Project ecm_56805 under AESME Lot 7.

Long-term impacts of agri-environment management including sward enhancement interventions on upland hay meadows

Final report to Natural England

22 June 2021

Belinda R. Wheeler[1] & Philip J. Wilson[2]

[1]Belinda Wheeler, BSc (Hons), DPhil, MCIEEM.

Cloudstreet, Brentor Road, Mary Tavy, Tavistock, Devon. PL19 9PY.
ecology@belindawheeler.co.uk2

[2]Philip Wilson, BSc (Hons), PhD, MCIEEM.

Pennyhayes, Shute, Axminster, Devon. EX13 7QP.

philipjohnwilson@aol.com

Contents

Acknowledgements

The authors would like to thank Dave Martin and Andy Cooke of Natural England for their help and guidance during this project and their assistance with submission of soil data and comments on the draft report. We would also like to gratefully acknowledge detailed comments and suggestions from our two peer reviewers; Clive Hurford (Serapias Ltd) and Sophie Lake (Footprint Ecology Ltd). Andrew Cole (Natural England) and Kerry Vitalis (Defra) also provided useful feedback on the first draft.

We are extremely grateful to the following people and organisations for their generosity in providing data on their meadow restoration projects and their valuable time in collating it: Ruth Starr-Keddle and Chris Woodley-Stewart (North Pennine AONB Partnership), Sarah Robinson (Forest of Bowland AONB), Isobel Hall, Catherine Mercer and Michaela Brennan (Yorkshire Dales Millennium Trust) and Graham Jackson-Pitt, Christa Nelson and Christine Davison (Cumbria Wildlife Trust).

In addition to the authors of this report, the survey team included Clive Bealey, Claire Cornish, Phil Eades, Eleanor Hewins, Daniel Madden, Gail Quartly-Bishop, Marian Reed and John O'Reilly. Marian Reed also helped with draft editing, interpreting management questionnaires and historic farming data. Simon Poulton of BioEcoSS provided historic survey data extracted from EMD and carried out all initial data transformations.

None of this work would have been possible without the help and co-operation of the farmers, landowners and managers, too numerous to mention here, who allowed us to survey their grasslands.

Summary

Upland Hay Meadow (UHM) is a rare and declining habitat in the UK with less than 1000 ha remaining, concentrated in the North Pennines and Yorkshire Dales. It is a Priority Habitat for action under Biodiversity 2020 (Section 41 of NERC Act 2006) and included in Annex 1 of the Habitats Regulations. Agri-environment schemes have been the major vehicle for delivering conservation and restoration management since the inception of the Environmentally Sensitive Area (ESA) scheme in 1987 and much UHM has remained under conservation management with each consecutive scheme. Many meadows have now been managed continuously under agri-environment schemes for *c.* 30 years.

The objective of this project was to provide an updated assessment of the impact of agri-environment schemes on UHM by resurveying the condition of UHM stands in a core sample of sites currently managed under Higher Level Stewardship (HLS) or Countryside Stewardship (CS) for which there are existing data from 2012, and earlier for many sites. The resurvey included 95 of 103 sites surveyed in 2012, of which 29 were under HLS option HK6 (maintenance of species-rich grassland) and 66 under HLS option HK7 (restoration of species-rich grassland). Nine of these are now in the corresponding CS options GS6 and GS7.

An additional objective was to look at a sample of meadows which have had sward enhancement interventions through the introduction of plant material (green hay, seed, or plug plants). A sample group of 34 meadows under restoration options HK7/GS7 that had received enhancement under one of the partner organisations' hay meadow restoration projects were surveyed. A further 18 extra sites were selected for survey which had been in the original ESA monitoring sample but had not had a recent history of management under HLS or CS.

The botanical monitoring was supplemented by soil sampling and management information collected from farmers. Relationships between vegetation condition, soil and management variables, including sward enhancement measures, were explored to provide evidence for the drivers of change in the condition of stands over time. Recommendations are made for delivering grassland restoration in future land management schemes.

The UHM communities encountered within the survey sample were not of the highest quality. MG3, the typical community of drier meadows, was found in 25% of the core sample of stands in 2020 and the wetter MG8 grassland in 33% of stands. Typical positive indicator associates of MG3 were missing from many stands. In a structured walk condition assessment *Geranium sylvaticum* occurred in 44% of MG3 meadows, *Alchemilla vulgaris* agg. in 53% and *Sanguisorba officinalis* in 75%, and the frequency of typical associates was low. *Geranium sylvaticum, Trollius europaeus, Alchemilla vulgaris* and *Cirsium heterophyllum* were more frequent in unsampled areas such as uncut banks and nearby road verges. MG8 stands were the most diverse across the sample, but richness was lower within individual sites. A greater proportion of the stands had closest affinities with MG6b. These varied widely in species richness and many stands are likely to be degraded stands of MG3 or MG8.

The sward enhancement sample meadows were predominantly MG6b (82%) and the non-agreement control sample was dominated by poorer grassland (MG6b - 50%, MG7 - 29%) although a few stands of MG3 and MG8 were found.

