The impact of green hay addition to upland hay meadows in the North Pennines through the Hay Time project (2006 – 2012)

Introduction

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 ran between 2006 and 2012. The aim was to coordinate the reintroduction of seeds in 'green hay' to multiple meadows across the North Pennines and to monitor the impact of this. Two types of harvesting machinery were used: 1) The 'Amazon green-keeper' towed by a tractor which harvests the whole hay crop as green hay; 2) the 'hay concentrate' machine, towed by a quad-bike which harvests the top third of the hay crop. The harvested material was spread using a conventional muck spreader. In total, green hay was added to 236 ha of meadows (93 fields).

Botanical surveys

Between 2006 and 2012 Hay Time project officers undertook baseline botanical surveys prior to seed addition and later monitoring surveys after seed addition on 46 meadows (130ha). These surveys consisted of a W-shaped walk through the meadow during which all species were recorded and allocated a frequency score between 1 – 5 (1 = rare, 2 = occasional, 3 = frequent, 4 = abundant, 5 = dominant). Eleven of the meadows were surveyed in more detail by volunteer botanists using 15 quadrats (1 m x 1 m squares) per meadow per year, prior to seed addition and in the following years after seed addition. A further 14 meadows had a baseline survey in 2008 and a follow-up survey in 2012; these meadows did not have green hay added (the controls).

Calculating meadow scores

For each meadow the botanical survey data was used to calculate the total number of species found (species richness), the positive indicator species score (P+) and the negative indicator species score (N-). To do this, each plant species is given a score ranging from -2 through to +4. For example, creeping buttercup is -2 and great burnet is +3. Plants typical of upland hay meadows have a higher positive score, plants that are found in all grasslands receive zero (neutral species) and plant species that are competitive or "weedy" receive negative scores.

Data analysis

The baseline surveys and latest monitoring surveys were compared for the 46 meadows that had seed added and the 14 meadows that did not have seed added (the controls) using paired sample t-tests in MINITAB. The differences between species richness, the positive indicator species score (P+) and negative indicator species score (N-) were compared; in addition, a selection of the common plant species' frequencies were compared. The detailed quadrat data from eleven meadows was analysed separately and examples are described as case-studies. The quadrat data was compared using a general linear model (GLM) in MINITAB.

Results

Species richness

The addition of seed has been successful in introducing new species into meadows and increasing botanical diversity. The number of species present has statistically significantly increased by three in meadows that have had seed added whereas the number of species present did not significantly increase in meadows that have not had seed added (Figure 1).

Positive indicator species score (P+)

The addition of seed has been successful in increasing the positive indicator species score (P+) in meadows. Positive indicator species score (P+) has also increased in the controls but this was much less than in the meadows that received seed. After seed addition, positive indicator species score (P+) increased in 40 out of 46 meadows (87%), whilst five meadows declined (11%) and one meadow stayed the same (2%). On average, positive indicator species score (P+) statistically significantly increased by 18 P+ in meadows that have had seed added. In meadows that have not had seed added (the controls), positive indicator species score (P+) increased in nine out of 14 meadows (64%), whilst two meadows declined (14%) and three meadows stayed the same (21%). On average, positive indicator species score (P+) statistically significantly increased by 8 P+ in meadows that have not had seed added (Figure 2).

