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Simple modifications of mowing regime promote butterflies in extensively managed meadows: Evidence from field-scale experiments

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ABSTRACT

Restoring biodiversity-rich grasslands within cultivated matrices represents a real conservation challenge. One set of options consists in adopting less disruptive mowing regimes, as mowing impacts on invertebrates can be considerable. We experimentally tested the effect on butterfly populations of a spatio-temporal modification of mowing regimes within extensively managed meadows. The control regime (C) followed the standard Swiss agri-environment schemes (AES) regulation: no cutting before 15 June and no fertilisation. The second regime consisted of delaying (D) the first possible cut by one month (to 15 July). The third regime consisted in maintaining a 10–20% uncut grass refuge (R) during mowing operations. This experiment was replicated at 12 study sites across the Swiss lowlands, and applied yearly since 2010. Butterflies were sampled in 2013. Butterflies generally benefitted from D- and R-regimes. Before the onset of mowing operations, both D- and R-regimes yielded higher butterfly densities (+70%) compared to the C-regime, demonstrating positive cumulative effects (i.e. carry-over effects from one year to the next), not only for the whole butterfly community, but also for resident, multivoltine, mono- and oligophagous species. After 15 June, densities were about six times higher in D- than in C- and R-meadows until D-meadows were cut mid-July. Species richness of specialist butterflies was significantly higher in R-meadows (+60%) compared to C-meadows. This study is the first that demonstrates positive and cumulative effects of delaying the first cut or leaving a refuge on butterfly populations. It would be easy to implement these measures within European and Swiss AES regulations.

1. Introduction

Extensively managed grasslands are among the most biodiversity-rich ecosystems in Europe and indispensable habitats for many plants and animals (Veen et al., 2009). However, changes in their management, such as increased fertiliser application and improved mechanisation of the harvesting process have led to a massive deterioration of habitat quality and a progressive homogenization of the landscape (Tscharntke et al., 2005). These changes have caused a widespread decline of farmland wildlife across the continent, dramatically impacting birds and arthropods (van Swaay et al., 2010; Vickery et al., 2001). Butterflies, have, for instance, experienced acute declines over recent decades, so that nowadays almost 20% of all European species are considered to be threatened or near threatened (van Swaay et al., 2010). In western European countries the figures are often worse: for example in Switzerland 35% (78 species) of all butterflies appear on the country's Red List as threatened, and 19.5% (44 species) as near threatened (Wermeille et al., 2014), while in Great Britain, only 28 species (45%) of butterflies are considered to be not threatened (Fox et al., 2010). Specialists with narrow niche-breadth (i.e. few host plants) and low dispersal ability have been reported to decline most rapidly (Börschig et al., 2013; Ekroos et al., 2010; Heer et al., 2013). Hence, communities in many of today's EU lowland grasslands are dominated by a few ubiquitous generalists that are less prone to disturbances (Ekroos et al., 2010; van Dyck et al., 2009).

Although many agri-environment schemes (AES) are specifically targeted to grasslands, they have so far provided only limited benefits for biodiversity (Kleijn et al., 2006; Princé et al., 2012). It has been argued that they are mostly too small in size and offer too little spatio-temporal heterogeneity in terms of both habitat types and land-uses (Botham et al., 2015; Cizek et al., 2012; Konvicka et al., 2008), thus failing to promote habitats of sufficient quality for sensitive, more specialised species (Ekroos et al., 2010). Moreover, a great deal of research on the effects of management upon grassland biodiversity has been targeted at plant assemblages, which are typically moulded by other limiting factors than animal communities (Andrey et al., 2014; Hudewenz et al., 2012; Littlewood et al., 2012). Defining efficient conservation and restoration measures to improve arthropod biodiversity in semi-natural grasslands is therefore urgently needed.

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Diversifying the mode and timing of mowing operations enables some spatio-temporal heterogeneity to be restored among farmland habitats, at both field and landscape scales, which, in turn, can benefit arthropod communities and boost population density (e.g. Buri et al., 2013, 2014; Cizek et al., 2012; Noordijk et al., 2009). Even so, mowing can also cause substantial immediate damage to butterflies, notably because caterpillars are destroyed by the grass harvesting process, while nectar sources for imagines are suddenly annihilated (Dover et al., 2010; Humbert et al., 2010b). If applied indiscriminately or badly timed, mowing can have long-term negative effects on butterfly population survival, especially for species with a flying period in late summer, low dispersal ability and/or highly specific resource requirements (Humbert et al., 2012b; Johst et al., 2006; Konvicka et al., 2008; Walter et al., 2007).

