



# Following the dance: Ground survey of flowers and flower-visiting insects in a summer foraging hotspot identified via honey bee waggle dance decoding



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## ABSTRACT

Decoding of honey bee waggle dances has previously shown that average foraging distances are longest during July and August in Sussex, United Kingdom, indicating a scarcity of summer floral resources. However, it also identified a summer foraging 'hotspot' in agricultural land at 2–3 km distance. Unfortunately, dance decoding does not yield precise foraging locations or information on the flower species visited. Therefore, we surveyed this hotspot during July and August 2012 and 2013 in order to identify the habitats and flower species used by honey bees and other flower-visiting insects (FVI).

The hotspot area consisted predominantly of four habitat types potentially attractive to FVI: pasture fields, field margins/hedgerows of arable fields, set-aside and a National Nature Reserve. We surveyed three fields within each habitat type. The abundance of flowers was found to be a key determinant of FVI abundance per field ( $p = 0.002$ ). Field margins/hedgerows were the most flower abundant habitat type ( $p = 0.002$ ) and had more than twice (235%) the FVI abundance ( $p = 0.001$ ) and species richness ( $p = 0.035$ ) per unit area than did pasture fields. Areas with long grass had greater flower abundance ( $p < 0.001$ ) and FVI species richness ( $p = 0.009$ ) than those with short grass ( $\leq 30$  cm). The five plants on which we recorded the greatest number of FVI were species considered to be agricultural weeds.

Honey bees represented 19% of all FVI, showing that dance decoding had located a hotspot that was an important foraging location not just for honey bees but also for other types of FVI. Honey bee abundance, per transect, was strongly correlated with that of other FVI ( $p = 0.001$ ), particularly bumble bees ( $p < 0.001$ ). However, FVI groups were not found uniformly across our study site and honey bee abundance was only weakly linked to overall species richness ( $p = 0.069$ ).

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## 1. Introduction

Agriculture is occupying a growing share of the Earth's land area (Tilman et al., 2011). This, together with increasingly intense farmland management during the last century has often been linked to declining population of flower-visiting insects: hoverflies (Biesmeijer et al., 2006), butterflies (Asher et al., 2001), bees and wasps (Ollerton et al., 2014). However, since the mid-1990s the European Union's (EU) Common Agricultural Policy has sought to halt the general decline of farmland biodiversity (reviewed in

Robinson and Sutherland, 2002) by subsidising (2007–13: € 22.2 billion; EUROPA, 2011) less intensive crop management and by taking some land entirely out of production (Reviewed in Bignal, 1998). These agri-environmental schemes are now widespread and cover 59% of the UK's agricultural land (DEFRA, 2013).

Research that identified honey bee (*Apis mellifera*) foraging locations by decoding their waggle dances (Von Frisch, 1967) has indicated that late summer (July–August) is the period of the year with the greatest average foraging distances in two UK localities (Beekman and Ratnieks, 2000; Couvillon et al., 2014a). As honey bees are well known to be economically rational foragers, this implies a relative shortage of floral resources during these months. These may not be just British phenomena, as a relative dearth in late-season flowers has also been reported in the Dutch agricultural landscape (Schepe et al., 2014).

In one of these studies, Sussex, UK, dance decoding identified an area located 2–3 km from the study hives as a foraging

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'hotspot' during the challenging months of July and August (2009–11; Couvillon et al., 2014b). This hotspot is agricultural land in the South Downs, and encompasses Environmental Stewardship Scheme (ESS) farmland, including the Castle Hill National Nature Reserve (NNR) and an adjacent Site of Special Scientific Interest (SSSI). Although honey bee dance decoding is a useful and unique tool for studying honey bee foraging locations (reviewed in Couvillon et al., 2014b) it cannot pinpoint exact foraging locations (Schürch and Couvillon, 2013). As such dance decoding cannot differentiate between adjacent habitats (Schürch et al., 2013), nor can it indicate the species of flower visited by the dancing bee.

In order to ascertain the flower species and habitats which honey bees are visiting, we surveyed the hotspot during July and August in both 2012 and 2013. We also recorded the habitats types which occurred there, the species of flowers in bloom, the other insects present and the flower species they were visiting.

With these data we first aimed to identify which features of this agricultural landscape are attracting honey bees over long distances. Second, we explored whether the hotspot identified via honey bee dance decoding is also important to other flower-visitors. Thirdly, we identified which sub-habitats and flower species are most commonly utilised.

