THE EFFECTS OF FIELD MARGIN RESTORATION ON THE MEADOW BROWN BUTTERFLY (*MANIOLA JURTINA*)

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ABSTRACT

We examine the extent to which simple changes in management of boundary strips can increase the value of farmland as a habitat for the meadow brown butterfly (*Maniola jurtina*). Butterfly transects were conducted on a farm with conventionally managed field boundaries, and on experimental, extended-width field margins which were subject to ten contrasting management regimes. More butterflies were associated with grassy boundary strips than with other field edge habitats. Plots which were sown with a wild flower seed mixture and left uncut during the summer attracted the highest numbers of *M. jurtina*. Nectar sources which were preferred by *M. jurtina* were most abundant on these plots. Plots sprayed with glyphosate became progressively less attractive to butterflies over a three year period.

INTRODUCTION

Agricultural intensification has not only resulted in the loss of semi-natural habitats, but has also had deleterious effects on smaller, interstitial areas of uncultivated land within the arable landscape. Arable farmland in lowland Britain is currently considered to support an impoverished butterfly fauna, consisting mainly of mobile species such as the large white (*Pieris brassicae*; Thomas, 1984). In other European countries, the declining abundance of several species has been linked to agricultural intensification (e.g. van Swaay, 1990).

Intensification has affected habitat suitability for butterflies on farmland in several ways. Field boundaries, which remain the primary uncropped habitats available to butterflies within arable farmland, have traditionally been associated with high floral and faunal diversity, but have been degraded by modern farming methods. Herbicide drift and the application of herbicides directly to the hedge base, together with the high nutrient status of field boundary soils caused by inadvertent fertiliser application, ensures the perpetuation of species-poor communities dominated by pernicious weeds (Smith & Macdonald, 1989; Smith *et al.*, this volume). These practices are likely to have reduced substantially the quality and quantity of both adult and larval food resources on farmland (Feber & Smith, in press; Dover, this volume). Habitat fragmentation and unpredictable patterns of resource supply further militate against the persistence of populations of less mobile species.

Simple methods for re-creating and managing field boundary swards could potentially result in radical improvements in the availability of larval and adult resources for common grassland and hedgerow butterflies. We describe the effects of contrasting methods of creating and managing boundary strips on the meadow brown butterfly (*Maniola jurtina*). Although the larvae are grass feeders, they require permanent swards in which to overwinter and this, combined with relatively low adult mobility, makes *M. jurtina* vulnerable on farmland. However, because its habitat requirements are fairly simple, it is a good target species for conservation within farmland and the high densities which can occur in established colonies make it ideal for comparative studies of habitat management.

METHODS

In autumn 1987 we created 2 m wide boundary strips around arable fields at the University of Oxford's farm at Wytham. These comprised the original boundary strip, about 0.5 m wide, and a fallowed extension of about 1.5 m on to cultivated land. Swards were established on the fallowed strips either by allowing natural regeneration ('unsown' swards) or by sowing a mixture of wild grasses and forbs ('sown' swards: see Smith *et al.*, this volume). 50 m long plots were established on both sward types and subjected to the following management regimes: uncut, or cut (with cuttings removed) in (a) summer only (b) spring and summer or (c) spring and autumn. Two further treatments were imposed on unsown plots only: (a) cut in spring and summer with hay left lying and (b) uncut but sprayed with glyphosate in late June or early July. The plots were cut in the last weeks of April, June and September ('spring', 'summer' and 'autumn' respectively). Glyphosate (3 l/ha Roundup in 175 litres water) was first sprayed in 1989. The treatments were randomised in eight blocks, each occupying a single field. From the time that they were fallowed, the field margins were protected from fertiliser and spray drift.

Butterfly transects (see Pollard, 1977) were conducted on the experimental margins weekly from April to September between 1989 and 1991. In 1991, transects were also conducted on a neighbouring farm with narrow, unmanaged boundary strips, which received agrochemical drift and direct herbicide applications. Mark-release-recapture studies, together with behavioural observations, were also conducted on *M. jurtina* on the experimental margins (Feber, 1993). The larvae were sampled by sweep-netting and visual searching in spring 1991. The abundance of flowers of all broad-leaved species on the experimental margins was estimated monthly on a six-point scale in the same year (Feber, 1993).

RESULTS AND DISCUSSION

Effects of boundary strip creation on the abundance of adult *Maniola jurtina*

Maniola jurtina individuals were significantly more abundant per kilometre on the extended-width experimental margins at the University Farm than on the neighbouring farm (Wilcoxon 2-tailed test, $P<0.05$). At the University Farm, significantly more butterflies per unit area were associated with the grassy boundary strips than with the hedges, ditches, crops, tracks, or sterile strips ($\chi^2=1164.26$, $P<0.001$). Grassy boundary strips are thus important field margin components for butterfly conservation.

Effects of boundary strip management on abundance of adult *Maniola jurtina*

Although butterflies were more abundant on the expanded experimental margins than on narrow conventional margins, transect results showed that experimental plots at the University Farm were not equally attractive to butterflies. There were highly significant differences in the abundances of *M. jurtina* between experimental treatments in all three years of the study (Table 1).

