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Research Paper

Local conditions in small habitats and surrounding landscape are important for pollination services, biological pest control and seed predation

Jessica Lindgren*, Regina Lindborg, Sara A.O. Cousins

Biogeography & Geomatics, Department of Physical Geography, Stockholm University, 106 91 Stockholm, Sweden

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ABSTRACT

Small semi-natural and natural habitats in agricultural landscapes are important for biodiversity. With modern and more intensive agricultural practices they have become smaller (less than 1600 m^2) and more isolated study which also affects ecosystem functions. Most ecosystem function studies using field experiments focus on a single function. Here, we investigate three functions in the same landscape at the same time. We investigated how local (trees, shrubs and grass-cover in small remnant habitats) and landscape factors (amount of and distance from key habitats i.e. forest and semi-natural grasslands) affect pollination, biological pest control and seed predation. We applied a multifunctional approach using different organisms to analyze pollination success (*Primula veris*), predation on aphid pests *(Rhopalosiphum padi)* and seed predation (of *Helianthus annuus*). A set-up of 3 different experiments were placed in situ on 12 midfield islets. Pollination was more affected by local factors than landscape factors, although pollination success was improved by a smaller proportions of surrounding crop fields. Seed predation was higher on islets with more surrounding forest and also with more trees on the habitat, especially close to shrubs, compared to more open areas of habitat. Predation on aphids decreased on midfield islets with a larger amount of nearby forest but was positively affected by increasing local tree cover on the habitat.

We show that managing semi-open habitats that are connected to other natural or semi-natural habitats can improve pollination success and biological pest and weed control, thus potentially increasing yield in surrounding crop fields.

1. Introduction

Large-scale landscape changes have transformed former heterogeneous agricultural landscapes into more homogenous landscapes with less natural and semi-natural habitats. Homogenization of agroecosystems and expansion of monocultures is negatively affecting biodiversity (Winqvist et al., 2011; Newbold et al., 2015, 2016; Wood et al., 2015). For example, a major percentage (32.8%) of all endangered species in the Swedish red-list are species associated with agriculture landscapes (Eriksson, 2016). A decline in biodiversity often also leads to changes in ecosystem functions (Hector and Bagchi, 2007; Gamfeldt et al., 2008). Species diversity increases the ability to sustain agricultural production while maintaining substantial ecosystem functions in the system. Further, high biodiversity results in a greater diversity of functional traits present within the ecosystem, increasing resilience towards environmental changes (Tilman et al., 1996; Tscharntke et al., 2012).

There is a concern that in intensively used agricultural landscapes, several ecosystem functions will change or be lost as a result of biodiversity declines. The destruction and associated increasing isolation and fragmentation of key habitats may have negative or positive effects on organisms performing specific functions in the landscape. The risk of an outbreak of pests or smaller harvest due to fewer predators and pollinators in the landscape is higher in homogenous agricultural landscapes (Klein et al., 2012; Tscharntke et al., 2012; Hatt et al., 2017). An increasing knowledge on what controls pests in crop-fields can help minimize these effects on agricultural production, while potentially allowing pesticides to be used in smaller doses (Hatt et al., 2017).

To maintain high biodiversity and associated essential functions in agricultural landscapes we need to know how local environment, landscape context and distance to key habitats (forests and semi-natural grasslands) affect the ecosystem functioning of small habitats, and the benefits they provide to the nearby surroundings (Kennedy et al., 2013). Some of the key ecosystem functions in agriculture landscapes are pollination, biological pest control and seed predation, which have been linked to landscape composition (Bianchi et al., 2006; Hector and

* Corresponding author.
E-mail addresses: jessica.lindgren@natgeo.su.se (J. Lindgren), regina.lindborg@natgeo.su.se (R. Lindborg), sara.cousins@natgeo.su.se (S.A.O. Cousins).

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Bagchi, 2007; Herbertsson et al., 2016). Several studies have found that to uphold a sustainable level of ecosystem functions, a certain amount of species-rich natural and semi-natural habitats are needed in the landscape (Tscharntke et al., 2012; Kammerer et al., 2016b). A higher amount of natural habitats will increase the spillover of species and functions from natural habitats to surrounding agricultural area (Alignier et al., 2014; Andersson et al., 2014; Kammerer et al., 2016b).

Small natural and semi-natural habitats in agricultural landscapes, e.g. forest edges, road verges, hedgerows and midfield islets, have been shown to be important to maintain species richness and to act as stepping stones for many species (Cousins, 2006; Cousins and Eriksson, 2008; Lindborg et al., 2014; Kammerer et al., 2016b) and as sources of ecosystem functions in agriculture landscapes (Mitchell et al., 2014). Amount of forest in the surrounding landscape have been suggested as an important factor determining pollination functions in landscapes, as forest and the forest edge can provide shelter suitable nesting places (dead wood, cavities and banks), and flowering shrubs and trees for foraging (Kammerer et al., 2016b, Lindgren, Cousins & Kimberley, manuscript).

Pollinators provide valuable services to both native and cultivated plants. Their presence and abundance are determined by the availability food and sites for nesting and overwintering within foraging distance (Winfree, 2010). Even though pollinators use both crops and natural habitats for foraging and move between them (Blitzer et al., 2012), they depend on non-crop habitat for nesting and overwintering sites as well as for food when crops are not flowering. Aphids (Hemiptera: Aphididae) are a major pest on cereal crops as aphids can reduce plant growth (Wojciechowicz-Zytko and Jankowska, 2016). In a local patch, the diversity and abundance of most biological pest predators has been observed to decrease with isolation from other woody habitats (Schuepp et al., 2014) although, isolation has been reported to have a positive effect on pest predation (Ibáñes et al., 2014). Hence pollinators, predators of aphids and aphids in themselves are all mobile organisms and depend not only on local environment but also on landscape factors (Tews et al., 2004; Bianchi et al., 2006; Alignier et al., 2014).

