Leaving an uncut grass refuge promotes butterfly abundance in extensively managed lowland hay meadows in Switzerland

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SUMMARY

The main goal of this study was to experimentally test whether maintaining a fraction of a meadow uncut would create a refuge that can efficiently conserve butterflies in extensively managed meadows registered as biodiversity promoting areas, the most common type of agri-environment scheme in Switzerland. Leaving part of the meadow uncut was expected to benefit butterflies by providing shelter and food resources once the rest of the meadow has been mown. The measure was experimentally applied since 2010 in 12 sites of the Swiss lowlands (Plateau). There were two experimental meadows per site, with one mowing regime applied at random within the pair. One meadow was managed according to the standard regulations for meadows in biodiversity promoting areas, meaning that the meadow was entirely mown at least once a year, but not before 15 June (control meadows). The second meadow was only partially mown, and a grass refuge of 10-20% of its area was left uncut during mowing operations (refuge meadows). In 2013 we conducted Pollard walk surveys to assess the efficiency of the refuge scheme. Results indicate that after mowing the uncut refuges were occupied by butterflies, with much higher abundances than in control meadows. Keeping an unmown grass refuge within hay meadows would be a simple and easy measure to promote butterfly populations within current agri-environment schemes.

BACKGROUND

The intensification of agricultural practices has led to spatially and temporally over-simplified agricultural landscapes throughout most of the western European lowlands. Among invertebrates, diurnal butterflies (Lepidoptera) have been drastically affected by these changes. As a result, more than 20% of European grassland butterfly species are now considered as threatened (Van Swaay *et al.* 2006, Ekroos *et al.* 2010). In Switzerland 35% (78 species) appear on the Swiss Red List, most of these occurring in dry grasslands at low to medium altitude (Wermeille *et al.* 2014).

In order to promote semi-natural farmland habitats and counter biodiversity loss, agri-environment schemes (AES) were introduced in Switzerland in 1993. Formerly termed ecological compensation areas, Swiss AES were recently renamed biodiversity promoting areas (BPA). Extensively managed meadows are the most common type of BPA in Switzerland (52% of the whole area devoted to BPA), covering about 7% of the total agricultural area of the country. BPA meadows cannot be fertilised or treated with pesticides. They must be mown at least once a year, but not before 15 June in the lowlands.

Swiss BPA, as well as other European AES, have had only moderate positive effects on biodiversity so far (e.g. Kleijn *et al.* 2006, Aviron *et al.* 2009), notably upon invertebrates. The main reason has been suggested to be excessive landscape fragmentation and a lack of source populations to allow colonisation of otherwise suitable habitat (Ekroos *et al.* 2010). We further suggest that current BPA do not offer the necessary spatio-temporal heterogeneity within farmland for successfully restoring invertebrate biodiversity. In other words BPA extensively managed meadows are mown almost simultaneously, leaving nowhere for butterflies to feed, roost and reproduce.

Butterflies experience both sedentary and mobile life history stages, with each stage depending upon specific resources. Alteration of a single resource, such as host plant availability for caterpillars, can have drastic effects on butterfly population dynamics (e.g. Johst *et al.* 2006). They can be massively impacted by mowing operations on meadowland, especially due to sudden decreases in the availability of shelters, egg-laying sites and nectar sources (Dover *et al.* 2010, Cizek *et al.* 2012). Not surprisingly, leaving areas of uncut grass (refuges) after mowing operations has been advocated for mitigating these negative effects (Dover *et al.* 2010, Humbert *et al.* 2012). Such refuges likely maintain some continuity in the availability of host plants, nectar sources and shelters, while guaranteeing a diversity of microclimatic conditions throughout the season. In addition to providing food and shelter for adult butterflies, uncut grass refuges may further decrease the direct mortality of caterpillars and pupae caused by mowing machinery (Valtonen *et al.* 2006, Humbert *et al.* 2010). This would in particular benefit rare species whose caterpillar and pupae stages coincide with the mowing date (Walter *et al.* 2007).

The aim of this study was to experimentally test, at field scale, whether butterflies would use and benefit from such refuges among meadowland (Figure 1). This study was carried

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Figure 1. An extensively managed meadow in the Swiss lowlands showing an area of uncut grass left behind after mowing operations. The picture was taken in mid-July, about one month after meadow mowing.

out in extensively managed meadows located at 12 lowland sites spread across the Swiss Plateau (see Buri *et al.* 2014, for details on study sites). Study sites were more than 5 km apart and comprised two meadows each, which were more than 440 m from each other. The study meadows had been registered as BPA since at least 2004 and had an area greater than 3000 m^2.

ACTION

The experiment began in 2010. It consisted of a random allocation of one of two mowing regimes to a meadow within each site pair. These mowing regimes were implemented using a randomised block design, where sites represented blocks. The two mowing regimes were:

1. Control meadows. Extensively managed meadows with first grass cut not before 15 June and without restriction regarding the number and frequency of subsequent cuts. This corresponds to the standard for meadows declared as BPA under the Swiss regulation. These meadows constituted our controls although they already involve a specific management targeting biodiversity.
2. Refuge meadows. Meadows with similar management conditions to control meadows, but with an extra rotational uncut refuge left on 10–20% of the meadow area. This was achieved by not mowing a corresponding fraction of the area of the meadow each time the meadow was mown.