When assessed against the criteria and thresholds for UHM priority grassland (habitat G09 in the ES Farm Environment Plan [FEP] and CS Baseline Evaluation of Higher Tier Agreements [BEHTA]) only 45% of the UHM stands in core sample sites were Favourable condition G09 UHM priority habitat grassland, 34% were Unfavourable condition and 19% were not a priority grassland type. The criterion most frequently failed (55%) was frequency of positive indicator species followed by cover of qualifying wildflower species (25%). HLS option HK6 and CS option GS6 are aimed at maintaining species-rich grassland, yet in 2020 only 50% of sites managed under HK6/GS6 were in Favourable condition, compared with 42% managed under the 'restoration' option of HK7/GS7. Whilst 82% of stands within SSSI units were in Favourable condition under priority habitat criteria, only 23% passed the CSM assessment for statutory sites. Favourable condition was related to low levels of available phosphate, but higher levels of nitrogen in the soil. There was also an association between the use of traditional cattle and sheep and better condition sites.

Of the core sample of 95 sites, 69% of sites that already supported stands of species-rich priority grassland in Favourable condition in 2012, maintained their Favourable status in 2020 but the rest declined in condition. Declines were greatest under the HK7 restoration option, with a significant reduction in mean number of species m^2 since 2012, and the numbers and frequency of positive indicator species also declined. G09 grassland indicator species were associated with low phosphate and potassium levels, and grazing by traditional livestock. A positive change in condition was also related to cutting for hay rather than haylage, and with later cutting dates. Sward enhanced HK7 meadows showed an increase in the number and summed frequency of positive indicator species since enhancement had taken place, but increases were within a restricted suite of species. Re-establishment of target MG3-associates did not occur. Stands within sites not in an agreement since exiting the ESA scheme not only declined in condition but over 50% of were no longer managed as meadows in 2020 but were managed as permanent sheep pastures.

Length of time since the start of agri-environment management had a significant effect on vegetation composition. Across all sites the numbers of species recorded across all quadrats per site, numbers of positive indicator species across all quadrats per site and mean numbers of species per quadrat all declined from 1987 to 2020. These declines were however different under the different management options studied, and did not follow a consistent trajectory through time. Number of species per quadrat within the whole sample increased from 1987 to 1995. Between 1995 and 2002 however, numbers began a significant decline which continued to 2020, although this differed between options. This was most marked in fields which were not in an agri-environment scheme, but was very small in those fields which had received sward enhancement. The number of positive indicator species declined in fields not managed under an agri-environment scheme, but remained relatively stable where fields were under scheme management, increasing slightly but not significantly between 2002/2012 and 2020 where swards were enhanced.

Upland hay meadows were already suffering biodiversity loss at the time of entry into the ESA scheme in the 1980s due to agricultural intensification since the 1940s. Although ESA management resulted in early successes, some major changes happened in farming systems in the northern English uplands between 1995 and 2002, which further affected the ecology of hay-meadows. The potential impact of changes in grazing stock, cutting regimes, temperature, rainfall and the possible impact of atmospheric deposition of nitrogen are discussed in relation to changes in the composition and condition of upland hay meadows. Scheme management may have had a positive impact in slowing but not halting deterioration.

1 Introduction

1.1 Context

This project forms part of the 'Framework for the delivery of Environmental Stewardship monitoring and evaluation' contract number FRW22707. It lies within the scope of Framework Contract Lot 7 and will contribute to a programme of thematic projects 4 describing specific elements of scheme delivery. Outputs of this project will contribute to regular reports supporting the Rural Development Programme monitoring framework and describing the overall outcomes of the programme

1.2 Background

Upland Hay Meadow is a Priority Habitat for action under Biodiversity 2020, recognised under Section 41 of the Natural Environment and Rural Communities Act (NERC) 2006 (UK Government, 2006), and is afforded protection under Annex 1 of the Habitats Regulations as analogous with habitat 38.3, mountain hay meadows. The habitat is defined by the National Vegetation Classification (NVC) (Rodwell, 1992) as Community MG3 (*Anthoxanthum odoratum–Geranium sylvaticum* grassland) and has its main UK distribution in the valleys of Northern England, where traditional hay meadow management has been practiced at elevations of 200–400 m.a.s.l. Some meadows include communities that represent an upland variant of NVC Community MG8 (*Cynosurus cristatus–Caltha palustris* grassland), whilst meadows that have been subject to a degree of improvement may be closer to other grassland communities such as MG5 (*Cynosurus cristatus – Centaurea nigra* grassland), MG6 (*Lolium perenne–Cynosurus cristatus* grassland) and MG7 perennial leys. Many of the best Upland Hay Meadow sites have been designated as Sites of Special Scientific Interest (SSSI), and a selection fall within the North Pennine Dales Meadows Special Area of Conservation (SAC).

With such a restricted range and being vulnerable to agricultural improvement and potentially to climate change, the extent of Upland Hay Meadow habitat is small, and based on Habitat Action Plan reporting, may have continued to decline. This suggestion is also supported by previous agri-environment scheme monitoring (Critchley *et al*, 2007; Hamilton *et al.*, 2014) and a study of *Geranium sylvaticum* (Pacha & Petit, 2008).