In all years there was a significant effect of mowing on *M. jurtina* abundance. Butterfly abundance was highest on treatments which were left uncut, or which were cut in spring and autumn. Although butterflies utilised all plots before the summer cut, *M.*

TABLE 1. The effects of management on the abundance of *Maniola jurtina* on the field margins 1989-1991. Analyses performed on log-transformed means. Means presented are back-transformed. Significance levels: *** $P<0.001$, ** $P<0.01$, * $P<0.05$, ns not significant.

(a) Mean numbers of *M. jurtina* individuals per 50 m length of field margin.

Treatment	Mean number of butterflies per 50m length of field margin[1]		
	1989	1990	1991
Sown, cut spring+autumn	13.5	52.2	19.9
Sown, uncut	18.9	39.2	13.3
Sown, cut spring+summer	15.0	21.4	7.8
Unsown, cut spring+autumn	14.6	8.2	7.3
Unsown, cut spring+summer, hay left	7.4	4.8	4.6
Sown, cut summer only	11.9	22.1	4.4
Unsown, uncut	12.7	9.9	4.3
Unsown, cut summer only	6.7	5.4	4.1
Unsown, cut spring+summer	9.6	5.6	3.9
Unsown, sprayed	14.5	4.1	2.6

[1] Minimum Significant Differences (Tukey's Studentized Range Test; $P=0.05$): 1989, 0.94; 1990, 1.26; 1991, 1.07.

(b) Significance of planned comparisons between treatments. Main effects from 3-way ANOVA using the eight treatments that form a 4x2 factorial design (Smith *et al.* 1993).

	d.f.	1989	1990	1991
Main effects				
Block	7,49	*	***	ns
Sowing	1,49	*	***	***
Cutting	3,49	*	*	***
Sow x cut	3,49	ns	ns	ns
Planned comparisons between means				
Cut *vs* uncut	1,49	ns	ns	ns
Cut in summer *vs* not cut in summer	1,49	*	**	***
Cut spring+autumn *vs* uncut	1,49	ns	ns	*

jurtina responded to the summer cut by immediately moving to uncut plots (Figure 1). This change in distribution was typical of the majority of butterfly species whose flight period spanned the summer cut (Feber, 1993). The main advantage to *M. jurtina* of plots which were left uncut, or which were cut in spring and autumn, lay in their continuity of provision of nectar supply throughout the flight period. In many arable areas nectar sources are likely to be patchily distributed, both spatially and temporally, and may limit the potential for this, and other less mobile species, to establish populations. Of the two treatments, spring and autumn cutting is a more desirable management strategy than leaving swards uncut. As well as preventing invasion by woody species, our experiments have shown that plant species richness was significantly lower on uncut than on spring and autumn cut swards (Smith & Macdonald, 1992). As these underlying differences increase they are likely to have increasing impacts on the availability of nectar sources and larval foodplants. By 1991, *M. jurtina* was significantly less abundant on uncut swards than on spring and autumn cut swards (Table 1).

Sown swards attracted more butterflies than unsown swards and, in 1990 and 1991, sprayed plots attracted significantly fewer butterflies than other plots (Table 1). These differences were attributable to the abundance of a small number of preferred nectar sources rather than to the gross abundance of flowers. Flower abundance in July and August on sown and unsown plots did not differ significantly (Friedman's Test, P=0.132 and P=0.483 respectively). Sown plots, however, contained several important nectar sources including oxeye daisy (*Leucanthemum vulgare*), field scabious (*Knautia arvensis*) and common and greater knapweeds (*Centaurea nigra* and *C. scabiosa*), which were heavily utilised by *M. jurtina* (Table 2). The best single predictor of *M. jurtina* abundance in July was the abundance of *L. vulgare* (R^2=0.212, P<0.001). Sown plots also contained more perennial plant species in flower than unsown plots in July and August (3-way ANOVA, $F_{(1,49)}$=13.47, P<0.001 and $F_{(1,49)}$=14.11, P<0.001 respectively; Figure 2). There is some evidence to suggest that perennials may provide higher nectar rewards than annuals (Feber & Smith, in press).

TABLE 2. Nectar source utilisation by *Maniola jurtina* in July 1991. All broad-leaved plant species were ranked in order of the mean abundance of their flowers. Data are percentages of total observations of feeding butterflies (300 systematic observations).

