Restoration of a floodplain meadow in Wiltshire, UK through application of green hay and conversion from pasture to meadow management

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SUMMARY

In July 2010 green hay from a species-rich donor field was used to diversify a species-poor floodplain meadow (the receiver field), which had previously been managed as a pasture. The receiver site was prepared through harrowing. Green hay was then collected from the donor site and spread on the receiver site using a bale shredder and spreader. It was then managed as a hay meadow, with an annual hay cut in July or August, followed by aftermath grazing. The vegetation in the receiver field was monitored from 2010-2017, as was an adjacent species-rich meadow, which was used as a target reference site. Over this period, the receiver field moved towards a species-rich sward, similar to the target *Alopecurus pratensis-Sansguisorba officinalis* floodplain community. In 2011, 12 months after the green hay application and change of management, species richness had increased significantly, as had the goodness-of-fit to the target floodplain-meadow community. The transformation from species-poor eutrophicated grassland to a more herb-rich floodplain meadow continued over the following six years, with further increases in the frequency and cover of target species.

BACKGROUND

Species-rich floodplain meadows, classically described as the *Sanguisorba officinalis–Alopecurus pratensis* grassland community (MG4 in the UK National Vegetation Classification, Rodwell 1992), are rare in the UK. Less than 1200 ha remain, and they are listed under the European Habitats Directive as the Annex 1 habitat: (6510) Lowland Meadows. There is currently substantial effort in the UK to undertake restoration and recreation of this habitat, which can attract agri-environment scheme support (Lawson & Rothero 2016).

Forty previous studies in Conservation Evidence showed a positive impact of using ten different techniques to restore species-rich grassland (Dicks *et al.* 2018); however few specifically focus on wet grasslands. Somerford Mead, the only example found of a UK floodplain-meadow restoration scheme, had still not moved to a fully restored beetle or plant community assemblage after 18 years of management (Woodcock *et al.* 2006). The time taken for positive effects to be seen in other studies ranges from five to more than ten years.

Meadow restoration through the application of green hay has been shown to be successful elsewhere in Europe (Kiehl & Wagner 2006, Edwards *et al.* 2007, Hedberg & Kotowski 2010). However, the hydrological complexity of restoring meadows in floodplains may result in low levels of success, and until recently floodplain meadows have not been a priority for restoration when compared to dry grasslands.

Clattinger Farm is part of one of the five Special Areas for Conservation (SAC) designated under the EU Habitats Directive for floodplain-meadow habitat in the UK. Together with the adjacent Lower Moor farm and Oaksey Farm it forms part of the Lower Moor Farm nature reserve, owned and managed by the Wiltshire Wildlife Trust. Clattinger Farm was acquired by the Trust in 1996. The previous owner had not used herbicides nor applied excess nutrients to the grassland (Ratcliffe 1977). Accordingly, the fields were in an unusually unmodified condition with an outstandingly diverse flora. In contrast, the fields on Lower Moor Farm had a history of year-round grazing by cattle and sheep, and in consequence were comparatively species poor.

The meadows were entered into a Higher Level Stewardship agri-environment agreement in 2010. Under the agreement, green hay was added to one relatively species-poor 'receiver' meadow on Lower Moor Farm, with the aim of diversifying the field, increasing the area of MG4 community, and creating a buffer area to the SAC. The work was carried out in partnership with Natural England. The 2.86 ha receiver field, Swill Brook, which was adjacent to the SAC, was strewn with green hay from the nearby Oaksey Moor Farm Meadow (the donor field) in July 2010. Sheep were introduced after the green hay was spread to lightly trample in the seed. The subsequent management involved an annual hay cut, followed by aftermath grazing. The donor site, Oaksey Moor Farm Meadow was considered to be a good example of a species rich floodplain meadow in favourable condition at the time of the restoration effort. The receiver field had vegetation of the MG7c *Lolium perenne-Alopecurus pratensis-Festuca* grassland type, and was less agriculturally improved than the rest of the Lower Moor Farm holding. The rare snake's-head fritillary *Fritillaria meleagris* was also present in the receiver field. Monitoring was established to explore the changes following application of green hay combined with a change in management, but did not compare the two interventions separately.

ACTION

Green hay application and subsequent management: In late July 2010, Swill Brook Meadow, the receiver field, was cut. A

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Figure 1. Spreading green hay. Photograph by Catherine Hosie.