To investigate whether butterflies benefit from the uncut refuges, butterfly abundance in each meadow was sampled by conducting line transect surveys, also called Pollard walks (Pollard & Yates 1993), in three different configurations: 1) inside the refuge area; 2) in the mown area outside the refuge; and 3) in the control meadow. The search for butterflies was carried out within 30 m long and 5 m wide transects, which were systematically placed in the centre of each meadow area so as to limit edge effects. In some refuge meadows, the uncut refuges were less than 5 m wide, and here we conducted two 2.5 m wide transect surveys within the band. Sampling was carried out after the first grass cut, between 18 June 2013 and 11 July 2013, exclusively on sunny days without excessive wind (< Beaufort 3).

Data were analysed with generalised linear mixed effects models using Poisson error distribution. The response variable was butterfly abundance/transect, while mowing regime was a fixed effect, and study site (12 spatial replicates) a random effect. To appraise differences among mowing regimes, a post hoc test was performed using the function *relevel* of R.

CONSEQUENCES

The average (± standard error) number of adult butterflies counted per transect was 1.08 (± 0.40) in the control meadows; 0.75 (± 0.33) in the mown part of the refuge meadows; and 3.25 (± 1.42) in the uncut refuge of the refuge meadows (Figure 2). No difference in butterfly abundance was found between the control meadows and mown area of the refuge meadows (estimate = -0.37, z = -0.84, p = 0.40). In contrast, the uncut areas of the refuge meadows harboured higher butterfly abundance, by a factor of about three, than both control meadows (estimate = 1.10, z = 3.40, $p < 0.001$) and the mown area of the refuge meadows (estimate = 1.47, z = 3.92, $p < 0.001$). By far the most dominant species was meadow brown *Maniolata jurtina*, followed by Essex skipper *Thymelicus lineola*, painted lady *Vanessa cardui*, marbled white *Melanargia galathea* and small white *Pieris rapae*.

DISCUSSION

The fact that butterfly densities in control meadows and in the mown part of the refuge meadows were comparable but three times lower than in the uncut grass refuges indicates that the butterflies actively used the refuges. Dover *et al.* (2010) did

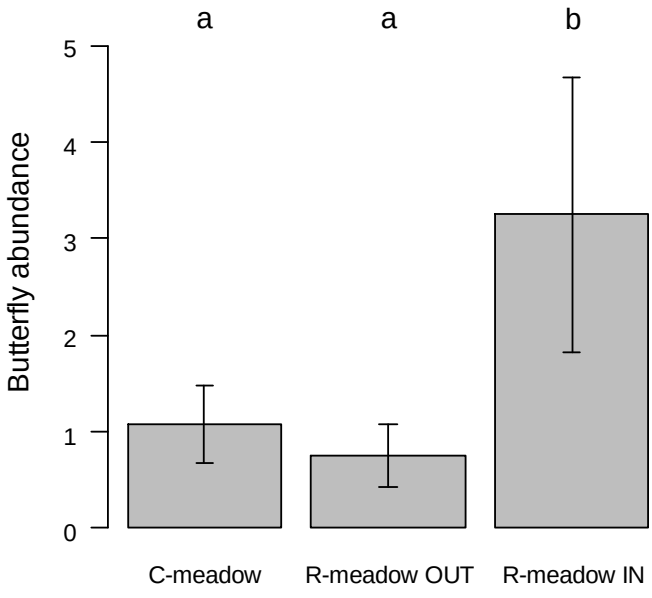

Figure 2. Average (± standard error) number of adult butterflies counted per transect in control (C-meadows) and refuge meadows (R-meadows) 13 ± 8 days, on average (± standard deviation), after mowing operations. Surveys in R-meadows were conducted both outside the refuge (R-meadow OUT) and inside it (R-meadow IN). Different letters indicate significant differences at an alpha rejection level of 0.05.

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not observe (but this was not quantified) any mass dispersal of butterflies after mowing in Spain, which suggests that butterflies do not move to neighbouring uncut meadows to seek the resources which have abruptly vanished from their previous habitat. Altogether, this suggests that systematically leaving unmown grass refuges within every meadow is a good measure to enhance butterfly abundance. The occurrence of very few uncut semi-natural grasslands across the Swiss Plateau from mid-June to mid-July might explain why butterflies have become so rare in our modern lowland agricultural landscapes.

Given the positive effects of this measure for butterflies (and also orthopterans and wild bees; Humbert *et al.* 2012, Buri *et al.* 2013), subsidies could be paid to farmers to compensate for any resulting hay losses. This measure would be easy to integrate within current AES prescriptions because leaving a section of a field unmown is extremely simple to implement.

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