Plant species	rank abundance	percentage of visits
Cirsium/Carduus spp.	13	38.0
Leucanthemum vulgare	4	33.0
Centaurea spp.	45	12.0
Knautia arvensis	19	7.7
Tripleurospermum inodorum	6	4.3
Trifolium spp.	12	2.0
Convolvulus spp.	24	1.3
Ranunculus spp.	25	0.7
Rubus spp.	23	0.3
Senecio jacobaea	59	0.3

Effects of the creation and management of boundary strips on *Maniola jurtina* larvae

Larval abundance did not differ significantly between treatments and larvae were found on all treatment types. A mean of 2.73 larvae was recorded per plot. They were recorded feeding on *Elymus repens*, *Lolium perenne*, *Trisetum flavescens*, *Arrhenatherum elatius*, *Bromus sterilis*, *Poa trivialis* and *Dactylis glomerata*. Several of these species are either common components of agricultural leys or are agricultural weeds. *Maniola jurtina* larvae overwinter in the base of grassy tussocks and there was no evidence that they were affected by spring or autumn mowing. Although more grass species were present in sown than unsown swards, these results suggest that the extension in width and exclusion of agrochemicals from the margin were sufficient to meet the requirements of *M. jurtina* larvae.

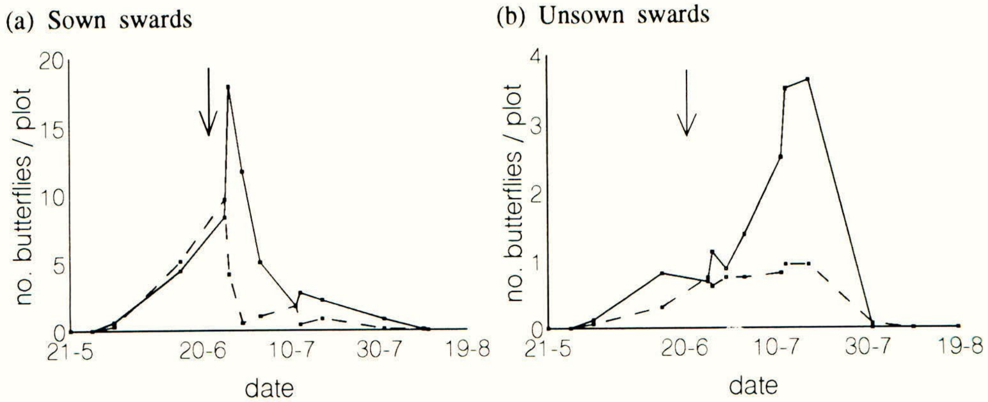

FIGURE 1. Changes in abundance of *M. jurtina*. Solid lines: abundance on swards not cut in summer. Dashed lines: abundance on swards cut in summer. Arrows indicate the date of cut. Note different vertical scales in (a) and (b).

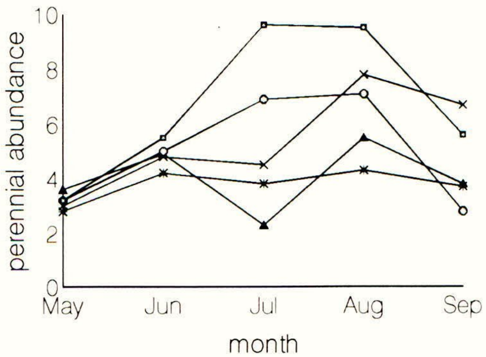

FIGURE 2. Differences in mean abundance of perennial species in flower, between plots sown and uncut in summer (-□-), unsown and uncut in summer (-○-), sown and cut in summer (-×-), unsown and cut in summer (-▲-) and sprayed with glyphosate (-✳-).

CONCLUSIONS

Maniola jurtina is considered to be a generalist in its habitat requirements but it nonetheless showed clear and significant responses to the creation and management of boundary strips. Simple management changes that were central to the establishment of the experimental field margins - extension in width and exclusion of agrochemicals - increased its abundance.

Of the different management regimes, summer mowing had the most profound effects on *M. jurtina* abundance. This removed nectar sources at a critical time during the butterfly's life cycle. Summer mowing may also remove larval foodplants of other butterfly species. It had consistently detrimental effects on the overall abundance and species richness of butterflies on the experimental margins (Feber, 1993). Sowing with a wild flower seed mixture, by contrast, significantly increased *M. jurtina* abundance.

On many conventionally managed arable farms, the existing flora is unlikely to provide nectar resources adequate to support butterfly populations. Seed mixtures are a particularly appropriate tool for reddressing this problem in situations where suitable sources of colonists have been eliminated by insensitive management (Smith *et al.*, this volume). Herbicide spraying was consistently the most devastating management practice for *M. jurtina*, removing nectar sources and unfavourably altering sward composition. Sprayed plots became progressively less attractive to butterflies over the three years.

Our results demonstrate the importance of extended-width, grassy boundary strips, which supply abundant nectar through the flight period, in influencing *M. jurtina* abundance. We suggest that *M. jurtina* larvae are less likely than adults to be severely constrained by food availability. Other butterfly species, however, have more specific larval requirements. In some cases, naturally regenerated swards may provide sufficient larval foodplants but, in others, wild flower seed mixtures may be tailored to meet specific conservation requirements (Smith *et al.*, this volume). In general, though, we consider that the butterfly species which can benefit most from restoration and conservation management of field margins are common grassland or hedgerow species which are not unduly demanding in their habitat requirements, but which have suffered as a result of agricultural intensification and poor field margin management practices.

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