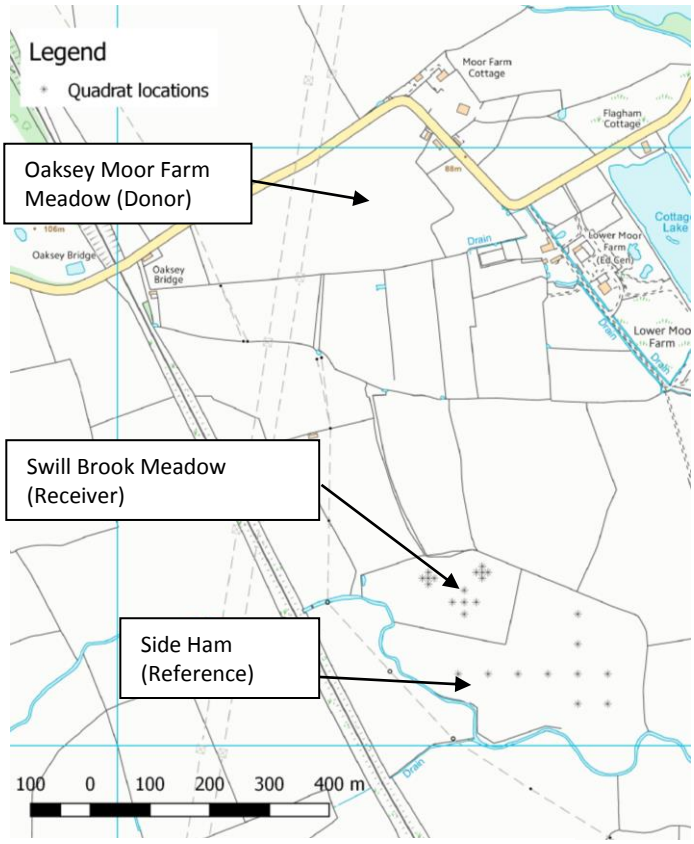

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Figure 2. Location of receiver, donor and reference fields, and monitoring quadrats within these. Each cross on the map indicates the location of the centre of a 1 x 1 m monitoring plot.

spring tine harrow was then used to break up the sward and create bare ground by pulling out dead vegetation and disturbing the soil surface. The area of bare ground created was approximately 25%, which is less than the recommended 40–50% (Natural England 2009) because of the presence of species of interest, including snakes-head fritillary.

Green hay was cut and baled in the donor field and transported 500 m to the receiver field (Figure 1), where it was spread within a few hours using a Kuhn Primor 3560 bale chopper and spreader (Figure 2). The angle of the spreader funnel and the speed of distribution were adjusted to allow the green hay to be spread in a uniformly light layer across the prepared ground surface. The receptor field was approximately three times larger than the donor field. Costs were minimal as the machinery used belonged to the Wildlife Trust and the green hay was collected and spread from Trust-owned adjacent fields. After spreading, the field was left to recover for a few weeks, then grazed lightly by sheep only.

Following green hay application, the meadow was managed from 2011-2017 with an annual hay cut between mid-July and early August, in line with agri-environment scheme requirements and depending on weather conditions. Aftermath grazing was carried out by a mixture of sheep and cattle, which also grazed several adjacent fields, until the ground became too wet. Typically, animals were on the fields from August to November, in densities between 0.5 and 4.6 animals/ha.

Monitoring and data analysis: Twenty-five 1 x 1 m quadrats were established in the spring of 2010, before either the green hay strewing or management change. Vegetation was monitored in the receiver field, and also an adjacent species-rich field, Side Ham, which provided a reference against which the success of the hay strewing and change of management could be assessed (referred to as the reference field). On the receiver site, three sets of five quadrats were monitored, while on the reference field a cross pattern of ten quadrats were monitored (Figure 2).

Initially it was planned to only seed part of the receiver field, so a block design for quadrats was established in this field. However, the hay was strewn over the entire receiver field, which was then managed as a single unit; since a year of baseline data had already been collected the sampling design remained unchanged. The positions of the quadrats were fixed using a real time differentiating GPS (Leica rX 1200, Switzerland), accurate to <10 mm for horizontal distances. All species of vascular plant and the principal bryophytes present within each quadrat were recorded, and assigned percentage cover values using visual estimates. The baseline vegetation survey was carried out in June 2010, just before the green hay was spread. Vegetation was subsequently monitored each June from 2011-2017.

The similarity of the samples from both the reference field and the receiver field to the communities of the National Vegetation Classification was assessed with the Czekanowski coefficient of similarity using the computer programme MATCH (Malloch 1995).

Table 1. Comparison of species richness at receiver and reference fields in 2010 and 2017 using Wilcoxon signed rank tests.

