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Mass flowering crops in a patchy agricultural landscape can reduce bee abundance in adjacent shrublands

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ABSTRACT

Pollinator spill-over among habitats can arise in order to fulfill the pollination function and whenever differences in floral offering change over time or space. Flowering crops offer pulsed and abundant floral resources (i.e., mass flowering crops) that might promote pollinator spill-over between cultivated and adjacent natural areas. We explored pollinator patterns in the mass flowering legume crop *Hedysarum coronarium* and its influence on the bee pollinator communities of adjacent shrublands in a heterogeneous and patchy agricultural landscape. We studied the temporal (i.e., during vs. after mass flowering in adjacent shrublands) and spatial (i.e., inside crops, adjacent and distant shrublands during mass flowering) functional pollinator spill-over. The honeybee was highly attracted to *Hedysarum* crops, yet its abundance and that of other bee species visiting native plants in adjacent shrublands did not differ during and after *Hedysarum* mass flowering. However, at the landscape scale, the honeybee and the other bee species were less abundant in shrublands adjacent to *Hedysarum* crops compared to distant ones; their visitation rates showing a similar trend.

These results show that some mass flowering crops can influence pollinator patterns in the surrounding landscape by competing for generalist pollinators with native plants. The characteristics of the crop species and the landscape can modulate and determine the role of mass flowering crops as competitors or supporters of wild pollinators for adjacent natural areas.

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1. Introduction

There is growing concern about local and regional declines in pollinator species and the pollination services they provide (Bartomeus et al., 2013; Potts et al., 2010). Moreover, plant–pollinator interactions may be even more sensitive than the species themselves (Tylianakis et al., 2008), and factors driving the decline of pollinators might interact in non-additive ways (González-Varo et al., 2013).

More than 75% of the cultivated species depend on, or benefit from, animal mediated pollination (Klein et al., 2007), and the area devoted to pollinator-dependent crops is disproportionately growing (Aizen et al., 2008). In this context, during the last two decades, scientists have explored the role of remaining natural areas within agricultural landscapes as reservoirs of pollinators to provide pollination service to pollinator-dependent crops. Maintaining and restoring these areas in agricultural landscapes is one of the most commonly implemented agri-environment schemes. The underlying rationale is that remaining natural areas offer pollinators feeding resources and/or nesting sites not provided by the crop or not stable over time due to the inherent disturbance frequency (Westphal et al., 2003).

Pollinators move from one area to another in order to meet their feeding and/or nesting requirements. When such a movement results in the achievement of their functions (e.g., pollination), it is called functional spill-over (hereafter, spill-over) (Blitzer et al., 2012). Spill-over can occur whenever the offer of required floral resources differs between habitats; therefore, it can occur in both directions. However, only recently has the spill-over of pollinators

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from entomophilous mass flowering crops (MFCs, hereafter) to natural habitats received the attention of scientists and managers (Blitzer et al., 2012; Holzschuh et al., 2011). MFCs, despite offering only pulsed floral rewards, could compensate for food resource limitation during periodic intervals, and help in maintaining and enhancing pollinator communities in agricultural landscapes (Westphal et al., 2003), as long as nesting sites and other feeding areas are also available within the foraging ranges of pollinators. Thus, those natural areas that offer alternative resources and that are close to MFCs could benefit from a pollinator spill-over from MFCs. That is, the MFC could exert a magnet effect (Johnson et al., 2003; Molina-Montenegro et al., 2008) over close natural areas. This magnet effect would more likely occur in heterogeneous agricultural landscapes (Blitzer et al., 2012).

In addition to spill-over between habitats with different resource offer at a given period of time (i.e., spatial spill-over), differences in resource offer between habitats can also arise at different moments in time (i.e., temporal spill-over). For instance, the high floral rewards of a MFC compared to its surrounding habitats can be reverted after the MFC flowering peak (Hanley et al., 2011).

Here we study the effect of the highly rewarding *Hedysarum coronarium* L. MFC on the pollinator community in adjacent shrublands in a patchy and heterogeneous Mediterranean agricultural landscape. We specifically focus on the bee pollinator community because this MFC is mainly bee-pollinated (the honeybee, *Apis mellifera* L., accounting for more than the 80% of its visits; Montero-Castaño et al., 2014). We address the following questions: (a) Does the MFC affect the bee community visiting plant species in adjacent shrublands through a temporal bee spill-over during and after mass flowering? (b) Is there a spatial bee spill-over from the MFC to adjacent shrublands during mass flowering? (c) Is the role of the honeybee (the main pollinator of the MFC) different from that of the other bee species, for both the temporal and spatial spill-over?

We expect the MFC to attract a large number of bees and to exert a magnet effect on adjacent shrublands. That is, increasing the abundance of bees in adjacent shrublands compared to shrublands away from MFCs (i.e., spatial spill-over). Additionally, after mass flowering, bees may spill-over from the MFC to adjacent shrublands (i.e., temporal spill-over). We expect both temporal and spatial spill-over to be largely mediated by the honeybee, as it is the main pollinator of the MFC.