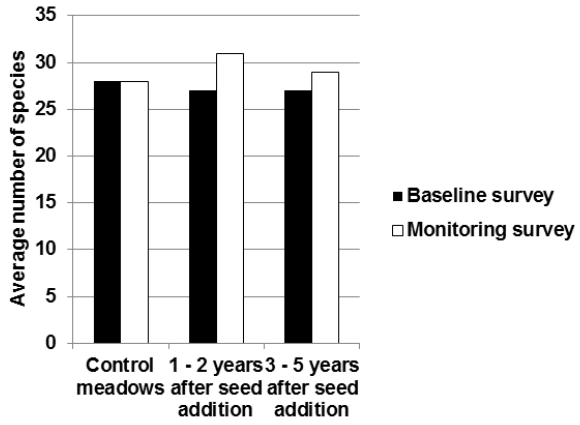

Figure 1. Change in number of species between baseline and latest surveys

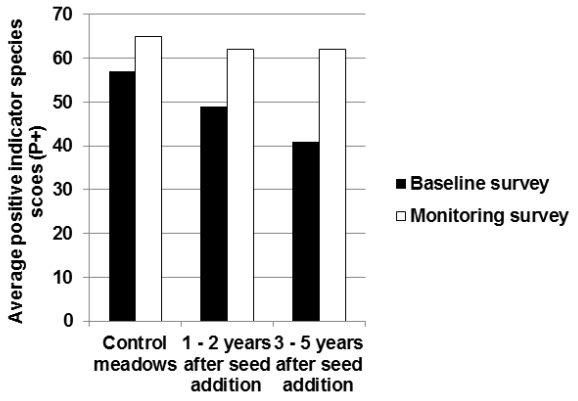

Figure 2. Change in positive indicator species score (P+) between baseline and latest surveys

Negative indicator species score (N-)

The addition of seed in green hay has increased the negative indicator species score (N-) in some meadows. On average, negative indicator species score (N-) statistically significantly increased by 3 N- in meadows that have had seed added. Negative indicator species score (N-) did not statistically significantly increase in meadows that have not had seed added.

Plant species trends

Positive indicator species

Common bent, sweet vernal-grass, crested dog's-tail, pignut, eyebright, red fescue, changing forget-me-not, ribwort plantain, meadow buttercup, yellow-rattle, great burnet, lesser trefoil, red clover and yellow oat-grass appear to have statistically significantly increased in frequency due to seed addition. Crested dog's-tail, eyebright, ribwort plantain, yellow-rattle, lesser trefoil and red clover establish one to two years after seed addition, whereas common bent, sweet vernal-grass, pignut, red fescue, changing forget-me-not and meadow buttercup appear to establish three years after seed addition (Figure 3, 4 & 6). Sweet vernal-grass, crested dog's-tail and eyebright also appear to have statistically significantly increased in frequency in the control meadows but at a lower frequency than in the meadows where seed has been added. Self-heal and common sorrel appear to be generally increasing in frequency in all meadows.

Negative indicator species

Cock's-foot, creeping buttercup, sharp-flowered rush and white clover appear to have statistically significantly increased in frequency following seed addition. Creeping buttercup appears to establish one to two years after seed addition, whereas cock's-foot and white clover appear to establish three years after seed addition. In addition, sharp-flowered rush and creeping buttercup appear to have statistically significantly increased in frequency in the control meadows but in slightly lower frequency than the meadows that have had seed added (Figure 5).

Figure 3. The change in the frequency of red clover between baseline and latest surveys.

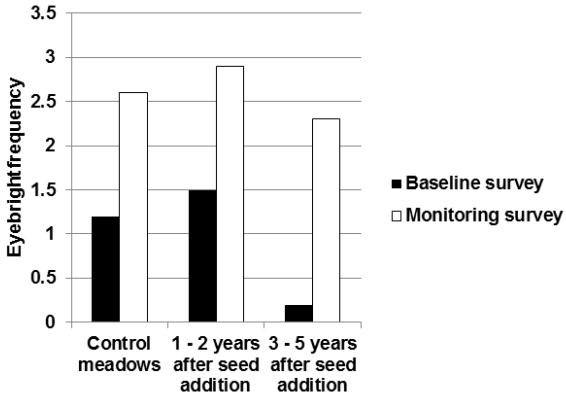

Figure 4. Change in frequency of eyebright between baseline and latest surveys.

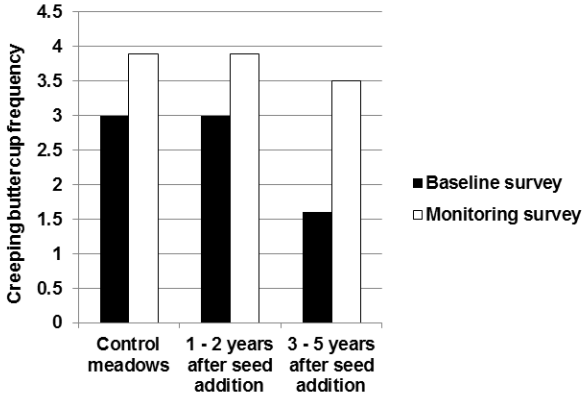

Figure 5. Change in frequency of creeping buttercup between baseline and latest surveys.

