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Restoring diverse grassland: What can be achieved where, and what will it do for us?

Hay Time: A landscape-scale approach to upland hay meadow restoration using green hay – preliminary results

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Summary

Upland hay meadows are one of the rarest grassland types in the UK. Restoration of a typical sward following agricultural improvement requires the deliberate reintroduction of plants as seed. The North Pennines AONB Partnership's Hay Time project began in 2006 to coordinate and monitor the reintroduction of seeds to multiple meadows across the North Pennines. In the first phase, seed was added to 94 ha of meadows. Interim analysis of monitoring data found an increase in species richness in 63% of sites, an increase in positive indicator species scores in 80% of sites and an increase in negative indicator species scores in 53% of sites. Seventeen species showed a statistically significant increase in frequency. The results demonstrate the start of a shift in sward composition towards that typical of MG3 upland hay meadow. It is anticipated that future monitoring will demonstrate further positive changes in the long process of meadow restoration.

Key words: North Pennines, MG3, seed addition, meadow score, *Rhinanthus minor*, *Geranium sylvaticum*

Introduction

Upland hay meadows corresponding to the National Vegetation Classification community MG3 *Anthoxanthum odoratum – Geranium sylvaticum* (Rodwell, 1992) are one of the rarest grassland types in the UK. They are characterised by high plant species diversity, most notably the sub-community MG3b *Briza media* with an average of 35 species per 4 m^2 (Rodwell, 1992). Estimates of the remaining extent of the community range from 750–1100 ha (Blackstock *et al*., 1999; Jackson & McLeod, 2000). These are likely to be over-estimates. The core resource is now confined to the upland valleys of County Durham, Northumberland, Cumbria, North Yorkshire and Lancashire (Jefferson, 2005; Pacha & Petit, 2008). Of this, the upper valleys of the North Pennines are a major stronghold.

A number of studies have demonstrated the importance of traditional farm management in maintaining the plant species diversity of upland hay meadows (Smith & Jones, 1991; Smith & Rushton 1994; Smith *et al*., 1996; Pacha & Petit, 2008). Since the late 1980s, farmers in the North Pennines have been invited to enter agri-environment schemes on a voluntary basis. The aims of these schemes have included the maintenance of semi-natural grasslands of existing high biodiversity value and the enhancement of those previously degraded by agricultural improvement or neglect (Critchley *et al*., 2003). Payments are made to participating farmers for adopting

prescribed traditional farming practices. Despite the existence of these schemes, the plant species diversity of hay meadows in the Pennine Dales continued to decline into the 21st century (Critchley *et al*., 2007)

Following agricultural improvement, the re-establishment of traditional hay meadow management alone is unlikely to result in the restoration of a typical upland hay meadow sward owing to a lack of suitable colonising seeds either from within the vegetation or the soil (Critchley *et al*., 2003). The deliberate reintroduction of plant species as seed is therefore needed.

The North Pennines AONB Partnership launched its project Hay Time in 2006 with the aim of reintroducing plants to multiple meadows across the North Pennines through seed addition (Rayner *et al*., 2007). The project is due to run until October 2012. Seed is harvested from species-rich meadows ('donor sites') and spread on species-poor meadows ('receptor sites') within the same valley ('dale'). This ensures seed is of known local provenance and genetic integrity is maintained. Seed is collected and spread in green hay which has been shown to be an effective method for creating a sward similar to that of the donor site (Edwards *et al*., 2007). Seeds are introduced in two stages. At the first stage ('restoration'), donor sites are selected that are rich in *Rhinanthus minor*, *Lotus corniculatus*, *Trifolium pratense*, *Anthoxanthum odoratum* and *Ranunculus acris*. The introduction of these plants has been shown to modify soil microbial communities towards those typically associated with traditional meadow management (Smith *et al*., 2008). *R. minor* is an important species to introduce at the restoration stage as it facilitates the establishment and survival of other species by reducing competition from the grass component of the sward (Pywell *et al*., 2004). Meadows that already support the suite of plants listed above are suitable for the second stage of seed addition ('enhancement'). Donor sites are carefully selected to match the soil conditions of the receptor site. Typically enhancement donor sites for dry meadows contain *G. sylvaticum*, *Sanguisorba officinalis*, *Centaurea nigra*, *Leontodon hispidus* and *Alchemilla* spp. and donor sites for wet meadows contain *Trollius europeaus*, *Geum rivale*, *Filipendula ulmaria* and *Lychnis flos-cuculi*. The costs for agricultural contractors to carry out this work and payment to the donor farmer for partial loss of their hay crop are covered under the terms of the receptor farmer's agri-environment agreement.

