage in flower strips over other types of habitats (e.g. Haenke et al., 2009; Meek et al., 2002), few have attempted to show whether flower strips also have consequences for pollinator populations across entire landscapes surrounding the strips (Scheper et al., 2013). In fact, by attracting pollinators, flower strips may even result in diluted populations in the surrounding landscape (Kleijn et al., 2011; Morandin and Kremen, 2013). Furthermore, at what scales these processes might act is also largely unknown. The only study that to our knowledge has investigated effects of flower strips outside of the flower strips themselves at a landscape scale found enhanced hoverfly abundance up to 50 m from the sown flower patches, but not at longer distances, and was unable to demonstrate any such effects on bees (Kohler et al., 2008). To demonstrate positive effects of flower strips on pollinator populations we need to show increased abundances of pollinators at landscape scales and that attraction of pollinators to flower strips does not leave depleted abundances in the vicinity of the strips. In addition, the effect of flower strips is expected to be more pronounced in simple and intensively farmed landscapes, where they create a greater ecological contrast (Heard et al., 2007; Scheper et al., 2013). Finally, because of fundamental differences in life history strategies (being or not being central-place foragers; Covich, 1976), bees and hoverflies may demonstrate contrasting responses to flower strips.

In this study we determined the effects of flower strips on the abundances of bees and hoverflies both locally and across entire landscapes surrounding the flower strips. At the local scale we investigated the attractiveness of flower strips to pollinators, as well as the range of a potential attraction effect exerted by flower strips on pollinators, by looking at the patterns of abundances in the immediate surroundings of flower strips and at longer distances away from flower strips. At larger spatial scales we studied whether including flower strips in a landscape increases the abundance of pollinators in field borders in the surrounding landscape. This would indicate that a local introduction of flower resources can boost pollinator populations at much larger spatial scales, across entire landscapes. We did this using replicated, independent study landscapes with and without flower strips, equally distributed along statistically independent gradients of landscape heterogeneity and farming intensity.

At a local scale we predicted flower strips to be more attractive to foraging pollinators than field borders, translating into higher pollinator abundances in flower strips than in field borders, and pollinator dilution in field borders close to flower strips, or alternatively decay by distance. At a landscape scale we predicted flower strips to increase pollinator abundances in field borders in landscapes with flower strips compared to landscapes without. Because of the stronger ecological contrast, we predicted these effects to be stronger in simple agricultural landscapes compared to landscapes with more remaining semi-natural habitat and hence flower resources. Finally, given that pollinator populations would increase due to extra food resources provided by flower strips, we predicted late-season increases in pollinator abundances.

2. Methods

2.1. Selection of study sites

The study was carried out 2011–2012 in the region of Scania, the southernmost part of Sweden (55°28′–56°10′N, 12°50′–14°9′E), which contains a mix of agricultural landscape types (Persson et al., 2010). To select study sites we characterised all farmland in non-overlapping 1 km-radius landscapes with >40% farmland within Scania. We chose 1 km as it is compatible with most known foraging ranges of bees (Westphal et al., 2006). Data on the amount of semi-natural grassland (i.e. permanent unimproved grasslands) and field borders (i.e. uncultivated linear habitats, often dominated by grassy vegetation, demarcating fields) in each landscape were extracted from the Swedish Integrated Administration and Control System database (IACS). We calculated an index of landscape heterogeneity as the first principal component of the proportion of semi-natural grassland and proportion of field borders (see Andersson et al., 2014 for details), such that an increasing landscape heterogeneity index described increasingly complex landscapes. As a proxy for farming intensity we extracted information about the amount of ley (i.e. cultivated grasslands used for production of animal fodder) in the same landscapes. Including leys in the crop rotation decreases farming intensity by e.g. reducing soil disturbance and pesticide input across the landscape (van Eekeren et al., 2008), and some studies have found positive effects of leys on farmland birds (Piha et al., 2007), moths (Pettersson, 2011) and bumblebees (Persson and Smith, 2013; Woodcock et al., 2014). Leys have the potential to provide more forage than arable crops, which may benefit pollinators. Less intensively managed leys could also provide nest-sites for ground nesting species (Persson and Smith, 2013). We used the average amount of ley in the three years prior to our surveys to obtain a long-term proxy for land-use intensity. The amount of ley in individual study years was highly correlated with the average amount of ley, i.e. landscapes had consistent levels of land-use intensity (Andersson et al., 2014). The index of landscape heterogeneity and the proxy for farming intensity was calculated for all farms for each study year.

Creation of flower strips is not an option available in the Swedish agri-environment program. Instead we capitalised on existing voluntary uptake of the practice among Swedish farmers as a means to boost game populations, increase pollination and/or benefit biodiversity. We shortlisted candidate farms with flower strips (hereafter flower farms) from the study site selection process in Jönsson et al. (2010), where 58 individual farms with 400 ha or more contiguous arable land were identified through the IACS, and by consulting local agricultural advisors. All landowners were interviewed with regards to game management and creation of wildlife promoting habitats. After follow-up field visits to 18 of these, nine farms with flower strips were selected along the gradients of landscape heterogeneity and farming intensity, such that these axes became orthogonal. Selected flower farms had at least one flower strip (range 1–21) within its 1 km-radius. The majority were elongate (2–20 m in width, 35–2900 m in length) and running along the sides of fields, but some were triangular, rectangular or irregular in shape (0.01–1.6 ha). A handful of flower strips were free-standing or situated adjacent to field islands. Two or more flower strips were sometimes created next to each other, and sometimes in conjunction with non-flowery strips. The sown contents varied between strips and farms (see Table A.1 in the online Appendix A for details). All created habitats on the selected flower farms were mapped and digitised in ArcGIS 10 Software (ESRI, Redlands, CA). Two of the 2011 flower farms did not sow flower strips in 2012 and were replaced with as similar farms as possible using a similar procedure. We selected nine control farms such that both the landscape heterogeneity index and farming intensity had similar and orthogonal distributions as for the flower farms. The area of semi-natural pastures ranged from 0 to 36.2 ha (mean 8.3 ± SD 11.0), and that of field boundaries from 1.9 to 5.8 ha (mean 3.7 ± SD 0.9), in the selected study landscapes (Pearson correlations between landscape heterogeneity index and area of pasture $r = 0.74$; between landscape heterogeneity index and area of field