Field	Number of quadrats	Mean species 2010	Mean species 2017	Wilcoxon Z	p
Side Ham (reference field)	10	28.9	33.7	2.81	0.005
Swill Brook Meadow (receiver field)	15	16.5	26.3	3.41	0.001

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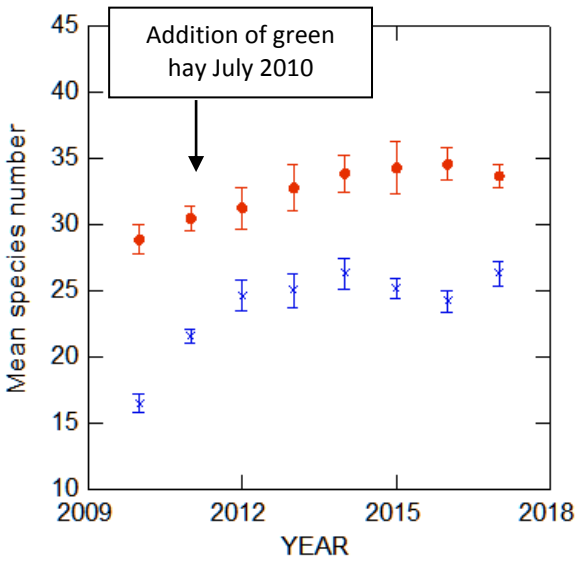

Figure 3. Average species richness (with standard error) for the reference (red circles) and receiver fields (blue crosses) between 2010 and 2017 based on 10 quadrats in the reference and 15 quadrats in the receiver field. Management for restoration began at the receiver field in 2011.

Table 2. Plant species that have appeared in the 15 quadrats in the receiver field since green hay spreading and management change in 2010. Species with a single occurrence in one or more years are not listed.

Species name	
Common knapweed	*Centaurea nigra*
Oxeye daisy	*Leucanthemum vulgare*
Common cats-ear	*Hypochaeris radicata*
Rough hawkbit	*Leontodon hispidus*
Bird's-foot trefoil	*Lotus corniculatus*
Ribwort plantain	*Plantago lanceolata*
Selfheal	*Prunella vulgaris*
Cowslip	*Primula veris*
Lesser yellow trefoil	*Trifolium dubium*
Yellow oat grass	*Trisetum flavescens*
Moss	*Brachythecium rutabulum*
Common spotted orchid	*Dactylorhiza fuchsii*
Red fescue	*Festuca rubra*
Ladies bedstraw	*Galium verum*
Fairy flax	*Linum catharticum*
Adder's-tongue fern	*Ophioglossum vulgatum*
Pepper saxifrage	*Silaum silaus*

CONSEQUENCES

Species richness showed a significant increase in the receiver field between 2010 and 2017, after green hay spreading and change in management (Figure 3, Table 1). Species richness increased most between 2010 and 2012, and then subsequently showed small annual fluctuations, with a further increase in 2017. The reference field also showed a small but significant increase in the number of species present since 2010 (Figure 3, Table 1). Overall, species richness in the receiver site showed a 60% increase between 2010 and 2017, whilst the reference field increased by 16%.

A number of new species colonised the receiver meadow in the years after the intervention (Table 2), whilst others increased in frequency, most notably autumn hawkbit, crested dog's-tail, bulbous buttercup, yellow rattle and common dandelion (Table 3).

Changes in species cover tended to be less marked. Meadow foxtail, white clover, field bindweed and creeping thistle (all prevalent in the receiver field prior to hay spreading) declined in cover between 2010 and 2017 (Table 3). The latter two species, which are indicators of disturbance and mismanagement, were absent from the reference field, but the decline in meadow foxtail occurred in both fields. There were temporary rises in rough-stalked meadow-grass *Poa trivialis* and Yorkshire fog *Holcus lanatus* in 2013. Ribwort plantain, new to the receiver field in 2011, was present in all quadrats in the receiver and reference fields by 2017, with an average cover of 27% in the receiver field, compared to 11% cover in the reference field. A peak cover of yellow rattle in 2014-2016

Table 3. Proportional change in frequency and cover of species in the receiver and reference fields between 2010 and 2017. Values expressed as proportional increase (>1.0), or decrease (< 1.0), of 2017 values compared to 2010 values. A value of 1.0 indicates no change. X indicates species not present in 2010.

Species	**Change in frequency**		**Change in cover**	
	Reference	**Receiver**	**Reference**	**Receiver**
Creeping thistle *Cirsium arvense*	X	0.32	X	0.22
Field bindweed *Convolvulus arvensis*	X	0.58	X	0.19
Rough-stalked meadow-grass *Poa trivialis*	0.66	0.33	0.50	0.88
Crested dog's-tail *Cynosurus cristatus*	0.60	2.70	0.48	0.58
Autumn hawkbit *Leontodon autumnalis*	1.28	5.71	1.41	135.0*
Bulbous buttercup *Ranunculus bulbosus*	2.00	2.20	2.25	2.62
Yellow rattle *Rhinanthus minor*	0.80	2.32	0.37	4.60
Common dandelion*Taraxacum officinale*	1.00	2.32	1.00	3.16
Red clover T*rifolium pratense*	1.00	1.55	1.55	2.06
Goat's beard *Tragopogon pratense*	0.50	1.85	0.50	1.50
Meadow foxtail *Alopecurus pratensis*	0.23	0.35	0.16	0.17
White clover *Trifolium repens*	1.50	0.86	1.00	0.17
Sweet vernal grass *Anthoxanthum odoratum*	0.90	2.65	2.5	3.53