The aim of this paper is to present preliminary results on the impact of seed introduction on sward composition for 94 ha of upland hay meadow following the first four years of the North Pennines AONB Partnership's Hay Time project (2006–2009).

Methods

Sites and surveys

Thirty upland hay meadows in the North Pennines, equating to 94 ha, had seed introduced using green hay between 2006 and 2009. Each meadow had a baseline botanical survey and a later monitoring survey undertaken by a Hay Time project officer (the later survey being undertaken between 2 and 4 years after restoration). The surveys took approximately 45 mins and all plant species were recorded during a slow walk following a "W" across the field (nomenclature according to Stace, 2010). Each plant species was given a frequency score between 1–5 (1 = rare, 2 = occasional, 3 = frequent, 4 = abundant, 5 = dominant). In addition, nine of the meadows had a more detailed baseline survey and later monitoring survey undertaken by skilled volunteers. These surveys took a day and consisted of 15 quadrats (1 m × 1 m) placed evenly across the field and following a "W". Only the mown part of the meadow was recorded. All plant species were identified and the percentage cover was estimated (nomenclature according to Stace (2010)).

Harvesting and spreading machinery

Two types of harvesting machinery were used. The 'Amazon Green-keeper' is pulled by a tractor and cuts the vegetation close to the ground, collecting the entire sward as green hay. The second harvester was developed and built by Ian Fletcher of Moorland and Meadow Seed Regeneration.

This machine is pulled by a quad-bike and cuts and collects only the top 10–15 cm of the sward as 'hay concentrate'. During harvesting a maximum of one third of the field was used as a seed source. The harvested vegetation was loaded into a clean muck spreader and transported to the receptor site. The receptor field had been scarified after the hay crop had been removed, exposing approximately 30% bareground. The green hay was spread onto the receptor site using the muck spreader. Green hay was spread no later than 1 h after being cut and collected. Afterwards the farmer was asked to let cattle or other livestock into the meadow to graze the aftermath and trample in the seeds.

Calculating meadow scores

The botanical survey data was used to calculate the total number of species found per meadow (species richness) and the positive indicator species score (P+), negative indicator species score (N-) and total meadow score (TM) for each meadow. Each plant species is given a score ranging from -2 through to +4. For example, *Ranunculus repens* is -2 and *G. sylvaticum* is +3. The plants typical of upland hay meadows have a higher positive score, the plants that are found in all grasslands receive zero (neutral species) and plant species that are competitive or "weedy" receive negative scores. The score was multiplied by the frequency for each species and totalled to give the total meadow scores (O'Reilly/North Pennines AONB Partnership, 2006).

Data analysis

The baseline surveys and latest monitoring surveys were compared for the 30 meadows using paired sample *t*-tests in MINITAB. The differences between species richness, the positive indicator species score (P+), negative indicator species score (N-) and total meadow score (TM) were compared; in addition, a selection of the common plant species' frequencies were compared. The nine meadows surveyed in more detail were analysed separately and one example is described as a case-study in this paper. This quadrat data was compared using a general linear model (GLM) in MINITAB.

Results

Species richness increased in 19 of the 30 meadows (63%) by an average of four species between the baseline and the latest survey ($T = -2.30$, $P = 0.029$). Positive indicator species scores increased in 24 of the 30 meadows (80%) and 10 of the meadows (30%) increased in score by over 25. On average, there was an increase in the positive indicator species score of +14 between the baseline and the latest survey ($T = -5.92$, $P < 0.001$). The negative indicator species scores increased in 16 of the 30 meadows (53%). However, the majority of the meadows that showed an increase in the negative indicator species scores only had an increase of up to -10, whereas the majority of the meadows that showed an increase in the positive indicator species scores had an increase of over +15. On average, the negative indicator species scores increased by -4 between the baseline and the latest survey ($T = 2.33$, $P = 0.027$). As the increase in positive indicator species scores was far greater than the increase in negative indicator species scores, the total meadow scores increased in 17 out of the 30 meadows (57%) and in seven of the meadows (23%) the score increased by >30. From the baseline to the latest survey there was an average increase in the total meadow scores of +13 ($T = -4.14$, $P < 0.001$) (Table 1).

