What goes wrong? Why the restoration of beetle assemblages lags behind plants during the restoration of a species rich flood-plain meadow

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Summary

With under 1500 ha of species rich floodplain meadows (*Alopecurus - Sanguisorba* MG4 grassland) remaining in England and Wales there is a great potential for restoration to re-establish and extend areas of this habitat. Restoration has conventionally considered only the plant communities that define these floodplain meadows; however there are many other biotic and abiotic elements that must be considered if restoration is to be successful. In this paper we consider how restoration management used during the re-establishment of such floodplain meadows will affect not only the plant, but also a dominant component of the invertebrate communities, the beetles. While both the plants and beetles benefit from hay cut followed by aftermath grazing, there is evidence that beetle communities lag behind the plants in the success achieved during restoration.   We attribute this to fundamental differences in the way establishment of plants and beetles are promoted during restoration, specifically that the plants are artificially introduced as seed, whereas colonisation by beetles is by natural immigration. We suggest that this may have important long term consequences for restoration, namely that while a restored grassland may show strong floristic similarity to that of target floodplain meadows, such similarity may be superficial and not seen for other trophic levels.

Introduction

Although, originally widespread, agricultural intensification, urbanization, extraction of coarse river sediments and changes in water table levels have caused a wide scale decline in species rich floodplain meadows in lowland England and Wales (Rodwell, 1993; Hopkins and Hopkins 1994; Gowing *et al.* 2002). In the UK, these grasslands are conservatively estimated to cover less than 1500 ha (Jackson and McLeod 2000) and as a result have been designated as sites of conservation importance both at British and European scales (CEC 1992; also see Jefferson and Pinches this volume).

Traditionally these grasslands have been managed using annual hay cutting in June or July, followed by light aftermath grazing during the autumn period, predominantly by cattle. While there is no addition of inorganic fertiliser, nutrient deposition due to autumn flooding and manure from grazing livestock occurs annually (Rodwell 1993; McDonald 2001; Gowing *et al.* 2002). Hydrological requirements of these grasslands are strict, and relatively small changes can result in a succession to secondary floral communities, e.g. inundation grasslands (Jefferson 1997).

Due to the small extent of remaining floodplain meadows, there is considerable potential for habitat re-creation to augment the existing area and to provide buffer zones or corridors/stepping stones between remaining fragments (Schwartz 1997; Gowing *et al.* 2002). While attempts at recreating these grasslands have been made (McDonald 1993, 2001), measures of success have focused almost exclusively on the floral community. Although the plant community arguably defines a grassland type, the influence of recreation management on other trophic levels is poorly understood. Invertebrates represent a large and diverse component of grassland communities and serve diverse functional roles integral to nutrient cycling and pollination, as well as being important as herbivores, predators and as food for higher trophic levels, such as

birds (Duffey et al. 1974; Naumann 1994). There is also evidence that some invertebrates play a key role in structuring plant communities during floral successions, and are as such of direct importance during grassland restoration (Gange and Brown 2002).

In this paper we consider why success in the restoration of floodplain meadow plant communities does not necessarily result in similar levels of success for the restoration of other trophic levels, i.e. the beetles. This assessment is based on a reassessment of two previously published articles on the restoration of plant and beetle assemblages during a long-term (18 years) floodplain meadow re-creation experiment (Woodcock *et al.* 2005; Woodcock *et al.* 2006). As such, results from these two studies will be considered only in summary here. For electronic copies of these papers, please e-mail the authors.

The study system

For more details of the study site and experimental design, see the article by McDonald in this volume, which describes in detail the nine experimental plots used to assess the effect of ungrazed (control), cattle-grazed and sheep-grazed management during floodplain grassland restoration. Using suction sampling these experimental plots were sampled for beetles in 2004 (Woodcock *et al.* 2006). To assess the success of the re-creation management at the Somerford Mead site, floodplain meadows at Oxey Mead (the original seed donor site) and Yarnton Mead (NGR: SP470103) were used as target communities. Both sites are considered as Special Areas of Conservation (SAC's) and occur less than 3 km from the re-creation plots at Somerford Mead. At each site in 2004, two sampling areas, each one a 0.4 ha plot, were established and sampled for plants and beetles (Woodcock *et al.* 2006).

