Biological Conservation 144 (2011) 2602–2606

Contents lists available at ScienceDirect

Biological Conservation

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

Gardens benefit bees and enhance pollination in intensively managed farmland

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ARTICLE INFO

Article history:
Received 3 January 2011
Received in revised form 3 July 2011
Accepted 8 July 2011
Available online 10 August 2011

Keywords:
Apoidea
Bombus
Campanula
Pollinator
Seed set
Agriculture
Landscape

ABSTRACT

The recent loss of pollinating insects and out-crossing plants in agricultural landscapes has raised concern for the maintenance of ecosystem services. Wild bees have been shown to benefit from garden habitats in urban and suburban areas. We investigated the effects of distance from garden habitats on wild bees and seed set of a native out-crossing plant *Campanula persicifolia*, in intensively managed agricultural landscapes in Southern Sweden. Bee abundance and species richness, as well as plant seed set, were higher closer to gardens (<15 m) than further away (>140 m). This highlights private gardens as a landscape wide resource for pollinators but also the lack of sufficient pollination of wild plants in contemporary agricultural landscapes.

1. Introduction

Agricultural intensification, resulting in loss and fragmentation of natural habitats, has caused large-scale losses of farmland biodiversity in general (Krebs et al., 1999). Widespread declines of pollinators have received particular attention because of the risk to the ecosystem service they provide (Kremen et al., 2002; Potts et al., 2010; Steffan-Dewenter et al., 2005). In fragmented landscapes, a main threat to wild plant reproduction is pollination failure, caused by lack either of mates or of pollinators (Wilcock and Neiland, 2002). In fact, large-scale losses of pollinators have been paralleled by losses of out-crossing plant species (Biesmeijer et al., 2006; Gabriel and Tscharntke, 2007).

Semi-natural habitats are known to positively affect pollinators in the surrounding agricultural landscape (e.g. Öckinger and Smith, 2007; Ricketts et al., 2008) presumably through contributing both nest sites and forage resources. Other non-crop areas such as field margins may also be beneficial provided that they are rich in flower resources (Kleijn and van Langevelde, 2006). Linear landscape elements are also known to be important for bumblebee nesting (Lye et al., 2009; Osborne et al., 2008; Svensson et al., 2000). Non-crop, semi-natural areas add heterogeneity to otherwise, in many aspects, simplified agricultural landscapes (Benton et al., 2003). Another type of non-crop areas is domestic gardens situated in the countryside. In heavily cultivated surroundings gardens can be assumed to enhance floral abundance and diversity, as well as three-dimensional structure (i.e. habitat complexity). Lately attention has been drawn to the positive impact of urban gardens and allotment gardens on pollinators (Ahrné et al., 2009; Goddard et al., 2010) and on the process of pollination (Cussans et al., 2010). Gardens often provide a continuous supply of nectar and pollen which bees can utilise (Fussell and Corbet, 1992). Suburban gardens have been shown to increase growth of experimental colonies of *Bombus terrestris* compared to rural areas (Goulson et al., 2002). In urban gardens, habitat complexity and diversity of flowering plants have been shown to be positively related to bumblebee and solitary bee diversity (Smith et al., 2006). Gardens can provide suitable habitats for bees to nest and have been shown to contain higher densities of bumblebee nests than grasslands and woodlands in arable landscapes (Osborne et al., 2008). Hence, gardens may promote pollinator abundance and species richness also in agricultural landscapes.

However, measures promoting pollinators may not necessarily benefit pollination of wild plants, because species may vary in their effectiveness as pollinators (Klein et al., 2003). Species may for example vary in rates of removal and deposition of pollen (Wilson and Thomson, 1991) and also in their degree of flower constancy (Goulson, 1999). Another example of a more indirect effect on pollination is large-scale cultivation of oilseed rape, *Brassica napus* L. This mass flowering crop may be beneficial for some early emerging and short-tongued bumblebee species, but results in reduced abundance of long-tongued bumblebees, which are in turn important

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doi:10.1016/j.biocon.2011.07.008

pollinators of plants with deep corollas (Diekötter et al., 2010). Thus, it is important to determine the effect of gardens not only on the general abundance of pollinators, but also on different groups of pollinators and pollination *per se*. It has also been shown that the decline with distance (from natural or semi-natural habitats) of native pollinator visits to crops is steeper than the decline of pollinator richness with distance (Ricketts et al., 2008), which again highlights the importance of studies including the pollination service itself. Foraging ranges of bees are positively related to body size (Greenleaf et al., 2007). In the region of this study, bee body size correlates with sociality in that social bees (*Bombus* species and *Apis mellifera*) are larger than solitary bees.

Our aim was to investigate whether gardens in landscapes highly dominated by agriculture can act as sources of pollinators and subsequently benefit pollination of wild out-crossing plants. To this end we investigated whether species richness and abundance of bees were higher close to gardens than further away, whether the abundance of two groups of pollinators (large social and small solitary bees) were differently affected by distance and whether, because of improved pollination, plant seed set for a native out-crossing plant was higher close to gardens. We focused on bees (Hymenoptera: Apoidea) as they are an important group of pollinators (Winfree et al., 2008). Bees can benefit from gardens for both nesting and foraging but as they are central place foragers with restricted foraging ranges (Goulson, 2003) they may also be negatively affected by distance between nests and forage sites and thus indirectly allow detection of their source of origin.