All 17 plant species that had a statistically significant change in frequency from the baseline to the latest survey increased in frequency, rather than decreased. Eleven of these species were positive indicator species, three were neutral species and three were negative indicator species. *Agrostis capillaris*, *Euphrasia arctica*, *Myosotis discolor*, *R. repens*, *R. minor*, *T. pratense* and *Trifolium repens* had a highly significant change. *R. minor* and *A. capillaris* more than doubled in frequency. Three positive indicators with a species score of 3 (*L. flos-cuculi*, *G. sylvaticum* and *S. officinalis*) increased from the baseline to the latest survey, although *G. sylvaticum* and *S. officinalis* were only slightly significant (Table 2).

Table 1. *The differences in the mean meadow scores of 30 meadows that had a statistically significant change between the baseline and latest surveys*

Calculated meadow score	Baseline survey	Latest survey	Significance
Species richness	28 ± 1.3	32 ± 1.3	T = -2.30, $P = 0.029$*
Positive indicator species score	41 ± 3.4	55 ± 3.1	T = -5.92, $P < 0.001$***
Negative indicator species score	-22 ± 1.4	-26 ± 1.3	T = 2.33, $P = 0.027$**
Total meadow score	18 ± 3.2	31 ± 3.4	T = -4.14, $P < 0.001$***

Statistical differences are graded from * ≥ 0.04 (slightly significant), ** ≥ 0.01 (significant), *** ≤ 0.01 (highly significant).

Table 2. *The differences in the mean frequency of each plant species that had a statistically significant change between the baseline and latest surveys*

Scientific Name	Common Name	Species scores	Mean frequency of baseline survey	Mean frequency of latest survey	Significance
Agrostis capillaris	Common Bent	1	1.9 ± 0.4	4.1 ± 0.2	T = -4.89, $P < 0.001$***
Alopecurus pratensis	Meadow Foxtail	0	2.2 ± 0.3	3.2 ± 0.3	T = -2.37, $P = 0.025$**
Cerastium fontanum	Common Mouse-ear	0	2 ± 0.3	2.6 ± 0.3	T = -2.07, $P = 0.048$*
Cynosurus cristatus	Crested Dogs-tail	1	2.8 ± 0.4	3.5 ± 0.3	T = -2.33, $P = 0.028$**
Euphrasia arctica	Eyebright	2	0.5 ± 0.3	2.2 ± 0.3	T = -7.14, $P < 0.001$***
Geranium sylvaticum	Wood Crane's-bill	3	0.7 ± 0.7	2 ± 0.6	T = -4, $P = 0.057$*
Lychnis flos-cuculi	Ragged Robin	3	0.3 ± 0.3	1.5 ± 0.3	T = -5, $P = 0.015$**
Myosotis discolor	Changing Forget-me-not	1	0.9 ± 0.3	1.9 ± 0.2	T = -3.24, $P = 0.004$***
Phleum pratense	Timothy	-1	1.3 ± 0.4	2.1 ± 0.4	T = -2.24, $P = 0.038$**
Plantago lanceolata	Ribwort Plantain	1	2.1 ± 0.4	2.8 ± 0.3	T = -2.48, $P = 0.021$**
Ranunculus repens	Creeping Buttercup	-2	2.3 ± 0.3	3.3 ± 0.2	T = -4.20, $P < 0.001$***
Rhinanthus minor	Hay Rattle	2	1.5 ± 0.3	3.7 ± 0.2	T = -7.98, $P < 0.001$***
Rumex acetosa	Common Sorrel	0	3.1 ± 0.2	3.7 ± 0.3	T = -1.98, $P = 0.058$*
Sanguisorba officinalis	Great Burnet	3	0.5 ± 0.3	1.3 ± 0.3	T = -3, $P = 0.058$*
Trifolium dubium	Lesser Trefoil	1	1.6 ± 0.4	2.6 ± 0.4	T = -2.69, $P = 0.015$**
Trifolium pratense	Red Clover	1	1.9 ± 0.3	2.6 ± 0.3	T = -3.10, $P = 0.004$***
Trifolium repens	White Clover	-1	2.6 ± 0.3	3.5 ± 0.2	T = -3.45, $P = 0.002$***