Differing success of the plants and the beetles

Measuring success during the restoration of any habitat requires the use of metrics of community structure that will provide a benchmark for assessing how similar a site after restoration management has become to a target community (Ehrenfeld 2000). At its most basic such goals may be as simple as trying to achieve similar levels of species richness between restoration sites and target habitats. Indeed, if we look at the beetles of Somerford mead after 18 years of restoration management, species richness of the cattle and sheep grazed treatments has now become equivalent to that of target floodplain grasslands at Oxey and Yarnton Meads (Figure 1). Certainly where grazing management has been used to restore the grasslands far more species are present than in those plots that receive no aftermath grazing. Although this is a useful guide to the success of restoration there is an obvious failing with such an approach. Specifically two grasslands may differ in what species are present, but may still have the same species richness. For this reason, similarities in species richness between restoration sites and target grassland communities have limited use as a metric for the assessment of restoration success.
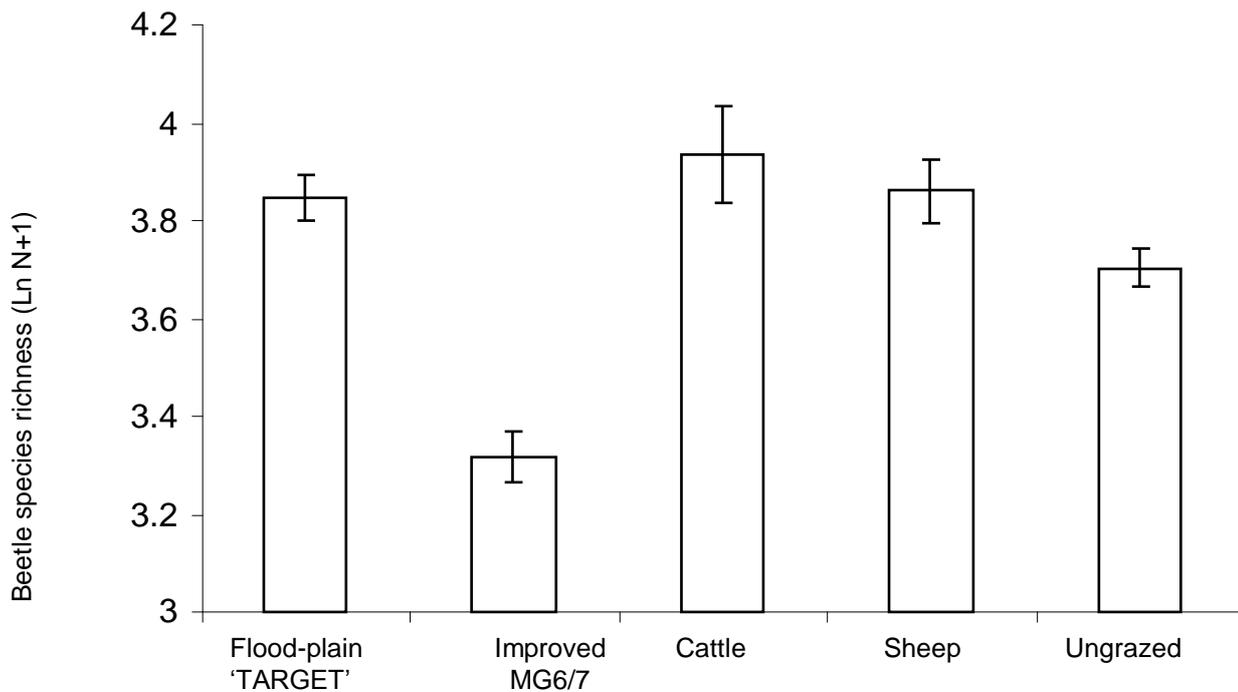
Figure 1: Beetle species richness within the three restoration management treatments of cattle, sheep and ungrazed at Somerford Mead in 2004 compared to existing species rich floodplain meadows (Oxey and Yarnton meads) and an example of an intensively managed grassland (MG6/7 *Lolium perenne* dominated sward).

An alternative and far more rigorous approach is to assess restoration success using similarities between two communities in the species present and their relative abundances or plant percentage cover (Mitchell *et al.* 2000; Davis *et al.* 2003; Woodcock *et al.* 2006; Woodcock *et al.* in press). There are many different measures of similarity, information on which can be found in many standard ecology text books (e.g. Krebs 1999). The use of such similarity measures provides a far more rigorous assessment of restoration success than can be achieved by simple comparisons of species richness. Note that other approaches to assessing restoration success exist, for example the quantification of trophic interactions. However, while informative such approaches remain time consuming in data collection and as such are often hard to implement on a large scale (Forup and Memmott 2005). It is this metric of restoration success that considers the similarity between two communities, in this study the plants and beetles which we will consider hereafter.