A recommendation that has been repeatedly framed to avoid the negative impact of mowing on butterflies is to delay the first mowing date (Humbert et al., 2012b; Potts et al., 2009; Valtonen et al., 2006), but it has never been experimentally tested at the field scale. Late-summer cuts are in effect less harmful to butterflies than early summer cuts because they enable most species to accomplish their reproductive cycle (Walter et al., 2007). In addition to extending the temporal availability of crucial resources, delaying mowing diminishes the overall seasonal pressure exerted by mowing activities, notably via a reduction in the number of annual cuts (Buri et al., 2013). Leaving an uncut grass refuge on a fraction of the meadow is another grassland management option that contributes to a lower mortality of field invertebrates that are otherwise decimated by the mowing process (e.g. on orthopterans Humbert et al., 2012a). Such grass refuges provide continuous shelter and food supply (Valtonen et al., 2006; Weibull et al., 2000) and can offer permanent oviposition sites to insects that lay their eggs directly on meadow plants (Erhardt, 1985). The tremendously beneficial effect of maintaining a grass refuge within a meadow has recently been demonstrated for orthopterans (Buri et al., 2013; Humbert et al., 2012a). This measure has been suggested for butterflies as well (Dover et al., 2010; Kühne et al., 2015; Lebeau et al., 2015), but we lack quantitative evidence about its effects on butterfly populations.

The aim of this study was to experimentally test, at the field scale, whether leaving uncut grass refuges and delaying mowing within extensively managed lowland grasslands declared under Swiss AES can enhance butterfly communities and populations. The ultimate goal was to deliver evidence-based management recommendations in order to improve habitat conditions for farmland butterflies.

2. Materials and methods

2.1. Study sites

In 2010, 35 extensively managed hay meadows declared under Swiss AES since at least 2004 were selected across the Swiss lowlands (Plateau). The Swiss Plateau can be characterised mainly as a simple landscape where non-farmland semi-natural habitats (e.g. hedges and forest patches) are still present, but constitute usually only 1–20% of the matrix. All meadows were located between 390 and 826 m altitude (Appendix S1). The majority of the meadows could be assigned to *Arrhenatherum elatius* or *Alopecurus pratensis* grassland types, harbouring between 25 and 35 species per 16 m^2 (unpublished data). They were equally distributed among twelve geographic sites, all but one harbouring three meadows (one site had only two meadows as one had been converted into a gravel pit in 2012). While there was a minimal distance of 5 km between study sites, the three meadows per site were clustered within a 3.5 km radius with a minimum distance of 440 m between each other. While butterflies can easily migrate several km, average daily movement rates rarely exceed 200 m (e.g. Debinski et al., 2001; Schneider et al., 2003). Meadows had a minimum size of 0.3 ha (range: 0.3–1.7 ha).

2.2. Experimental design

The experiment was arranged in a randomised block design, in which three mowing regimes were randomly applied to one of the three meadows at a site (block), resulting in twelve independent replications of each regime (except the D-regime, see below, that had only eleven replicates). The following three mowing regimes were applied continuously during the entire duration of the experiment:

1. The first mowing regime, which corresponded to our control (hereafter called C-meadows), conforms to the standard regulations for extensively managed meadows as declared under Swiss AES: no fertiliser application and first cut not before 15 June, but with no restriction on the number and frequency of subsequent cuts.
2. In the second mowing regime, the first possible cut of an extensively managed meadow as declared under Swiss AES was delayed (D-meadows) by one month to the 15 July at the earliest.
3. The third mowing regime was again applied to an extensively managed meadow in conformity with Swiss AES, but here a small fraction (10–20%) was left uncut as a refuge (R-meadows) at each mowing operation. There was no restriction regarding the shape of the refuge, but its location within the meadow had to be changed at each mowing.

2.3. Butterfly sampling

In summer 2013, butterflies and Zygaenidae were sampled along line transects. A distance sampling method was adopted, which enabled the incorporation of detectability by additionally recording the perpendicular distances, in m-intervals, between the observed butterfly and the transect line (Buckland et al., 2001). Distance sampling is an extension of classic line-transect sampling techniques (see prescriptions by Pollard and Yates, 1993). Although so far mainly used for bird sampling, it has recently been suggested that it would lead to more reliable estimates of butterfly population abundance (Pellet et al., 2012). It was selected here mainly to account for possible differences in detectability due to the distinct vegetation structures generated by various mowing regimes.

Sampling transects were positioned along the longest diagonal line cutting through the centre of the meadow; average length was 111 m (range 65–215 m). Before each survey, the start, middle and end points of transect lines as well as the 5-m intervals on both sides of the transect were marked with coloured flags to ensure better visibility. Transects were walked in a single direction at a continuous, steady pace, alternating start points between surveys. All detected butterflies as well as their perpendicular distance to the transect line were recorded. Visual identification was performed, as far as feasible. In cases of identification ambiguity, individuals were caught with a butterfly net, immediately identified and released. For identification we referred to the guides by Tolman and Lewington (2012).

Six surveys were conducted during the main butterfly flight season, from the end of April to the beginning of September. Three surveys were carried out before 15 June, one between 15 June and 15 July and two after 15 July, these threshold dates corresponding to the timing of mowing operations. Surveys were conducted between 10:00 and 17:00 on sunny, warm days with a minimal air temperature of 13 °C and a maximal wind speed of 3 Beaufort, as suggested by Pollard and Yates (Pollard and Yates, 1993). The chronological order of meadow surveys was randomised within a region on a given sampling day.

2.4. Data analysis

Initial analyses of abundance performed with distance sampling models (DSMs), using the *distsamp* function of the *Unmarked* package for R (Fiske and Chandler, 2011), showed that there were no significant differences in butterfly detectability among mowing regimes (Appendix