## 2. Methods

### 2.1. Study site and initial survey

During 2–15 July 2012 we conducted an initial survey of the flowers and habitats present in c. 5 km<sup>2</sup> in the Castle Hill area (United Kingdom, latitude: 50.84425916, longitude: –0.05170996). This centred on the area identified as a late summer hotspot for honey bee foraging in 2009–11 via waggle dance decoding (Couvillon et al., 2014b). The majority (>95%) of this area comprised 38 agricultural fields: pasture fields (25), arable fields (12) and set-aside (1). The remainder was a small wood (2.5 ha), farm outbuildings and a road (A270). The initial survey showed that this land comprised four main habitat types potentially attractive to honey bees and other flower-visiting insects (FVI): (i) *Pasture* fields, (ii) *Field margins/hedgerows*: <5 m strip of relatively untended land on the boundary of arable fields, (iii) *Set-aside*: fenced, uncultivated, arable field corners of approximately 0.5 ha (ESS options: EF1/HF1; NE, 2012a,b), (iv) *Nature reserve*: pasture fields in the Castle Hill NNR (1949 National Parks and Access to the Countryside Act) and the adjacent SSSI (1991 Wildlife and Countryside Act). The woodland and arable fields were found to be almost bereft of blooming plants and hence were not surveyed further.

As it was not feasible to survey such a large area in detail, we conducted an intensive survey of three fields considered the most FVI-attractive within each of the four habitat types. These fields were selected by combining the abundance and diversity of flowers estimated in our initial survey with waggle dance hotspot approximations from July and August 2009–2011 (Couvillon et al., 2014b).

### 2.2. Quantifying flower-visiting insect abundance

Transect sampling was used to quantify the abundance and richness of foraging FVI and the flower species they were visiting. Transects were conducted in the 12 study fields between 10.00–15.00, July and August 2012 and 2013, during weather conditions suitable for all FVI activity ( $\geq 16^{\circ}\text{C}$  and light wind). Insects actively visiting flowers, and the plant species, were recorded in 1 × 200m in field margins/hedgerows and 2 × 100m

transects in the three other habitat types. In order to give equal survey areas, we walked the centre of each 2 × 100m transect recording 1m to the left and right side, but recorded on only one side in the 1 × 200m transects.

In each study field we made multiple transects (mean 26; range 16–42). The number per field was determined by its relative area, from Ordinance Survey maps. Fields were further stratified into three sub-habitat types (scrub, short grass or long grass) and sampling effort was again apportioned according to their relative areas. The first transect began approximately in the centre of the sub-habitat area and followed the direction of a randomly-generated compass angle. Field margin/hedgerow transects followed the edge of the field boundary, always in the same direction to distribute sampling effort equally. The next transect began where the previous one ended. If a field boundary or the edge of the sub-habitat was reached, the transect was redirected by 90 degrees back into the study area.

FVI were identified using field-guides (Chinery, 1989; Chinery, 1993; Baldock and Collins 2008; Ball et al., 2013). All FVI were recorded except Coleoptera and Neuroptera which were not numerous, and non-Syrphidae Diptera, which could not be adequately identified. Flower-visitors were identified to species or genus with the exception of some parasitoid wasps and sawflies (Symphyta), which accounted for less than 1% of all FVI. As such, all biodiversity indexes are calculated at the genus level, except from the number of FVI species per transect. This was achieved by further identifying FVI to morphospecies during each transect. Due to the difficulty of differentiating between cryptic species in the field (e.g. *Bombus terrestris* and *Bombus lucorum*; Wolf et al., 2010) the number of species per transect may be slightly underestimated. However, many individuals were caught and/or photographed for detailed examination. We also recorded whether visible pollen loads were present on foraging bees.

### 2.3. Quantifying flower abundance

Flower abundance was quantified by counting the number of 'flower units' for all blooming insect attractive species inside five 1 m × 1 m quadrats per transect, one every 20 m (Southwood, 1966). We alternated quadrats locations between the left and right of the midline of each transect, except in field margins/hedgerows where this was not possible (i.e. 1 × 200m transects). Flower species were identified using field guides (Streeter and Hart-Davies 2009; Sterry, 2010). Flower units were categorised as a single flower (e.g. *R. fruticosus*), stem (e.g. *Galium verum*) or inflorescence (e.g. *Centaurea nigra*) as appropriate.

Because flowers and flower units are of different sizes, it is not straightforward to compare the quantity present per species. Therefore, we employed a measure of flower abundance that allows different plant species to be assessed on a more even footing. This was realised by calculating the mean 'petal area' represented by a flower unit for each species recorded. The petal area per flower unit was determined by collecting 10 flower units per species. 30 flowers (or florets) from each were then cut open, placed flat on graph paper and photographed. Petal images were categorised to the closest approximate geometric shape (circle, semi-circle, quarter circle, rectangle etc.) and relevant measurements (e.g. diameter, height) determined using ImageJ software (ImageJ, 2014, version 1.48).

### 2.4. Statistical analysis

Generalized Linear Models (GLM) were simplified using backwards elimination of non-significant variables and model comparison using ANOVA. Because our count data was over-dispersed a quasipoisson error structure was used all GLM

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