When community similarity between the experimental restoration treatments of cattle, sheep and ungrazed are compared to target floodplain meadows, general patterns were encountered between the plants and the beetles (Woodcock *et al.* 2006). For both the plants and the beetles restoration was clearly dependent on the use of grazing management. For the plants, there is very little difference in the success achieved with either cattle or sheep grazing, although for the beetles cattle grazing is the superior restoration management practice (Figure 2). What is clear is that there exist general patterns of similarity between the plants and the beetles in which management is most likely to promote restoration, i.e. a hay cut followed by grazing management

of some description. The clear superiority of cattle grazing for the beetles is thought to reflect differences in the way sheep and cattle graze. Specifically, sheep tend to graze the sward evenly, while cattle create a much patchier sward structure (Duffey *et al.* 1974; Morris 2000). Such patchy sward structures provide structural refuges for many invertebrates. This can be extremely important for predatory species, which will have no direct dependency on a plant as a food source, e.g. those that use tussock grasses as refuges (Luff 1966). Independent of these relatively minor differences in the impacts of different grazing animals, what is apparent is that both plant and beetle communities respond in a similar positive manner to grazing management. However, there is a major difference in the levels of success achieved during restoration between the plants and the beetles. Specifically, there is a consistent tendency for the success of restoration in the beetle communities to consistently lag behind that of the plants (Figure 2). If the aim of floodplain grassland restoration is to replicate all biotic components of a target community then the reasons for this lag have important implications for floodplain meadow restoration.
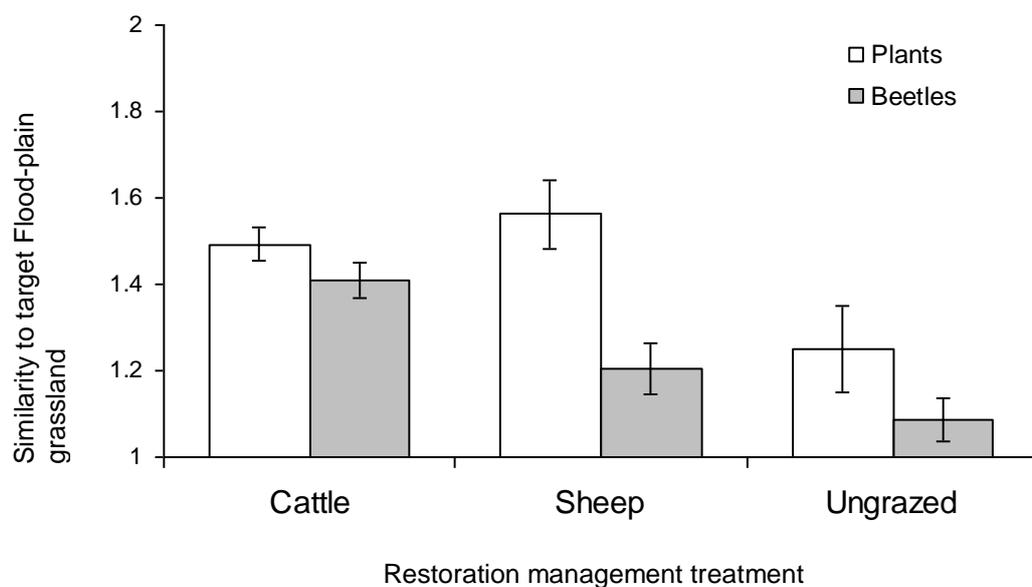

Figure 2: Similarity (1/Euclidean distance) between the restoration management treatments of cattle, sheep and ungrazed with the target floodplain meadows.

Why do beetle communities lag behind during restoration?

What lies behind these contrasting patterns is not entirely clear. To a degree the restoration of any invertebrate community may be expected to lag behind that of the plants, as without suitable host plants present their colonisation by phytophagous insects cannot happen (Woodcock *et al.* 2006; Woodcock *et al.* in press). However, it is likely that there is more to this pattern than simply the need for suitable host plants, as frequently suitable hosts remain uncolonised by beetle species typical of floodplain meadows. Indeed, this lag in restoration success between plant and beetle communities seems to be a common factor of restoration across a variety of grassland types (Woodcock *et al.* in press). It is also important to note that while such a lag has

to our knowledge only been demonstrated for the beetle communities, it is likely that it represents a common characteristic across many invertebrate groups.

