Agriculture, Ecosystems and Environment 232 (2016) 336–344

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Bee diversity and abundance in a livestock drove road and its impact on pollination and seed set in adjacent sunflower fields

Violeta Hevia[a,*], Jordi Bosch[b], Francisco M. Azcárate[c], Eva Fernández[a], Anselm Rodrigo[b,d], Helena Barril-Graells[b], José A. González[a]

[a] Social-ecological Systems Laboratory, Department of Ecology, Universidad Autónoma de Madrid, Darwin 2, 28049 Madrid, Spain
[b] CREAF, 08193 Cerdanyola del Vallès, Spain
[c] Terrestrial Ecology Group, Department of Ecology, Universidad Autónoma de Madrid, Darwin 2, 28049 Madrid, Spain
[d] Universitat Autònoma de Barcelona, 08193 Cerdanyola del Vallès, Spain

ARTICLE INFO

Article history:
Received 4 April 2016
Received in revised form 11 August 2016
Accepted 15 August 2016
Available online xxx

Keywords:
Ecosystem services
Pollinators
Sunflower
Livestock transhumance
Wild bees

ABSTRACT

Natural and semi-natural habitats within agricultural landscapes provide food and nesting resources for wild bees, thus promoting crop pollination services. In central Spain, a large network of drove roads (DRs) crosses extensive areas of intensive agricultural fields. DRs are tracks (20–75 m wide) with semi-natural vegetation, protected for their priority function of transhumant livestock herding. In this study, we analyse the bee community of one of the main Spanish DRs, and evaluate its effects on flower visitation and seed set in adjacent sunflower fields. We used pan traps to assess bee abundance and richness at 13 sites along the DR and in adjacent sunflower fields at 10, 75 and 150 m from the DR. We also conducted visual counts to assess visitation rates to sunflower heads and measured seed set. Wild bee abundance and richness were significantly higher in the DR than in sunflower fields; but there were no significant differences among distances within sunflower fields. Honey bee abundance did not differ between the DR and sunflower fields. Wild bee visitation to sunflower heads was higher at 10 m compared to 75 and 150 m from the DR, but differences in honey bee visitation were non-significant. Sunflower seed set was significantly higher at 10 m compared to 75 and 150 m, and was associated with wild bee abundance, but not with honey bee abundance. Our results show that livestock DRs act as reservoirs of wild bee diversity within intensive agricultural matrices, enhancing wild bee visitation and seed set in adjacent sunflower crops.

1. Introduction

Land use intensification usually causes declines in species diversity (Batáry et al., 2011), impacting both ecosystem functioning (Flynn et al., 2009) and ecosystem services (Millenium Ecosystem Assessment, 2005). In particular, agricultural land use intensification has had a noticeable impact on insect pollinators (Connelly et al., 2015; Kennedy et al., 2013), because it typically reduces floral and nesting resources (Le Féon et al., 2010).

Pollination services provided by insects contribute to the productivity of >75% of the world's crop species (Klein et al., 2007). The global value of pollinator-dependent crops has been estimated annually at US$ 235-577 billion (IPBES, 2016). Thus, a pollinator decline could cause a sharp reduction in crop yields (Garibaldi et al., 2009; Richards, 2001).

Bees (Apiformes) are the most important pollinator group in most geographical regions (Potts et al., 2010). Although many crops are pollinated with managed honey bees (*Apis mellifera*), an increasing number of studies have shown that pollination and yields are often enhanced by wild pollinators, even in the presence of honey bees (Breeze et al., 2011; Garibaldi et al., 2013; Greenleaf and Kremen, 2006). Thus, wild bee communities provide insurance against honey bee scarcity (Kremen et al., 2002), with their pollination services potentially exceeding those provided by honey bees (Garibaldi et al., 2013; Winfree et al., 2007).

To enhance and maintain the pollination service, environments favourable to wild bees (including floral and nesting resources, as well as low pesticide pressure) are needed within agricultural landscapes (Ricketts et al., 2008). Because pollinator diversity is

* Corresponding author.
E-mail address: violeta.hevia@uam.es (V. Hevia).

http://dx.doi.org/10.1016/j.agee.2016.08.021
0167-8809/

often associated with flower diversity (Roulston and Goodell, 2011), habitats with high floristic diversity are expected to provide better pollination services to adjacent croplands (Garibaldi et al., 2011, 2013, 2016).

In particular, in intensive agricultural landscapes, well-connected remnant patches of natural and semi-natural habitat may act as reservoirs of biodiversity (Geslin et al., 2016; Hendrickx et al., 2007; Hevia et al., 2013), and as important providers of several ecosystem services (Carvalheiro et al., 2011; Tscharntke et al., 2005). As central place foragers, wild bees nesting in these habitats may pollinate crops within their foraging range (Ricketts, 2004). Therefore, the spatial scale that affects agricultural production is determined by foraging distance (Greenleaf et al., 2007).

In the Mediterranean region of Spain, many areas of intensive agriculture are crossed by livestock drove roads (DRs), which represent a highly conspicuous diversifying feature within the agricultural landscape (see Appendix A in Supplementary material). DRs are long tracks used for transhumance, an ancient customary practice involving the migration of livestock between summer and winter pasturelands. Because DRs are used for short periods of time, they harbour an important vegetation cover. Plant composition is strongly influenced by seasonal fertilisation and grazing, with many species of entomophilous plants being present year-round, even in the driest summer months (see Appendix B in Supplementary material). DRs are an important feature of the landscape in Spain (*cañadas*; Oteros-Rozas et al., 2012) and other countries, including Australia (*stock routes*, Lentini et al., 2011), France (*drailles*; Biber, 2010) and Italy (*tratturi*; Di Martino et al., 2006). Corridors for transhumance have also been described in several regions of Africa (Niamir-Fuller, 1999), central Asia (Fernandez-Gimenez and Le Febre, 2006) and South America (Stewart et al., 1976), although these livestock routes are seldom officially demarcated.