Statistical differences are graded from * ≥ 0.04 (slightly significant), ** ≥ 0.01 (significant), *** ≤ 0.01 (highly significant).

In the nine meadows surveyed in detail by the volunteers, the positive indicator species scores increased from a mean of 58 ± 5 to a mean of 70 ± 5 (T = -4.35, $P = 0.002$). In one meadow example, *A. odoratum* significantly increased from a mean cover of 5% in 2007 to 18% in 2009

($F_{2,39}$=8.24, P = 0.001), whereas the grass *Holcus lanatus* declined from a mean cover of 44% to 9% ($F_{2,39}$=38.15, P = 0.001) and the grass *Cynosurus cristatus* declined from a mean cover of 45% to 18% ($F_{2,39}$=4.35, P = 0.02). Three positive indicator species increased between 2007 and 2009: *Conopodium majus* increased from a mean cover of 1% to 16% ($F_{2,39}$=11.18, P = 0.001), *M. discolor* increased from a mean cover of 0.3% to 4% ($F_{2,39}$=4.76, P = 0.014) and *R. minor* increased from a mean cover of 2% to 21% ($F_{2,39}$=7.86, P = 0.001). *C. majus* was found in two quadrats in 2007 but was found in nine quadrats in 2009 and *R. minor* was found in four quadrats in 2007 but 13 quadrats in 2009.

Discussion

The interim results from monitoring the impact of seed addition through green hay spreading offer good evidence to demonstrate a change in sward composition towards that typical of MG3 upland hay meadow. The most striking result has been the clear increase in positive indicator species, especially *R. minor*. The number of plant species found in the meadows has increased in the majority of cases and these species tend to be upland hay meadow key indicators. Similar evidence for seed establishment using green hay was found by Edwards *et al*. (2007), although these sites concerned lowland grassland where different species established.

There is evidence to suggest that *R. minor* is reducing the more competitive grasses and as *R. minor* increases in frequency, so do a number of other positive indicators. This trend has been found in other studies (Pywell *et al*., 2004; Smith *et al*., 2008). In the first year after seed introduction, the annuals *R. minor*, *E. arctica* and *T. dubium* quickly established and spread. Other species such as *T. pratense* and *P. lanceolata* were seen in the second or third year after seed addition. *P. lanceolata* was similarly found to increase by Edwards *et al*. (2007). There was some indication that *G. sylvaticum* and *S. officinalis* have increased; however, these are long-lived perennial plants that take a long time to mature so it is likely that establishment of these species will be more noticable in a few years time. Considering that Petit & Pacha (2008) have shown that *G. sylvaticum* has been lost from 40% of upland hay meadows in the Yorkshire Dales between the 1980s and early 21st century, an effective mechanism to successfully reintroduce this species would be welcomed.

It is unfortunate that a number of negative indicator species have increased; however, it is not surprising that if these species are present in the donor meadow when the seeds are gathered, that they too will be introduced to the receptor site. Donor sites with few negative indicator species are carefully chosen so that only a small number of such species can be transferred this way.

It is clear from the analysis of the data gathered by volunteers that their quadrats enable finer trends in species composition to be identified. *C. majus* and *R. acris* were both found to be increasing at individual sites studied in detail whereas these trends were not picked up from the more rapid project officer surveys.