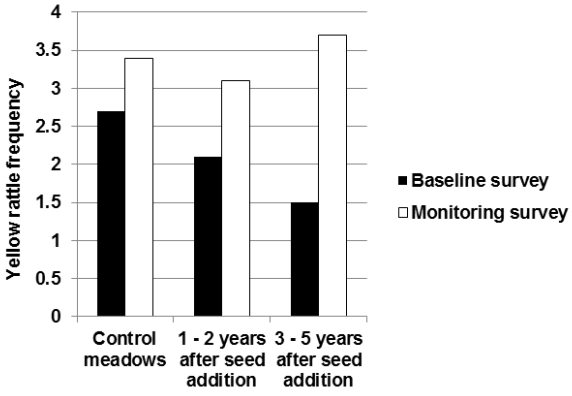

Figure 6. Change in frequency of yellow rattle between baseline and latest surveys.

Photo 1. A meadow in Weardale before seed addition in 2007

Photo 2. The same meadow five years after seed addition in 2012

Soil data

Phosphate and magnesium levels have statistically significantly increased in the majority of meadows. The phosphate index has significantly increased from an average of 1.2 in the baseline soil samples to an average of 1.7 in the latest soil samples. There has been an increase in phosphate in 14 out of 25 meadows (56%), a decrease in two meadows (8%) and nine meadows (36%) have remained the same. Magnesium has significantly increased from an average of 148 ppm in the baseline soil samples to 201 ppm in the most recent soil samples. Magnesium has increased in 22 out of 25 meadows (88%). Potassium and pH have not significantly changed over time. Many studies have shown that increases in soil fertility lead to decreases in plant species diversity.

Case studies

Eleven meadows that had seed added were surveyed in detail by volunteer botanists. Statistically significant changes in botanical composition were found in all of the meadows that had seed added. Nine of the eleven meadows (82%) had significant increases in the number of species (an average increase of three species per quadrat) and eight of the eleven (73%) had significant increases in the positive indicator species score (an average of 19 P+ per quadrat). Four of the eleven (36%) had significant decreases in the negative indicator species score (an average of 10 N-).

Sweet vernal-grass, eyebright, meadow vetchling, autumn hawkbit, meadow buttercup, yellow rattle, lesser trefoil and red clover significantly increased in the majority of the meadows two to three years after seed addition. Pignut, changing forget-me-not, ribwort plantain and common sorrel significantly increased in a number of meadows. There was evidence that wood crane's-bill, bird's-foot trefoil, red fescue, self-heal and rough hawkbit were beginning to establish in some quadrats in 2012. Few negative indicator species increased; sharp-flowered rush and white clover increased in a couple of meadows, and creeping buttercup increased in only one meadow that had seed added.

Case study 1

This meadow in Allendale had seed added in 2009. On average there was a significant increase of two species per quadrat, positive indicator species score significantly increased by 15 P+ per quadrat and negative indicator species score decreased by 8 N- per quadrat by 2012, three years after seed addition. Pignut, crested dog's-tail, eyebright, changing forget-me-not, ribwort plantain, meadow buttercup, yellow rattle (Figure 7), common sorrel and red clover significantly increased in cover (%) by 2012, three years after seed addition. Pignut, eyebright and changing forget-me-not were not found in the baseline quadrats; meadow buttercup, yellow-rattle and red clover increased from low cover (%) in 2009 to high cover (%) by 2012. There was evidence that lesser trefoil, wood crane's-bill and cat's-ear were beginning to establish in the quadrats in 2012.