According to Merino and Alier (2004), the Spanish network of DRs includes ca. 125.000 km of 20–75 m wide tracks, and occupies about 0.8% of the national territory. Importantly, Spanish DRs are legally protected for livestock movement (Drove Roads Act from 1995). Previous studies have shown that DRs serve as important reservoirs of both plants (Azcárate et al., 2013a) and ants (Azcárate et al., 2013b; Hevia et al., 2013). In addition, as other semi-natural habitats in agricultural environments that act as reservoirs of pollinators (Bailey et al., 2014), DRs provide areas of untilled bare ground suitable for ground-nesting bees. DRs also contribute to the provision of other ecosystem services, such as seed dispersal and soil fertility (Acín-Carrera et al., 2013; Manzano and Malo, 2006; Oteros-Rozas et al., 2012).

In central Spain, livestock DRs that still remain in use cross important areas of intensive sunflower farming. Sunflower (*Helianthus annuus*) is one of the most important worldwide sources of oil for human consumption. According to Eurostat, sunflower seed crops in Europe cover almost 4.2 million ha, with an estimated annual production of ca. 9.2 million tonnes. The sunflower inflorescence is a capitulum or head, characteristic of the Compositae family, containing between 1000 and 2000 individual sessile protandrous florets. Florets within a head open from the periphery inwards. Each sunflower head flowers for about 6-10 days. A crop flowers for about 3–5 weeks, depending on local conditions (Free, 1993).

Sunflower plants are highly dependent on pollinators for seed production. Although honey bees are usually the main flower visitors, wild bees have often been found to be more effective pollinators (Free, 1993). Wild plants that grow along sunflower field margins act as important pollen/nectar sources for wild bees and other pollinators (Sabatino et al., 2010; Sáez et al., 2012). In addition to their direct positive effect on sunflower pollination, wild bees have been found to have an indirect effect mediated by interspecific behavioural interactions with honey bees, whereby the sunflower pollination efficiency of honey bees is enhanced when wild bees are present (Greenleaf and Kremen, 2006).

In this study, we aim to (a) evaluate the bee community of a major livestock DR crossing a highly transformed agricultural matrix, and (b) explore the potential influence of the DR bee community on pollination services in adjacent, intensively farmed, sunflower fields. We predict that (1) DRs act as reservoirs of wild bees, (2) wild bee abundance and richness in adjacent sunflower fields decreases with distance from DRs, and (3) sunflower seed set decreases with distance from DRs and increases with increasing wild bee abundance. Our results are expected to provide new insights on pollination services and seed production in intensively farmed sunflower fields.

2. Material and methods

2.1. Study area

The study site is a quite homogeneous agricultural landscape in the Autonomous Community of Castilla-La Mancha (Spain) that extends across the municipalities of Altarejos, San Lorenzo de la Parrilla, Belmontejo, Cervera del Llano, Villalgordo del Marquesado and Villar de la Encina (Fig. 1). The area is a flat plateau (altitude ranging between 830 m and 900 m above sea level), and is characterised by a continental Mediterranean climate with severe summer droughts (mean annual precipitation: 531 mm; mean annual temperature: 13.5 °C). The lithology is dominated by loams, sandstones and clays from the Miocene. The landscape is mainly composed of non-irrigated cereals and oilseed sunflowers (linoleic variety) that are cultivated under a rotation regime. These crops are farmed intensively, including the use of sulfonylurea herbicides and various fertilizers. Honey bee hives from other parts of the country are customarily brought to the sunflower fields in July–August to enhance pollination. No bee hive was present in any of our sampling fields but we detected three hive groups in neighbouring semi-natural areas.

The study area is crossed by the *Cañada Real Conquense*, one of the few major DRs (c.a. 410 km long) that are still in use in Spain. Each year, some 8900 sheep and 250 cows walk this DR twice between the summering pasturelands in Montes Universales and Serranía de Cuenca (Teruel, Cuenca and Guadalajara provinces), and the southern wintering *dehesas* of Sierra Morena (Jaén and Ciudad Real provinces) (Fig. 1; Oteros-Rozas et al., 2012).

2.2. Sampling design and data collection

We established 13 sampling sites along a 32-km section of the DR. Sampling sites were selected so that (a) they were separated from each other by at least 1 km, and (b) they were located more than 1 km away from any other natural or semi-natural area (patches of forest, scrublands, wetlands) potentially harbouring a rich pollinator community. The 1 km distance was chosen because most solitary bees appear to forage within a range of 500 m (Gathmann and Tscharntke, 2002; Zurbuchen et al., 2010). All the fields sampled were planted with the same sunflower linoleic variety (P64LE19).

2.2.1. Bee community sampling

We used pan traps to survey the bee community at the 13 sites. Pan trapping is a good methodology to standardise sampling effort, and is widely used in studies comparing pollinator communities across different sites and environments (Southwood and Henderson, 2000; Westphal et al., 2008). As with any other sampling method, pan trapping has some limitations. Namely, pan traps have been found to underestimate bee richness (Popic et al., 2013),