Agri-environment schemes are the major vehicle for delivering management to conserve and restore Upland Hay Meadows; this was initially through the introduction of the Pennine Dales Environmentally Sensitive Area (ESA) in 1987, one of five ESAs launched in this year, with the Countryside Stewardship Scheme (CSS) addressing land outside the ESA from 1991; these schemes were then replaced by Higher Level Stewardship (HLS) from 2006 and most recently, with the closure of HLS to new agreements, some meadows have now been entered into the latest Countryside Stewardship Scheme. As a result, many meadows have now been managed continuously under agri-environment schemes for *c.* 30 years. Throughout this period, the schemes have aimed to deliver management that maintains the quality of the highest value meadows and facilitates the restoration of degraded meadows to Favourable condition, thereby increasing the extent of the habitat. To support the delivery of agri-environment schemes, Defra has also funded research into management and restoration techniques, including approaches to enhance botanical diversity in species-rich grasslands.

The schemes provide annual payments to support sustainable management and access to capital grants and guidance for enhancement work. In the three northern regions, 640 HLS agreements have included capital payments for native seed introduction over the course of the scheme, totalling £1.4m.

Defra and Natural England have monitored upland hay meadows since the introduction of agri-environment schemes in various ways.

- Permanent quadrats were established in the early days of the ESA scheme in a sample of meadows, providing a framework for monitoring the effectiveness of the ESA scheme. Many of these meadows have now been monitored several times since 1987, with the most recent survey undertaken in 2012 (Hamilton *et al.*, 2014), during which survey some new sites were added to the sample to reflect uptake of HLS.
- To support the development of an inventory of high-value sites, 'Phase 2' grassland monitoring surveys were undertaken of some meadows in the 1990s and 2000s by NCC/English Nature, this again involved recording of vegetation species and cover in representative quadrats.
- A Common Standards Monitoring (CSM) rapid condition assessment methodology was applied to a sample of non-statutory upland hay meadow sites in 2002 and repeated in 2017/18 (Wheeler & Wilson, in prep).
- Some upland hay meadow sites, mostly designated as SSSI, have been monitored through Natural England's 'Integrated Site Assessment' programme.

In addition, various local scale or more targeted monitoring activities for specific projects have been undertaken on upland hay meadows, for instance by AONBs and National Parks. Some of this is related to work by partner organisations such as the North Pennines AONB Partnership and Yorkshire Dales Millennium Trust to identify donor and receptor sites for targeted meadow enhancement work. These bodies were successful in obtaining additional external funding to provide greater support to agri-environment scheme agreement holders and co-ordination of restoration work on a significant scale, including project co-ordination staff, donor site identification and specialist machinery. Among the relevant projects delivered:

- The North Pennines Hay Time Project ran from 2006 to 2012, carrying out work on 93 fields (North Pennines AONB, 2013; Starr-Keddle, 2018);
- The Yorkshire Dales Hay Time project added seed to 141 fields between 2006 and 2011 (Gamble *et al*, 2012);
- A similar project in Bowland AONB dealt with 65 fields between 2012 and 2018; the original project reported by Robinson & Gamble, 2014.
- A further project by the Cumbria Wildlife Trust carried out restoration work on 114 meadows, partially reported in Cornish & Hooley (2012).

The existence of data from these various agri-environment monitoring programme and restoration project surveys ensures a robust quantitative dataset is available for comparison with contemporary data. In the context of Biodiversity 2020 targets and ongoing objectives described in the Government's 25 Year Environment Plan (Defra, 2018), it is important that these historic datasets are exploited to provide a more comprehensive and updated understanding of the condition of Upland Hay Meadows and the role of agri-environment schemes and in particular, more recently, Higher Level Stewardship in their conservation.

1.3 Botanical monitoring of grassland in the Pennine Dales ESA

The ESA monitoring programme was developed and implemented by ADAS in consultation with the then Ministry of Agriculture, Fisheries and Food (MAFF) and the national conservation agencies including English Nature, and funded by MAFF. Monitoring activities included breeding waders, landscape, historic environment and botanical quality. The methods and results for the botanical monitoring of the Pennine Dales ESA grasslands for the period from 1987–1995 are reported in full in ADAS (1996) with the 2002 partial resurvey reported in Critchley *et al.* (2004). The sample included meadows and pastures, and comprised a range of unimproved grasslands, good and poor semi-improved grasslands and agriculturally improved grasslands.

In short, a broad-level study, the 'Indicative study', was set-up to monitor change at the field level through recording DAFOR scores in non-fixed 1m x 1m quadrats; whilst the 'Validation study' recorded more detailed botanical data with Domin scores for fixed 1m x 1m quadrats. Both surveys commenced in 1987 although additional fields were added to the Indicative study (the 'Extension') in 1992. Repeat surveys took place in 1990 and 1995 with partial resurveys in 1988, 1989 and 1992. The total number of fields in the Indicative study (1987 & 1992 extension combined) was 464, although these included pasture (including acid grassland and moorland) in addition to traditionally managed meadows: some fields were surveyed only once whilst others had up to five repeat surveys. The Validation study included 98 fields. Not all fields (64) were under ESA agreement at the start of the monitoring programme although by 1995 most had entered an ESA agreement: conversely a number of agreement sites had been taken out of agreement.