We suggest that this lag reflects fundamental differences in the way plant and beetle communities become established during restoration. For all species, whether plant or beetles, restoration is dependent on target species colonising a new site. Without the arrival of such species restoration would fail, no matter how suitable a site may be in terms of abiotic conditions or the way in which it has been managed. For this reason, it is now common practice during grassland restoration to introduce seeds typical of the target grassland type, i.e. those of floodplain meadows. This can be achieved in a variety of ways, either as a seed mix derived from cultivated sources, or more commonly by the application of green hay or seeds derived from green hay from a local example of the target habitat type (e.g. Manchester *et al.* 1998; Edwards *et al.* 2006). With the restoration experiment at Somerford Mead, seeds collected from a local floodplain meadow at Oxey Mead were spread on the restoration site to promote the establishment of target plant species. This approach contrasts dramatically with the beetles, where the establishment of any species into the restoration site is entirely dependent on natural immigration.

Superficially this may not appear that important. It could be argued that while the beetles may lag behind the plants, given enough time appropriate species will become established. While this may be the case, there are several reasons why simply time may not be enough for successful restoration to occur for all parts of the floodplain meadow community. For example if the target grassland type (e.g. the floodplain meadow) is not present in the areas surrounding the restoration site then the chances of beetle species typical of this habitat colonising may be small (Woodcock *et al.* 2006; Woodcock *et al.* in press). Indeed, while some invertebrates can travel large distances, e.g. ballooning spiders (Schmidt *et al.* 2005), for many species relatively small distances may provide a sufficient barrier to stop, or at least severely inhibit, rates of colonisation (Wratten *et al.* 2003; Tscharntke *et al.* 2005). For floodplain meadows, where so little of the habitat remains, the absence of suitable habitat, from which colonising individuals can originate, may be acting as a suitable barrier to restoration success. The result is that in an increasingly fragmented agri-environment the chances of beetles from floodplain meadows colonising restoration sites are low.

Perhaps more worryingly, not only will beetles typical of floodplain meadows be unable to colonise restoration sites, but species of other habitats immediately surrounding the areas intended for restoration may become established. Given that such surrounding habitats are likely to be intensively managed in terms of agri-chemical inputs and other agricultural practices (e.g. frequent silage cuts) the invertebrate species likely to colonise will be unlikely to be of conservation importance. Such agriculturally improved habitats are often characterised by common insect species that show generalist life history traits (Woodcock *et al.* 2007), in stark contrast to the many specialist species associated with floodplain meadows Where such common species become established they may provide an additional hurdle to the colonisation of the restoration site by beetles that are typical of floodplain meadows. Specifically, desired beetle species may now have to competitively displace those that have already become established during restoration from surrounding intensively managed agriculture. Given low colonisation rates, such an event may be highly unlikely. The result is that while a restored site may floristically

resemble floodplain meadows, on closer inspection it may have little or no similarity in other trophic levels such as the beetles.

To understand this problem, it is useful to produce a conceptual model of the process of restoration. One frequently used approach is to visualise restoration as a ball, representing the site to be restored, rolling across a landscape of hills and troughs. This landscape represents different communities, either of plants or invertebrates, while the topography of that landscape represents the ease or resistance with which the ball may move between two community types.   Normally restoration management is required where a degraded habitat has become stuck, within this conceptual model this would be represented by a ball becoming stuck in a trough at the top of a hill (Figure 3a). For restoration to be successful, the ball must leave the trough and roll down the hill toward the target community type. However, the resistance of the trough that it is stuck in prevents this happening. This resistance may be represented by, for example, inappropriate management or extremely high nutrient levels. Restoration management essentially aims to provide a kick to this ball knocking it out of the trough and down the hill towards a successful restoration thus overcoming these problems (Figure 3a).   Indeed, this is what we are suggesting is occurring for the plant communities of Somerford Mead. The combination of seed introduction and aftermath grazing is essentially knocking the ball down the hill toward successful restoration. Note we are not suggesting this has happened yet, but may do in time.