Semi-natural grasslands are a good resource for foraging of pollen and nectar and for nesting sites for insects, but smaller marginal areas such as road verges, set- asides or other habitats with floral resources can also be an asset to pollinators (Öckinger and Smith, 2007). Midfield islets have exceptionally high plant species richness as they are remnant habitats in former grazing systems (Auffret and Cousins, 2011). Larger midfield islets have a higher possibility to hold more species than smaller ones, following the species-area relationship (Arrhenius, 1921), while well-connected midfield islets will hold more species than isolated ones due to the relative ease with which they can be colonized by dispersal limited plants (Lindgren and Cousins, 2017). High floral resources benefit predators of aphids and also attract more pollinators (Ebeling et al., 2008; Ramsden et al., 2015; Kammerer et al., 2016b). Isolation of small habitats may therefore also reduce the ecosystem functions provided by the small habitat and limit the ability of pollinators and predators to reach the isolated habitat.

At landscape scales, pollinator diversity, aphids and their predators increase in more complex landscapes which contain a higher amount of semi-natural and woody habitats (Roschewitz et al., 2005; Bianchi et al., 2006; Kammerer et al., 2016b). Increased distance to species-rich grasslands results in fewer species of pollinators visiting isolated habitat (Steffan-Dewenter and Tscharntke, 1999; Öckinger and Smith, 2007) and may reduce the pollination success of plants.

Wooded habitats also provide habitats for predators, such as arthropods. Isolation from woody habitats has been shown to have negative effects on density of predators of herbivores (Stutz and Entling, 2011; Mitchell et al., 2014; Schuepp et al., 2014) and on species richness and abundance of pollinators (Klein et al., 2003; Kammerer et al., 2016a). However, the opposite effect has also been reported, at least for predators (Geiger et al., 2009) i.e. density of predatory arthropods was higher in open agriculture landscape compared to forested landscapes.

Seed predation can fulfil two opposing functions within a crop landscape. On the one hand it can result in reducing the amount of weeds present in the crops but on the other hand it can also reduce the crop itself (Brown et al., 2007; Schäckermann et al., 2015a; Fischer and Turke, 2016; Presotto et al., 2016). Seed predation is complex, higher distances to forest habitat has been shown to result in decreased seed predation (Farwig et al., 2009). In open land, seed predation is mainly performed by invertebrates and birds, while rodents prefer avoid open areas due to predation risks (Schäckermann et al., 2015a). As seeds are predated by several different groups e.g. invertebrates, birds and small mammals (Birthisel et al., 2015) the effect of landscape structures is difficult to predict and can vary depending on the main predator, often related to the habitat type (Birthisel et al., 2015).

Carabid beetles are one group of seed predating invertebrates. Species richness of Carabid beetles is positively affected by larger proportions of crop-field, resulting in a higher predation of weed seeds (Jonason et al., 2013). However, the opposing result has also been observed, with an increased amount of semi-natural habitats leading to greater diversity of ground beetles and seed predating birds (Schäckermann et al., 2015a; Rusch et al., 2016). In fact, the effect of landscape composition on seed predation and small mammals communities has been demonstrated to be highly species specific (Jackson and Fahrig, 2012) which makes it hard to assess the general importance of amount of a specific land use on overall seed predation levels.

Several theoretical studies, reviews, and models have been performed to understand how ecosystem functions are effected by different levels of agricultural and management intensity (Hodbod et al., 2016; Boerema and Meire, 2017), but few studies have simultaneously tested different ecosystem functions at the same time in a field experiment (but see Farwig et al. (2009)). A multifunctional experiment performed in an area with similar abiotic and biotic conditions and land use history facilitates the interpretation of how factors such as isolation, habitat loss and local environmental management affect different ecosystem functions at the same time.

Inspired by Farwig et al. (2009) we conducted a multifunctional field experiment to analyze the way in which local factors and surrounding landscape variables affect three different ecosystem functions, namely pollination success and predation on pests and seeds using 12 midfield islets. While Farwig et al., (2009) focused on the effect of surrounding landscape on ecosystem functions in grasslands, our specific aims were to investigate i) to what extent proportion of trees and open grassland (i.e. local factors) on small midfield islets have a positive impact on ecosystem functions, ii) if distance to semi-natural grassland and amount of forest in the surrounding landscape affects ecosystem functions.

2. Methods

2.1. Study region

The study landscape is located on Mörkö in Södermanland County, 70 km south of Stockholm, Sweden (58°99′N, 17°66′E). The landscape is dominated by crop-fields on clay soils in the lower terrain surrounded by bare bedrock outcrops or forest on moraine. The elevation runs from the sea level to 61 m above sea level. Mean annual temperature for January is −1/0 °C and for July 16–17 °C (2015) with a mean annual precipitation of 500–600 mm in 2015 (SMHI, 2017-03-16).

There is a long tradition of farming and grazing animals in the area (> 300 years). According to historical economical maps, agriculture has been present at least since the 17th century. Today it is an agricultural landscape using modern agriculture methods, with managed coniferous forest surrounding the crop fields.