In 2002 a partial resurvey was carried out of the meadow sites only and, using the data set from 1987–2002, focussed on identifying whether good quality meadows had been maintained and poorer semi-improved and improved stands had made gains towards achieving better condition since management under the ESA scheme began (Critchley *et al.*, 2004). This study also gathered information on management practices, and related these and soil chemistry variables to the condition and performance of the sample. Disappointingly the analyses showed an overall decline in herb richness in the unimproved hay meadow sample and little overall change in the semi-improved hay meadow stands. An increase overall in species richness in improved meadows – the majority of the sample – did not result in the re-establishment of an MG3-related community type. Relationships between hay meadow vegetation and management practices were clear, particularly cutting date, spring grazing and duration, grazing animal used, and level of inorganic fertiliser. Low levels of extractable P and K correlated with the best condition meadows. The findings from this 2002 resurvey helped inform the design of later agri-environment research projects funded by Defra such as that on the effects of spring grazing described in Smith *et al.* (2012) and on long-term fertiliser inputs described in Kirkham *et al*. (2012).

1.4 Project Objectives

The objective of this project was to provide an updated assessment of the impact of agri-environment schemes, including specific enhancement measures, on upland hay meadows by resurveying the condition of a core sample of sites for which there are existing data from 2012, and earlier for many sites. The assessment involved field survey and analysis of vegetation and soil data, including comparison with data collected previously. Where possible, basic site management information was collected and used in analysis. An additional objective of the project was to look at a sample of meadows which have had enhancement interventions within a specified time period and identified via the various project lead organisations. It was accepted that in doing this there would probably be some overlap with the existing 2012 agri-environment sample, but there would also be some variation in baseline methods between samples and within the sample of enhanced meadows derived from different geographical project areas.

The project aimed to:

1. Provide an assessment of the current condition of a sample of Upland Hay Meadow sites that are in HLS or CS management at the time of survey, including those subject to sward enhancement interventions.
2. Use data from the core sample gathered in 2012 and 2020 to explore any changes in the condition of Upland Hay Meadows that have been managed under HLS, making a comparison between meadows managed under maintenance and restoration management regimes.
3. Compare 2020 survey data from the meadows targeted for enhancement with baseline data collected by partner organisations prior to intervention.
4. Explore aspects of change in botanical quality including frequency of positive indicator species, goodness of fit to target communities, and indices of species diversity and environmental influence, e.g. Ellenberg (Ellenberg, 1988) and Suited Species Scores (Critchley *et al.*, 2002).
5. For those sites where data were available, assess the longer-term change in condition of the meadow in response to management in agri-environment schemes for 30 years, including where possible pre and post any enhancement intervention.
6. Evaluate management, soil and other relevant information and explore the reasons for any change in vegetation condition observed. The effectiveness of different restoration techniques and contributing factors, including subsequent management will be explored in the enhancement sample.
7. Make recommendations for delivering grassland restoration in future land management schemes.

2 Methods

2.1 Impact of the SARS-CoV-2 pandemic on project methods

The outbreak of the SARS-CoV-2 coronavirus causing the COVID-19 pandemic in the early part of 2020 affected the way in which this project was planned and executed. Although sample identification and contact with partner organisations took place in winter 2019/2020 during the first phase of the project, the deskwork associated with the planning and delivery of the field survey occurred whilst England was in a national lockdown. After lockdown was relaxed there were still restrictions on the movement of people within England – particularly with regard to staying away from home. Natural England also had a ban on farm visits for a period during and after lockdown to protect farmers and landowners, and their own staff and contractors. This ban was eventually relaxed and movement of workers allowed but the scope of the project, particularly the field survey, was necessarily revised so that it could follow all appropriate government guidance on working outdoors and working safely during the pandemic, following guidance published and regularly updated by the Chartered Institute of Ecology and Environmental Management (CIEEM) (https://cieem.net/i-am/covid-19/. The greatest impact resulted from a delay to the start of the field survey, reducing the time available for survey, and therefore the number of sites that could be surveyed and increasing the number of surveyors required for this shorter survey window. Restrictions on staying away from home resulted in longer commutes for the survey team, necessitated remote (telephone) training sessions and lone working with no face-to-face land owner contact was adopted.

2.2 Site selection

2.2.1 The core sample

In 2012 Penny Anderson Associates Ltd (PAA) were commissioned by Natural England to undertake a survey of the long-term effectiveness of Environmental Stewardship in conserving upland hay meadows in the Pennine Dales (Hamilton *et al.,* 2014). Sites were selected by Natural England to provide a sample of *c.* 100 hay meadows in the North Pennines that were under Higher Level Stewardship (HLS) stratified by options HK6 *Maintenance of species-rich semi-natural grassland* or HK7 *Restoration of species-rich semi-natural grassland*, to enable separate assessments of the impacts of each management option on the condition and performance of upland hay meadows. Of the 105 sites selected by Natural England, PAA surveyed all but two. The 103 remaining sites formed the 'core sample' for the 2020 resurvey. The aim was to resurvey each site to determine its current condition and explore differences between the HK6 and the HK7 sample; and to further identify any changes in each sample group since the 2012 survey. The 103 sites included 74 meadows that had been surveyed previously under the former ESA environmental monitoring programmes from 1987 onwards (although the year of baseline survey varied from 1987–1992) (ADAS, 1996; Critchley *et al.,* 2004) and 29 additional meadows that were managed under HLS options but had not been part of the former ESA monitoring (Table 1).

