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An agri-environmental scheme enhances butterfly dispersal in European agricultural landscapes

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ABSTRACT

The loss of connectivity caused by habitat fragmentation is one of the greatest threats to biodiversity. This is of particular concern in agricultural landscapes, which combine increased levels of fragmentation with larger numbers of endangered species than other landscapes. Corridors (e.g. linear landscape elements) are a popular conservation strategy to counteract fragmentation effects. Grassy field margins (GFMs) have been established throughout Europe as part of agri-environmental schemes. The primary goal of these measures is to protect water quality, but it is suggested biodiversity may benefit via a corridor function. Being set up along watercourses, GFMs may spontaneously form a coherent network of corridors in agricultural landscapes. We tested this hypothesis by monitoring movement strategies of Meadow brown butterflies (*Maniola jurtina* L.) in GFMs. Results indicated that butterfly movement was facilitated by this new landscape element, supporting its corridor function. Mechanistically, dispersal occurred through foraging movements rather than movements adapted to dispersal. Spatial configurations of GFMs were also explored in a large agricultural area and demonstrated that the GFM policy is adequate to provide a corridor function.

1. Introduction

Habitat fragmentation is one of the most obvious human footprints on the landscape, and is recognized as a major threat to biodiversity (Saunders et al., 1991). Among human activities, agriculture is one of the most important causes of fragmentation (Scharlemann et al., 2005). As a spatial process, fragmentation is defined as a progressive shift from large, natural habitat patches to small, isolated habitat remnants. At the landscape scale, it involves both loss and breaking apart of habitat (Fahrig, 2003), which can affect the long-term persistence of species due to decreased population viability (Hanski and Thomas, 1994), loss of the rescue effect (Clinchy, 1997; Fahrig, 2002), and decreasing the genetic variability of local populations (Debinski and Holt, 2000). The effects of fragmentation are most often driven by the subsequent loss of connectivity, which decreases the success of individual dispersal and increases its costs (Dover and Settele, 2009). Therefore, increasing connectivity among patches is a reasonable approach to mitigate the adverse effects of fragmentation (Fahrig and Merriam, 1985; Adler and Nuernberger, 1994).

Corridors, e.g. linear landscape elements (Forman, 1995) have been shown to increase connectivity for some species and rapidly counteract the loss of connectivity between habitat remnants. Corridors have become popular conservation strategies among stakeholders (Hilty et al., 2006), but the effects are controversial, and have yielded considerable debate over the last two decades (Simberloff et al., 1992; Dawson, 1994; Beier and Noss, 1998). Evidence for success is abundant, however corridors are sometimes criticized because of design flaws, confounding variables, artificial experimental systems or of the lack of alternative hypothesis in field tests, such as the intensity of dispersal through adjacent matrices (Dawson, 1994; Beier and Noss, 1998).

Fragmentation effects are known to be particularly important when the surrounding matrix is composed of agricultural land (Bayne and Hobson, 1997; Joly et al., 2001). Furthermore, theory predicts that conservation measures to restore landscape connectivity should be most effective when habitat loss exceeds an estimated threshold of 20–30% of the remaining semi-natural habitat (Flather and Bevers, 2002). Most of the European agricultural landscapes remain under this threshold, and support approximately 75% of endangered species in the European continent (Leroux et al., 2008). Therefore, restoring connectivity is of vital importance to counteract the negative effects of habitat loss on

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biodiversity in agricultural landscapes, and corridor may be the most direct management strategy to accomplish this goal.

One approach to promote corridors in agricultural landscapes is through conservation or creation of natural linear elements such as grassy field margins (Van Geert et al., 2010). Subsidies for the creation and maintenance of grassy field margins (GFM) were launched in 2005 throughout Europe, as part of the agri-environment schemes within the Common Agricultural Policy (CAP) framework of the European Union (EU Regulation 1290/2005). Similar measures have been implemented in the United States under the United States Department of Agriculture (Donald and Evans, 2006). GFMs are linear, grassy strips, typically 5–10 m in width that are preferentially set up along watercourses to act as buffers against nutrient runoff from crop fields (also referred to as "filter strips"). Consequently, GFMs may spontaneously form a coherent network of natural habitat in agricultural landscapes. Several reports suggest an overall positive influence of GFMs on biodiversity (Field et al., 2005, 2007; Reeder et al., 2005; Woodcock et al., 2007) which may eventually be due to their effect on habitat connectivity (Donald and Evans, 2006) and supposedly meadow species use as a corridor for movement (Sutcliffe et al., 2003; Delattre et al., 2010b). However, this effect has still to be proven. Moreover, GFMs were designed as a conservation measure with another specific function. Obtaining multiple ecological benefits under these circumstances can frequently be ineffective, if not counterproductive (Olson and Wäckers, 2007). Given the high amount of money spent in agri-environment schemes each year (Kleijn et al., 2001), assessing if they can be established to serve multiple conservation management issues could help distribute the costs over a broader range of ecological concerns and consequently, to save money in the long term. However, despite the promising potential of GFMs as corridors, this function has yet to be demonstrated.