For the beetles two alternative possibilities may occur, both of which will result in a lag in restoration success of the beetles behind the plants. The first possibility is that while restoration management (i.e. aftermath grazing) is knocking the ball (the beetle community) from the trough at the top of the hill, it is becoming stuck in a second trough before it is successfully restored (Figure 3b). This second trough represents resistance to restoration success created by limited colonisation of beetles typical of the target floodplain meadows. As already suggested, perhaps given enough time, such beetle species may eventually colonise and the resistance to restoration success defined by this trough may be overcome. A second possibility is that restoration management kicks the ball out of the trough from where it rolls down the wrong side of the hill, away from the target floodplain meadow community (Figure 3c). In this example, the colonisation of beetles in the restoration site, from surrounding habitats that are not floodplain meadows, has resulted in the establishment of a new stable state beetle community. Here a stable state community refers to the establishment of a new grassland type that will not converge with that typical of floodplain meadows, no matter how long restoration management is continued.

a) Successful restoration   b) Inhibited restoration

c) New stable state
established

○ = Pre-restoration site

⊙ = Post-restoration site

⊗ = Target flood-plain community

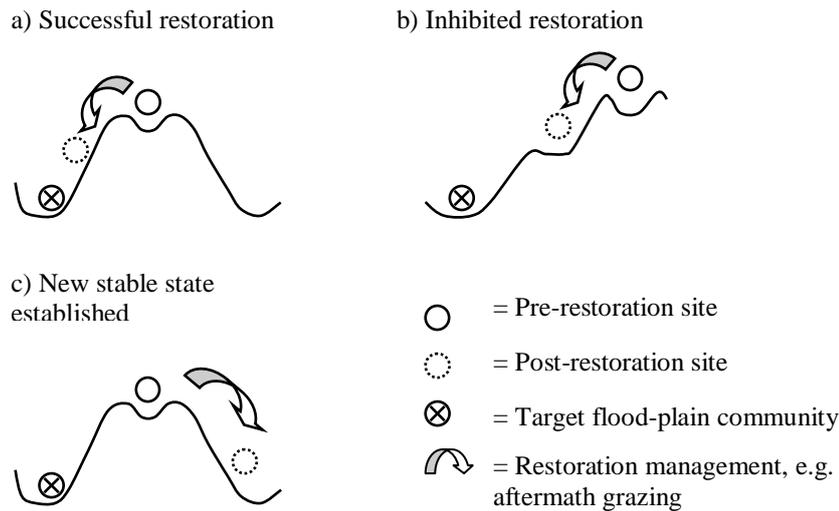↷ = Restoration management, e.g.
     aftermath grazing

Figure 3: Three conceptual models of restoration, where each site is visualised as a ball sitting on a landscape of hills and troughs. The position of the ball within this landscape (the horizontal axis) represents a particular community of either plants or beetles. The contours of the landscape (the vertical axis) represent resistance of movement between community types.

The situation that may arise is that the plant communities may move towards successful restoration (Figure 3a), while the restoration of the beetles is being either inhibited (Figure 3b) or failing (Figure 3c). If such an event is occurring, this raises important questions about what we are aiming to achieve when we attempt to restore any habitat. Do we accept restoration as being successful if the restored area bears a superficial resemblance to the target floodplain meadow, or do we need all its biotic components to be restored? Such a question is important as it provides a basis for the criteria we use when measuring restoration success, not only in floodplain meadows, but in all habitat types.

Conclusions

This study has highlighted how beetle communities during the restoration of floodplain meadows tend to lag behind those of the plants. This lag is likely to be due to dispersal limitations found within the beetle communities. While such dispersal limitations would also be encountered for the plants, the artificial introduction of seeds during restoration can contribute to overcoming this problem. The artificial introduction of invertebrates at a community level has rarely been attempted in restoration projects, a fact that reflects the prohibitive expense associated with the large scale movement of these communities. Thus, other approaches should be considered that will promote invertebrate establishment during grassland restoration. The most obvious of which is to restore areas of land adjoining existing examples of floodplain meadows. While such an approach is intuitively obvious, it would almost certainly increase the success of restoration, while potentially reducing the time scales over which restoration could occur. As an additional benefit the restored sites would

also serve to buffer the adjoining floodplain meadow from outside impacts of human activity. Obviously, such an approach may not always be practical, although where multiple sites are considered for restoration, efforts should be made to target limited resources to those closest to existing floodplain meadows.

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