2. Material and methods

2.1. Study set up

The study was carried out in southernmost Sweden (approx. 56°N, 13°30′E, Fig. 1). We selected nine landscape sectors (squares of 2.5 × 2.5 km) situated in a region largely dominated by agriculture. All landscapes were similar regarding the percentage area of sectors under agricultural land use which was on average 81.7 ± 10.7% (mean ± stdv). Of this area annual crop fields comprised 91.2 ± 5.9% and leys 5.9 ± 5.5% (mean ± stdv). The total area of permanent pastures was 1 ± 1.5% (mean ± stdv). Within each landscape sector two isolated domestic gardens were identified and inspected to ensure reasonable similarity with respect to features important to pollinator abundance and diversity (Osborne et al., 2007; Smith et al., 2006). All gardens had an area of at least 500 m^2 and included all the following features: planted flowers, native herbaceous plant species, trees, flowering bushes and sections with tall grass. The majority of gardens also included hedges and a compost heap.

Along a road verge bordering a non-flowering crop field and reaching out from the gardens, either phytometers (plants used to estimate pollination [cf. Albrecht et al., 2007], in this case *Campanula persicifolia*) or a set of three pan-traps were placed. Phytometers and traps were placed at two different distances, either "proximate" within 15 m from the edge of the garden or "distant" approximately 140 m away. Since the study was made up of paired potted plants and traps, respectively, separated by only ca. 125 m, factors related to land-use and management as well as vegetation and soil properties were largely controlled for. We did not use the same garden for both phytometers and traps because of the risk of pollinator depletion due to the traps. Which of the two gardens within a landscape received phytometers and traps, respectively, was randomly selected. One landscape also had a third garden with phytometers bagged in fine mesh. These plants served as pollinator free controls and were placed in the field to ensure similar weather and wind conditions to experimental plants.

The pan-traps were sets of three traps: one yellow, one white and one blue plastic cup, (6 cm deep, ∅ 15 cm) sprayed with the corresponding fluorescent colour (Sparvar, Leuchtfarbe). Traps were placed directly on the ground and filled with 50% propylene glycol. Each phytometer consisted of two plants of peach-leaved bellflower, *C. persicifolia*, a wild, self-incompatible flower native to Sweden (Nyman, 1992). The plants were purchased from a local garden centre at the beginning of May 2009 and were immediately replanted in 7.5 l pots with commercial garden soil. Both the phytometers and traps were kept in the field for 3 weeks, from the end of June until mid July, and were visited and watered twice a week. To be able to determine in which order inflorescences had bloomed, we marked all inflorescences that had started to bloom since the last visit (i.e. every 3rd to 4th day) with coloured thread and used a unique colour for each visit to keep track of the order of flowering.

C. persicifolia was present in one of the gardens where phytometers were placed. Lack of other suitable gardens made us unable to remove this garden from the study, but we do not believe that this will lead to any bias since the study design focuses on pollination in relation to distance from gardens rather than on pollination inside gardens. Both proximate and distant phytometers should benefit from a pollen source inside the garden. Insects caught in traps were collected and stored in 70% ethanol. After the field study all plants were transferred to a greenhouse.

2.2. Data collection

All capsules from *C. persicifolia* marked in the field, except those marked at the last visit, were harvested between 30 July and 20 August when ripe ($n = 233$). Seeds were weighed and we used

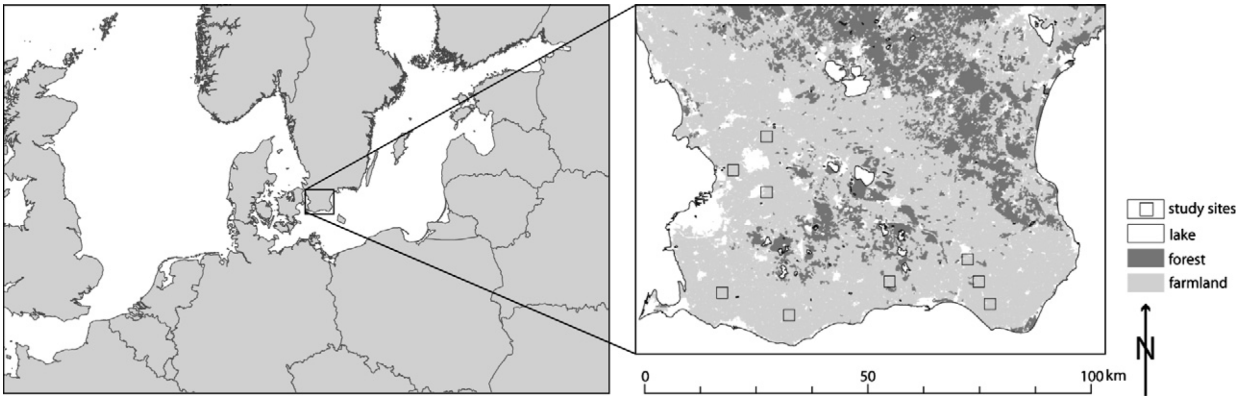

Fig. 1. Map of the study region in southernmost Sweden, which is largely dominated by agriculture. The nine landscape sectors (2.5 × 2.5 km quadrates) used in the study are drawn.