Table 1. Numbers of sites in the core sample in 2012 sub-divided by HLS management option and showing numbers of sites that were part of the former ESA monitoring scheme.

HLS management option	ESA monitoring site	'New' monitoring site in 2012	Total	Percentage of total sample
HK6	22	9	31	30.1%
HK7	52	20	72	69.9%
Totals	74	29	103	

2.2.2 The sward enhancement sample

To determine the impact of sward enhancement in addition to the standard management prescriptions under HLS, partner organisations who had carried out this work were contacted by Natural England prior to the commencement of the contract. These organisations, covering four different geographical regions, were: North Pennines AONB Partnership [1], Yorkshire Dales Millennium Trust [2], Forest of Bowland AONB Unit [3] and Cumbria Wildlife Trust [4] . On commencement of this project, key staff from each of these partner organisations generously supplied a long-list of potential upland hay meadow sites that had received sward enhancement such as green hay, harvested seed, plug plants or commercial seed under one of their own meadow restoration projects. The combined long-list of all potential sites numbered several hundred, beyond the scope of this project, so the following selection criteria were applied:

1. At least 5 years must have elapsed since the sward enhancement work was carried out, with a cut-off year of 2015.
2. Sites must be > 200m above sea level (unless borderline and known to support UHM species) to qualify as upland.
3. A maximum of 2 meadows per farm and to include different enhancement methods in each meadow where possible.
4. Baseline survey data held by project partners should be available digitally due to the difficulty accessing paper files during Covid-19 'work from home' rules for many project staff.
5. Data must be of sufficient quality (an assessment was made by the authors to confirm that frequency data was available in addition to presence within stand).
6. The methods of botanical collection in the baseline must allow meaningful comparison with the methods and data collected in the 2020 survey .
7. Enhancement sites must have been in HLS option HK7 when enhanced.

[1] North Pennines Hay Time and Nectarworks Projects, 2006 onwards.
[2] Yorkshire Dales Hay Time Project 2006 onwards.
[3] Forest of Bowland Hay Time Project 2012 onwards
[4] Cumbria Hay Meadows Project: various funded projects including Wealth of Wildlife Project 2006; Hay-day Project 2009; Cumbria Hay Meadows Restoration Project 2012; Meadow Life Project 2014-15

8. Where applicable – sites favoured/suggested by project leads as suitable and requiring an updated survey.

Prior to the coronavirus pandemic the aim was a final sample of 100 enhancement sites. During the enhancement site selection process it was found that there was some overlap between the core sample and partner organisation sward enhancement project sites: 16 sites within the HK7 core sample had also received sward enhancement and therefore contributed the first 16 sites to the enhancement sample. Due to the reduction in the survey window and reduced scope of the field survey a further 34 sites only were selected from the long-list resulting in an enhancement sample of 50 meadows (Table 2).

Table 2. Numbers of sites in the enhancement sample from each partner organisation project showing the number that were also part of the core sample in 2020.

Partner Organisation	Non-core sample sites	Core sample sites	Total
North Pennine AONB Partnership	13	10	23
Yorkshire Dales Millennium Trust	4	5	9
Forest of Bowland AONB Unit	4	0	4
Cumbria Wildlife Trust	13	1	14
Totals	34	16	50

2.2.3 The non-agreement control sample

To provide a control group of sites against which to compare the condition and performance over time of the sites within agri-environment management, 20 extra sites were selected. These were sites that were recorded in the original ESA monitoring sample but had not had a history of recent management under HLS or CS. These were chosen in liaison with Natural England from a potential long-list of sites. The selection criteria were simply that:

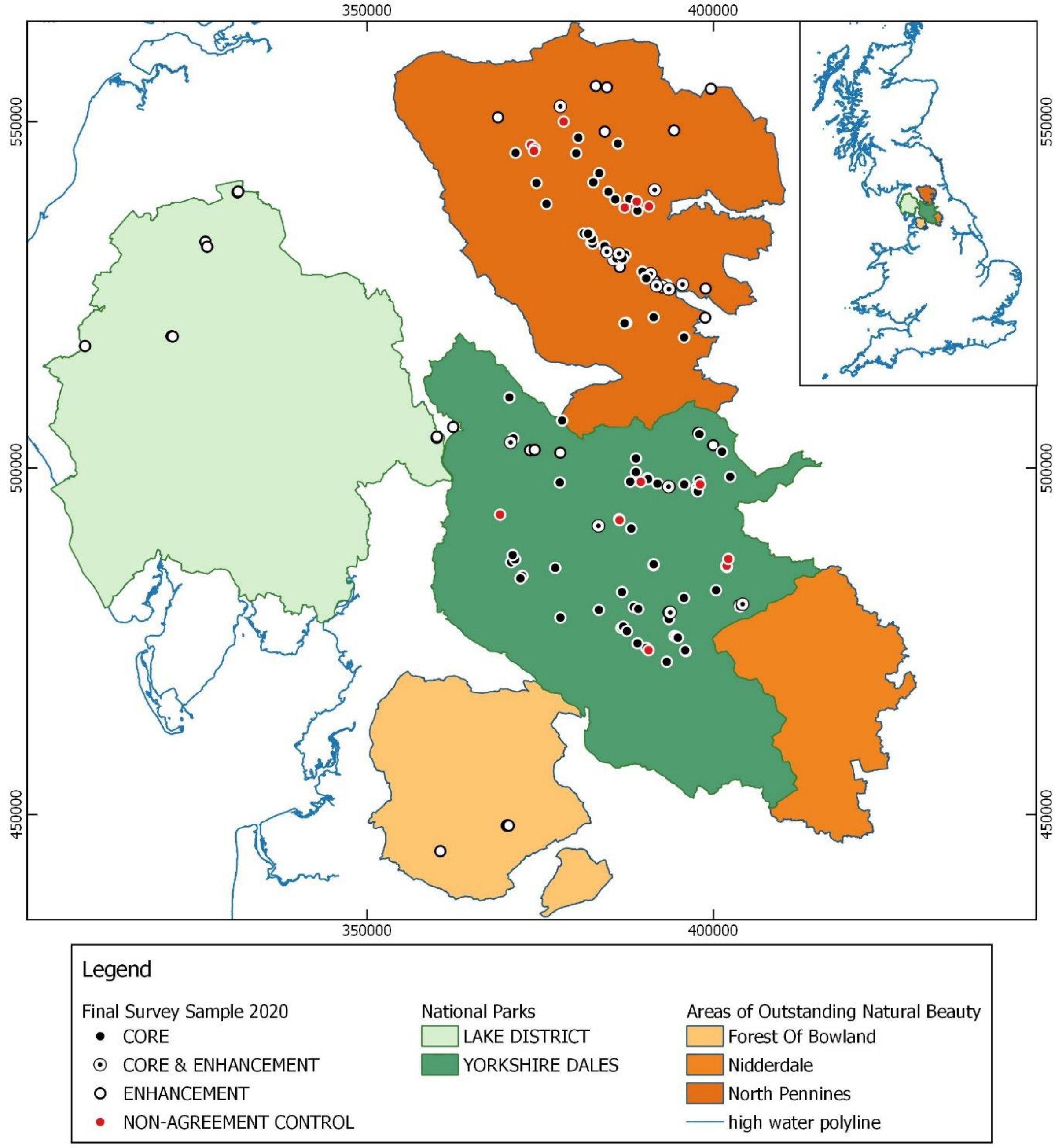
- The site must have been subject to a baseline monitoring survey under the previous ESA scheme (which included non-agreement sites).
- The site must not have entered HLS when the ESA scheme ended.
- Natural England could identify the owner (owners of non-agreement sites are harder to identify).

Originally the criteria included 'all sites must have entered the ESA scheme'. However, there were insufficient sites that met all criteria when this was included. The baseline vegetation community was not part of the selection criteria as this study focused on relative change in condition of the vegetation over time in relation to management rather than maintenance of good quality stands only. Although 20 sites were selected, ownership details proved to be incorrect for two sites and these eventually had to be excluded as access permission could not be gained. The final sample of 18 counterfactual sites were located across the North Pennine AONB and Yorkshire Dales National Park: 15 were formerly in ESA management whilst 3 were not (but had baseline surveys from 1987).

2.2.4 Geographic spread of the final sample

Figure 1 shows the geographic spread of the sites in the final sample.

Figure 1. The geographic spread of the final sample for the 2020 field survey: the core sample, the core + enhancement sample, the enhancement sample and the non-agreement control.



Scale: 1:750,000 @ A4

Map produced by Belinda Wheeler on behalf of Natural England. © Crown copyright and database rights (2020). Ordnance Survey 100022021.

2.3 Field survey methods

2.3.1 Survey preparation

Prior to survey Natural England staff had identified and contacted (by letter or email) all agreement holders, or landowners for non-agreement sites, to inform them of the project and request access permission for one of the survey team. A follow-up telephone call was made by the surveyor just prior to survey. Given the additional risks posed to the survey team and agreement holders from the Covid-19 pandemic, the survey was conducted with no on-site or other face-to-face contact.

For each field site[5] the surveyors were provided with a site dossier comprising digital copies of the following.

- 1:10,000 map of the site to enable location
- 1:2,500 base map with survey stand delineated within the site (the mown area) and location of the 2012 quadrats shown (scale generally 1:2500 but variable depending on the size of the stand)
- A copy of the most recent aerial photograph available showing the boundary of the survey stand (usually 1:2500)
- A list of 10-figure grid references of the 2012 quadrats
- An individual site description (‘pen portrait’) from the previous 2012 survey
- An aerial photograph from the 2012 survey with the route of the 2012 baseline survey condition assessment walk shown
- A copy of the completed 2012 management questionnaire
- A single digital image of each field site labelled with the origin location
- The original ESA survey map where applicable
- Part 3 of the HLS agreement with the Indicators of Success and Management prescriptions for HK6, HK7 and/or HK18 as applicable

A surveyor pack was distributed including digital copies of the following.