* Representing an increase from 0.1 to 0.9%

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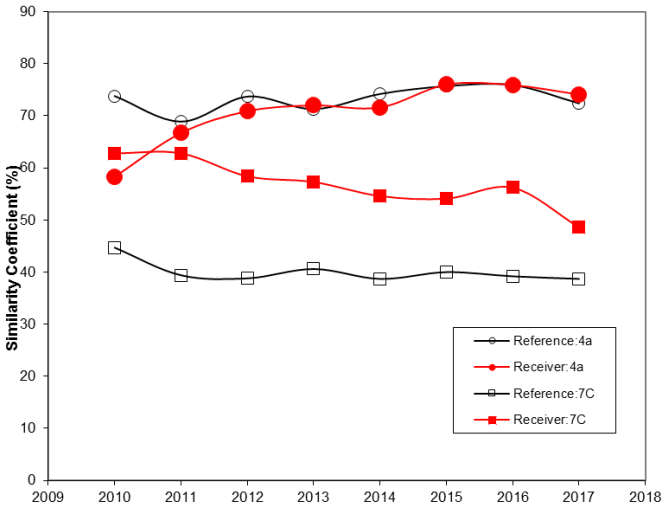

Figure 4. Change in the goodness of fit to the MG4a subcommunity of MG4 (labelled as 4a; Prosser and Wallace, in Rothero *et al.* 2016) and the MG7C *Lolium perenne-Alopecurus pratensis-Festuca pratensis* community (labelled as 7C, Rodwell 1992) for the receiver field and the reference field between 2010 and 2017. Similarity scores are Czekanowski coefficients of similarity calculated using the MATCH program (Malloch 1995).

on the receiver field may have contributed to the continuing decline in grass cover relative to that of herbs. The species remained constant in the reference field (Table 3).

The number and composition of species in the reference field remained fairly stable from 2010 to 2017 (Figure 3, Table 3). Tor grass *Brachypodium pinnatum*, first recorded in 2015, has persisted, whilst upright brome *Bromus erectus* peaked in 2012. Field woodrush *Luzula campestris* and saw-wort *Serratula tinctoria* increased in frequency.

Goodness of fit to the target MG4 community: The arrival of colonising species and an increase in the frequency of other species characteristic of the MG4 community after the changes in management resulted in an increase in the goodness of fit of the community at the receiver site to the target MG4 community (Figure 4). Using the recently updated definition of the MG4 community (Rothero *et al.* 2016), in 2010 the reference field was closest to the newly defined MG4a *Dactylis glomerata* subcommunity of MG4, the driest expression of the community. This remained the most similar community for the reference field between 2010 and 2017 and was therefore taken as the target community for the restoration field.

The goodness of fit of the receiver field to the target community showed marked changes between 2010 and 2017. In 2010, the highest similarity score was with the MG7C *Lolium perenne-Alopecurus pratensis-Festuca pratensis* grassland, but the goodness of fit to this community declined steadily between 2010 and 2017, whilst the similarity coefficient for the target MG4a community increased between 2010 and 2012 (Figure 4). In 2017, the similarity score for MG4a was over 20% higher than for the original MG7C community, reflecting an increased diversity of species and improvement in the herb to grass ratio. Changes in the reference field were small between 2010 and 2017 (Figure 4).

Between 2010 and 2012, the cover of herbs in the receiver field increased by 13% whilst that of grasses declined by 5%. By 2015, grass cover had declined by a further 13%, matched by a 13% increase in herb cover. In 2017 the sward could be classed as herb rich, with a grass/forb ratio of 0.60 compared to the initial value of 1.35 in 2010.

DISCUSSION

This restoration project has shown that using green hay and changed management from pasture to an annual hay cut followed by aftermath grazing can result in a more species-rich sward relatively quickly and cheaply if machinery and land are readily available. The biggest changes in species composition and goodness of fit to the target community occurred in the first two years after hay strewing, suggesting that the timing and treatment were appropriate for colonisation of many of the desirable species. Since then changes have been much more modest, with relatively small annual increments in frequency and cover of the target MG4a species. Despite the convergence of similarity scores between the receiver and reference fields the species in the receiver field remain patchy in their distribution and many years are still needed before local colonisation within the field produces a sward that is comparable to that of the reference field.

The use of simple monitoring before the restoration effort, and continued for a number of years afterwards, has been critical in assessing the success of the work.

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