2. Materials and methods

2.1. Crop species

The MFC species studied was *H. coronarium* L. (Fabaceae; hereafter *Hedysarum*). *Hedysarum* is a short-lived N-fixing perennial (Bullitta et al., 2000; Sulas et al., 2000) that can reach a height of 1.5 m (Bustamante et al., 1998; Montes Pérez, 2016). Its inflorescences are racemes with up to 30 pink flowers rich in pollen and nectar that bloom during April and May. Its flowers are self-compatible, although they need to be tripped, and have high out-crossing rates (Louati-Namouchi et al., 2000; Yagoubi and Chriki, 2000). Bees are the primary pollinators of *Hedysarum* with the honeybee being the most abundant (Louati-Namouchi et al., 2000; Montero-Castaño et al., 2014; Satta et al., 2000).

2.2. Study sites

We conducted our study in Menorca (Balearic Islands, Spain), where *Hedysarum* was introduced between the end of the 18th and the beginning of the 19th centuries (Ortells and Campos, 1983). Since 1860 it has been used in a traditional cyclical agro-farming system (Bustamante et al., 2007) which consists of growing crops of *Hedysarum* for two consecutive years, followed by cereal cropping in the third year, and leaving the land fallow during the fourth year (Bustamante et al., 2007). To some extent, this traditional system is still present in the extensive and heterogeneous agricultural landscape of the island, but the area devoted to it has been reduced by 97% in the last three decades due to land use intensification (Bustamante et al., 2000; Díaz-Ambrona Medrano et al., 2014). Currently, the public administration is attempting to restrain this trend by subsidizing *Hedysarum* crops.

Hedysarum is the only spring MFC on the island. Most *Hedysarum* crops are harvested during the flowering peak, when the balance between plant yield and its nutritional value is greatest (Bustamante et al., 2005), in order to provide feed for cattle during the summer.

In 2009, to explore whether there was a temporal bee spill-over between *Hedysarum* crops and adjacent shrublands, we selected four Mediterranean shrublands adjacent to *Hedysarum* crops (≤10 m apart), which were studied during and after mass flowering (i.e., after crops were harvested during the flowering peak). The distance among study shrublands ranged from 500 m to 12.01 km.

Table 1
Location, area and flower density of each study shrubland or *Hedysarum* MFC. The land uses of the 500 m radius surrounding landscape of each study shrubland are also given. Landscape characterization was based on the land-use cover map (Carreras et al., 2007).

Site	Treatment	Year	Latitude	Longitude	Area (m^2)	Flower density (flowers/m^2)	% Land-uses 500 m landscape			
							MFC	Other crops	Natural areas	Non-natural areas*
Binicalaf	Adjacent	2009	39°52′14.81″N	4°10′2.49″E	2940.30	54.65	0.49	34.82	55.17	9.14
	MFC		39°52′16.99″N	4°10′1.25″E	3844.45	208.75				
Binixabó	Adjacent	2009	39°56′12.04″N	4°6′57.23″E	873.54	11.43	0.43	47.03	47.95	4.48
	MFC		39°56′12.82″N	4°6′56.60″E	3379.52	216.88				
Mila1	Adjacent	2009	39°55′29.35″N	4°15′12.05″E	151.53	283.78	4.47	58.60	34.46	2.45
	MFC		39°55′28.61″N	4°15′15.34″E	15542.47	1038.37				
Mila2	Adjacent	2009	39°55′40.88″N	4°15′21.39″E	15837.37	145.05	4.59	55.36	35.89	2.14
	MFC		39°55′39.50″N	4°15′16.90″E	20522.74	1295.31				
Albufera	Distant	2010	39°56′27.50″N	4°15′21.11″E	29742.80	215.63	0.00	4.37	82.03	9.81
Binigurdó	Adjacent	2010	39°59′56.09″N	4°6′2.40″E	2707.70	24.28	0.29	60.54	36.48	2.35
	MFC		39°59′54.93″N	4°6′0.63″E	2240.15	494.51				
Favaraix	Distant	2010	39°58′26.19″N	4°13′39.69″E	13745.07	110.86	0.00	61.86	34.14	2.25
Molí	Adjacent	2010	39°59′50.42″N	4°5′34.13″E	455.82	38.45	1.46	79.30	13.65	5.52
	MFC		39°59′48.71″N	4°5′35.22″E	11487.12	308.52				
Mongofre	Adjacent	2010	39°59′3.85″N	4°13′18.29″E	3090.83	42.43	2.68	63.94	32.98	0.00
	MFC		39°59′3.14″N	4°13′17.40″E	21065.59	589.37				
Palafanguer	Adjacent	2010	39°55′35.74″N	4°14′15.21″E	132.95	323.35	0.78	44.23	54.09	0.88
	MFC		39°55′34.61″N	4°14′15.38″E	6110.35	307.50				

* Human settlements and infrastructures.

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