1. The Penny Anderson Associates 2012 project report (Hamilton *et al.*, 2014) of the core sample survey *ES in conserving UHM in Pennine Dales ESA NECR138_edition_1*
2. Quadrat recording form
3. Rapid Condition Assessment forms suitable for non-SSSI sites

---

[5] The term ‘site’ in this report generally refers to the enclosed parcel of land (field) selected for survey in this and preceding surveys, and carries a unique identification number (RLR field number). Sites support areas that are cut annually and managed as traditional hay meadow, plus areas, such as steep banks or ditches, that are not cut. This survey and all previous surveys recorded data from the hay-cut area of each site only – the survey stand or the sample stand. There is only one survey stand per site and these two words are sometimes used interchangeably.

   i. RCA fieldform MG3
   ii. RCA fieldform MG8-related (north)_MG3-related
4. Condition assessment form suitable for those sites that are within SSSIs
   i. SSSI condition assessment form MG3
   ii. SSSI condition assessment form M26, MG8-related (north), MG3-related
5. Site overview form for recording the character of the site and field observations to update the pen portrait
6. Management questionnaire form

A copy of the recording forms is provided in Appendix 1.

2.3.2 Management questionnaire

The management questionnaire (Appendix 1) was completed with the land-owner/manager by telephone. The questionnaire asked for details of crop type and cutting time, grazing times and stock, shutting-up date, fertiliser, lime and farmyard manure application, weed control and, where applicable, restoration methods.

2.3.3 Survey timing

The optimum time to survey upland hay meadows is during the period in which they are 'shut-up' (whilst stock are excluded to allow the hay crop to grow), with a survey time delay of around 2 weeks after shutting-up to allow the sward to recover from any spring grazing. Under HLS and Countryside Stewardship, meadows are usually shut-up around mid-May; consequently 1st June onwards is usually suitable for commencement of the survey. Survey becomes impossible when the hay is cut, which in non-agreement meadows can be early July but for agreement meadows is usually after 15th July depending on the management prescriptions in the relevant HLS agreement and on the weather. Derogations can be obtained to allow early cutting in very dry years. Due to the outbreak of the SARS-CoV-2 (COVID-19) virus the start of this project was delayed until mid-June when a survey programme could be developed that followed all appropriate government and CIEEM guidance on working safely and a COVID-19 specific risk assessment was developed and followed by all surveyors.

A team of ten surveyors carried out the field surveys during the period from 15 June to 22 July 2020, working alone due to Covid-19 restrictions. The final number of individual fields surveyed was 147: 95 of the 103 core sample, 34 additional enhancement sample and 18 non-agreement control sample. Access permission could not be obtained for 8 of the original core sample and 2 of the non-agreement sites selected. Surveyors were able to survey one or two sites per day depending upon size, complexity, species-richness and travel time involved (due to COVID-19 restrictions for much of the survey period, overnight stays away from home were not permitted and long commutes were sometimes involved).

2.3.4 Field survey tasks

At each survey site the following tasks were carried out:

1. Site photograph (digital image)
2. Botanical data collection – Quadrats
    i. Approximate relocation and recording of 3 existing quadrats for core sites only
    ii. Selection and recording of 2 additional quadrats (or 5 new for enhancement only and control sites)
3. Botanical data collection - Rapid Condition Assessment (RCA) by structured walk
4. Soil sample collection using standard methodology
5. Map boundary of mown UHM habitat using most recent aerial photograph (supplied) to assist in identifying boundaries of uncut banks etc.
6. Update/write pen portrait

2.3.5 Digital image of site

At all core sites a digital image was taken in 2012 with the origin and direction of image given in the file name. The location of these was often marked on the 2012 aerial photograph too (Figure 2). This was repeated at all core sites, with the image taken from the same approximate origin location and in the same direction. At enhancement and non-agreement control sites, where there was no previous image, surveyors selected an appropriate location from which to take an image of the site (along the site boundary or in a field corner) and recorded the origin location and direction.

2.3.6 Botanical data collection – quadrats

Relocation/location of quadrats

Core sample

Five quadrats were recorded in the original ESA monitoring studies (both Indicative and Validation studies) from 1987–1995; quadrats in the Indicative study were positioned in a 'W' pattern at each site, whilst for the Validation study quadrats were positioned along a transect line (ADAS, 1996). The 2002 partial resurvey and the 2012 PAA survey recorded only three quadrats of the original five. The three quadrats were selected by Critchley *et al.* (2004) to represent the target vegetation types. Quadrats were moved if they were found to be located in disturbed areas. Whilst fixed plots (quadrats) can provide botanical data for the same geographic area of land repeatedly over time and therefore record change at the plot-level, any variation in the positioning of the quadrat negates this.