This paper presents interim results on the early impact of seed introduction between 2006 and 2009 on sward composition for 94 ha of upland hay meadow in the North Pennines. Further data will be gathered for these sites, including collating information on management and soil fertility, plus additional monitoring during 2012 and monitoring of a sample of sites will continue into the future. Hay meadow restoration is a lengthy process and key botanical changes are likely to take place after the AONB Partnership's Hay Time project has ended. As Smith *et al*. (2008) pointed out, restoration can take a minimum of 20 years so these analyses are likely to be only addressing the start of a long process. In this respect it is encouraging that significant positive changes in sward composition have been picked up at the beginning of this large-scale meadow restoration programme.

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References

Blackstock T, Rimes C, Stevens D, Jefferson R, Robertson H, MacKintosh J, Hopkins J. 1999. The extent of semi-natural grassland communities in lowland England and Wales: a review of conservation surveys 1978–1996. *Grass and Forage Science* **54**:1–18.

Critchley C N R, Burke M J W, Stevens D P. 2003. Conservation of lowland semi-natural grasslands in the UK: a review of botanical monitoring results from agri-environment schemes. *Biological Conservation* **115**:263–278.

Critchley C N R, Fowbert J A, Wright B. 2007. Dynamics of species-rich upland hay meadows over 15 years and their relationship with agricultural management practices. *Applied Vegetation Science* **10**:307–314.

Edwards A R, Mortimer S R, Lawson C S, Westbury D B, Harris S J, Woodcock B A, Brown V K. 2007. Hay strewing, brush harvesting of seed and soil disturbance as tools for the enhancement of botanical diversity in grasslands. *Biological Conservation* **134**:372–382.

Jackson D L, McLeod C R. (Eds). 2000. *Handbook on the UK Status of EC Habitats Directive Interest Features: Provisional Data on the UK Distribution and Extent of Annex I Habitats and the UK Distribution and Population Size of Annex II Species*. JNCC Report 312. Peterborough, UK: Joint Nature Conservation Committee.

Jefferson R G. 2005. The conservation management of upland hay meadows in Britain: a review. *Grass and Forage Science* **60**:22–331.

O'Reilly J/North Pennines AONB Partnership. 2006. *Hay Time upland hay meadow scoring system*.

Pacha M J, Petit S. 2008. The effect of landscape structure and habitat quality on the occurrence of Geranium sylvaticum in fragmented meadows. *Agriculture, Ecosystems and Environment* **123**:81–87.

Pywell R F, Bullock J M, Walker K J, Coulson S J, Gregory S J, Stevenson M J. 2004. Facilitating grassland diversification using the hemiparasitic plant *Rhinanthus minor*. *Journal of Applied Ecology* **41**:880–887.

Rodwell J S. (Ed.). 1992. *British Plant Communities, Vol. 3, Grasslands and Montane Communities*. Cambridge, UK: Cambridge University Press.

Rayner P E, O'Reilly J, Barrett R M T, Gamble D M. 2007. Hay Time: hay meadow enhancement and restoration in the Pennine Dales, Northern England. In *High Value Grassland. Providing biodiversity, a clean environment and premium products*, pp. 309–312. BGS Occasional Symposium No. 38. Ed. J J Hopkins. Kenilworth, UK: British Grassland Society.

Smith R S, Jones L. 1991. The phenology of mesotrophic grassland in the Pennine Dales, Northern England: historic cutting dates, vegetation variation and plant species phenologies. *Journal of Applied Ecology* **28**:42–59.

Smith R S, Rushton S P. 1994. The effects of grazing management on the vegetation of mesotrophic (meadow) grassland in Northern England. *Journal of Applied Ecology* **31**:13–24.

Smith R S, Buckingham H, Bullard M J, Younger A. 1996. The conservation management of mesotrophic (meadow) grassland in Northern England. I. Effects of grazing, cutting date and fertiliser on the vegetation of a traditionally managed sward. *Grass and Forage Science* **51**:278–291.
Smith R S, Shiel R S, Bardgett R D, Millward D, Corkhill P, Evans P, Quirk H, Hobbs P J, Kometa S T. 2008. Long-term change in vegetation and soil microbial communities during the phased restoration of traditional meadow grassland. *Journal of Applied Ecology* **45**:670–679.
Stace C A. 2010. *New flora of the British Isles*. Cambridge, UK: Cambridge University Press.