Case study 2

This meadow in Weardale had seed added in 2007. On average there was a significant increase of eleven species per quadrat and positive indicator species score significantly increased by 12 P+ per quadrat by 2012 (Figure 8). Eyebright, red fescue, changing forget-me-not, meadow buttercup, yellow rattle, common sorrel and red clover significantly increased in cover (%) by 2012. The majority of these changes became significant in 2009, two years after seed addition. Meadow buttercup, yellow-rattle and red clover now form the dominant part of the botanical composition of the meadow. There was evidence that sweet vernal-grass, ragged robin and meadow vetchling were beginning to establish in the quadrats in 2012.

Case study 3

This meadow in Teesdale had seed added in 2006. On average there was a significant increase of four species per quadrat, positive indicator species score significantly increased by 48 P+ per quadrat and negative indicator species score decreased by 39 N- per quadrat by 2012, six years after seed addition. Crested dog's-tail, eyebright, rough hawkbit, yellow rattle, red clover and white clover significantly increased in cover (%) by 2012. Crested dog's-tail, eyebright, rough hawkbit, yellow rattle and red clover were not found in the baseline quadrats. The majority of these changes

started to show in 2008, two years after seed addition and changes have continued year by year. There was evidence that sweet vernal-grass, ragged robin, self-heal and lesser trefoil were beginning to establish in the quadrats in 2012.

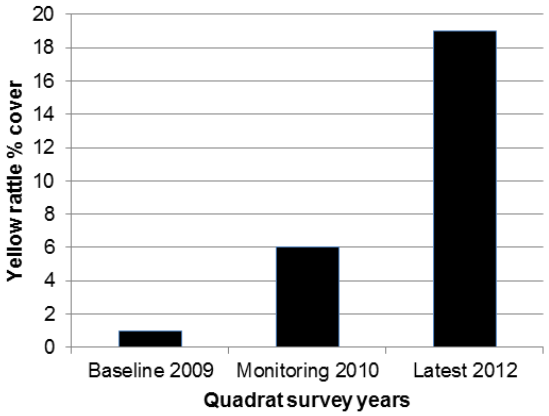

Figure 7. The change in yellow rattle % cover in a meadow in Allendale following seed addition.

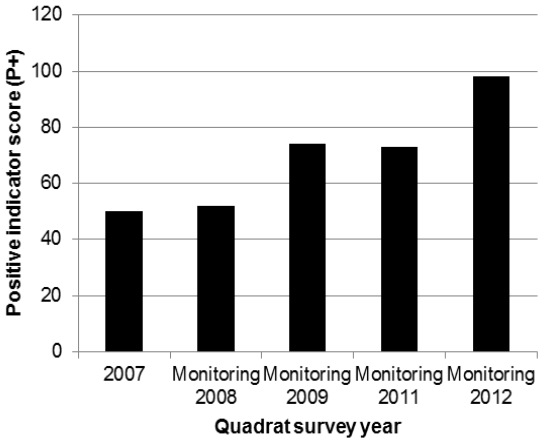

Figure 8. The change in positive indicator species score (P+) in a meadow in Teesdale following seed addition.

Conclusion

The analysis of botanical monitoring data following the addition of seed in green hay indicates the start of a shift in sward composition towards that typical of National Vegetation Classification (NVC) MG3 upland hay meadow. Hay meadow restoration is a lengthy process and botanical change is likely to continue after the end of the AONB Partnership's Hay Time project. Successful restoration can take up to 20 years so the changes found in this study mark only the start of a long process.

Adding seed is clearly an important step in hay meadow restoration but the beneficial impact of seed addition will only be sustained in the long-term if appropriate, traditional hay meadow management practices are followed. These practices, coupled with seed addition, offer a suitable approach for improving hay meadow botanical diversity. However, evidence that the majority of meadows are increasing in soil fertility suggests that the positive impact of seed addition may be short-lived.

It is encouraging that significant positive changes in sward composition have been shown during this large-scale but short-term meadow restoration programme. We hope that in association with appropriate traditional hay meadow management these positive trends will continue into the future.

The North Pennines AONB Partnership is grateful to all the farmers and smallholders who have assisted us during the Hay Time project by allowing access to their land for surveys, agreeing to have green hay harvested from or spread on their meadows and for discussing their farm management with us. Without such cooperation and support this project would not have been possible. Thank you very much.

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