Species distributional patterns across landscapes are known to result from small-scale, individual behavioral responses (Levey et al., 2005). Monitoring individual species movements is considered a valuable method to demonstrate the corridor function in a given landscape element, as it directly sheds light on behavioral mechanisms of corridor influence on species dispersal (Dover, 1997; Haddad, 1999; Dover and Fry, 2001; Chetkiewicz et al., 2006). In this way, it generates actual paths through both the corridor and matrix, and allow to generalize results based on dispersal traits – such as the probability to cross a boundary, the dispersal kernel or the different movement strategies used by a species – instead of providing limited species-specific data (Dover, 1990; Fry et al., 1992).

The Meadow Brown (*Maniola jurtina*) is a non-specialist butterfly inhabiting a wide range of grassy habitats, and is abundant in the agricultural landscapes of Western Europe. Its movement behavior has been extensively studied (Dover et al., 1992; Conradt et al., 2001; Schneider et al., 2003; Kindlmann et al., 2004; Conradt and Roper, 2006; Aviron et al., 2007; Ouin et al., 2008; Delattre et al., 2010a). Delattre et al. (2010b) performed simulation studies indicating that its dispersal rates may benefit from corridors at the landscape scale.

In the present study, we addressed the following topics relative to Meadow Brown use of GFMs as corridors: (1) was the butterflies' movement directed by GFMs; (2) was dispersal through corridors a by-product of foraging movement, or of movement adapted to dispersal; (3) was dispersal more likely to occur via the matrix or the corridor; and (4) we addressed if the current spatial configuration of the GFMs in a 13,000 ha agricultural landscape was designed effectively as a buffer strip to facilitate a potential corridor function at the landscape scale.

2. Materials and methods

2.1. The species

Butterflies are known to be good surrogates for the study of dispersal in a broad range of foraging organisms (Lewis and Bryant, 2002; Watt and Boggs, 2003). Adults are typically easy to follow individually and fly continuously searching for well-defined resources that are often organized in discrete aggregates. The Meadow Brown (*Maniola jurtina* L.) is one of the most abundant butterfly species in the agricultural landscapes of Western Europe. It is distributed in grassy habitats (open meadows, road verges, glades, hedgerows and forest paths) where larvae feed on various *Poa, Agrostis* and *Festuca* species, whereas adults use a wide range of nectaring plants (Porter et al., 1992).

M. jurtina shows dispersal rates that are characteristic of butterfly metapopulations in fragmented Western European landscapes (Conradt et al., 2000). Its dispersal behavior is far from the random movements predicted in theoretical models, with individuals recognizing patch boundaries, having considerable control over the departing habitat, and their subsequent trajectories (e.g. Conradt et al., 2001; Kindlmann et al., 2004; Conradt and Roper, 2006). This species is particularly known for two dispersal strategies: a systematic search strategy ("*foray search*") adapted to explore the immediate vicinity of the departure patch, in which individuals fly in loops around their departure point (Conradt et al., 2003), and a "*direct flights*" strategy adapted to long distance dispersal (Delattre et al., 2010a).

2.2. Study site

The study area was located in Brittany (South of the Mont Saint-Michel: 48°36′N, 1°32′W), France, in a 13,000 ha LTER site[1] (Fig. 1). The site was comprised of a mixture of crops, hedgerows and small grassland patches. *M. jurtina* habitat covered 11% of the total area, with mean distance between patches $d = 130$ m ± 110, and the probability of finding neighboring patches within the same habitat – "homogeneity index" – $h = 0.36$. Meadow surface ranged from 0.05 to 5 ha (mean = 0.75 ha, the typical surface in this study area). GFMs were five to 20 m – width (mean = 10 m) and 20–340 m long (mean = 150 m, see Fig. 2 for examples). All GFMs are typically planted with a standard set of Trifolium and Poacea, and floral resources were very similar in all the GFMs studied.

2.3. Mapping and quantifying movement behavior

Butterfly movement was examined in three sites separated by four to 8.5 km (Fig. 1). Each site was composed of one GFM and one adjacent meadow (habitat patch). Butterfly movement was monitored in both the GFM and the meadow. The meadow served as a reference of the actual movement behavior in habitat patches. Meadow sites were chosen on the basis of GFM characteristics: short herbaceous vegetation, rectilinear shape and length beyond *M. jurtina* perceptual range (c.a. 70 m (Conradt et al., 2000)). Each GFM had open boundaries with the agricultural matrix that posed no physical obstacle to movement (Collinge and Palmer, 2002). The surrounding crop fields (young wheat or barley fields, hereafter

[1] LTER: Long-Term Ecosystem Research. See http://www.caren.univ-rennes1.fr/pleine-fougeres/ for this particular study site and http://www.lter-europe.net/ for the European LTER Network.