Figure 2. Digital image of a core sample site from 12 June 2012 (labelled with origin location; above) and 22 June 2020 (below)

611_taken from NW corner of field looking SE towards barn_0803.jpg

Whilst most of the quadrats in the 1987 and 1992 surveys were permanently marked with metal pegs, some of those in the 1987 survey were not, and were recorded and mapped using distances and bearings (a common ESA monitoring method before the introduction of hand-held GPS units). In 2002 Critchley *et al* (2004) had limited success re-finding fixed quadrats using metal detectors and relied more on distances and bearings: the final location selected for the quadrat was then recorded using a hand-held GPS to aid future relocation. In 2002 the maximum accuracy of these units was *c.* 5m.

The 2012 re-survey also had very little success re-finding the fixed plot markers and relied on the 2002 GPS co-ordinates where these matched with other survey data, such as previous survey maps, bearings and distances. Where there was a mismatch, quadrats were moved. Where sites had not been included in the partial re-survey of 2002, three quadrats were selected from the original five in the former ESA study for that site. For sites that were not part of the original ESA monitoring studies (in the 2012 study a set of additional sites were added to the sample), three quadrats were placed in homogeneous and representative stands of vegetation for the site (Hamilton *et al.*, 2014). Differential GPS coordinates were recorded for the SW and NE corner points of all quadrats, although the data supplied to relocate the quadrats in 2020 included only one coordinate. Hamilton *et al.* (2014) also commented that considerable time was wasted in the field searching for buried markers. No replacement markers were installed in 2012. Differential GPS, while accurate, is still subject to error, and deviation of as little as 1m can mean that different vegetation is sampled in subsequent surveys. Localised events on the location of fixed quadrats (e.g. siting of hay bales, damage from farm machinery/wild animals/grazing animals etc.) can render the vegetation in a 'fixed quadrat' of little value in the analyses.

In 2020 it was therefore decided to dispense with the attempt to re-find 'fixed' plots. Instead the surveyor navigated to the location of the previous 2012 quadrats with a hand-held GPS unit, in combination with the base map and former ESA map. Once in the vicinity of the original quadrat the surveyor selected a representative homogeneous stand of vegetation, preferably on the spot indicated by the GPS unit but otherwise within 2 or 3 m. Surveyors avoided selecting a particularly species-rich stand if it was atypical of that part of the field, and avoided selecting an area that showed recent damage (e.g. poaching, feed stations etc.) unless this was typical of the vegetation overall. The final coordinates (10-figure grid reference) were collected from the SW corner of the quadrat.

To ensure better representation of vegetation within the field, two further quadrats representative of the main community were selected by the surveyor, spatially separated from the first three and avoiding edge-effects, atypical stands or differing NVC communities unless a mosaic of two main communities was represented (e.g. MG3 and MG8 mosaics).

Enhancement sample

As the 34 additional sites of the enhancement sample were drawn from partner organization meadow sites there were no pre-existing fixed quadrats. In these meadows the surveyors were instructed to select and position five quadrats in suitable stands of homogeneous vegetation as in the core sample, suitably distanced from the other quadrats to cover the area of the field that was subject to hay-cutting.

Non-agreement control

All non-agreement control sites were part of one of the former ESA monitoring studies in which five quadrats had previously been recorded, in one or more survey. They had not, however, been part of the partial resurveys of 2002 and 2012 so no GPS coordinates were recorded for the quadrats. Each site had a sketch map of the quadrats with pacings and bearings. Surveyors used the original ESA survey maps to position the five quadrats in the general vicinity of the former quadrat location where appropriate, or to move the quadrat to a more appropriate position where stands were not representative of the main stand, too heterogeneous, disturbed or otherwise unsuitable.

Recording the quadrats

The five quadrats were positioned and botanical data collected using the same method as the PAA survey in 2012 (Hamilton *et al.*, 2014) to enable comparison with the botanical data collected in that study. Quadrats measured 2 × 2 m with a 1 × 1 m quadrat nested within them, and located in the SW corner. Quadrats were aligned north along the y-axis (Figure 3).

The following botanical data were collected for each quadrat:

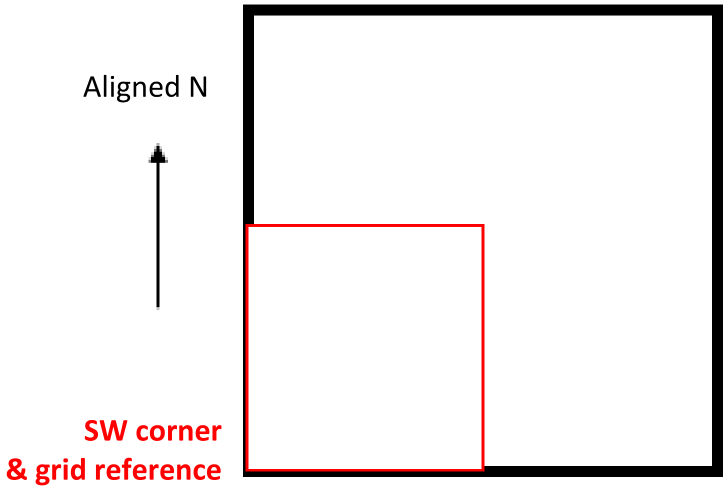
1 × 1 m quadrat

- % cover all vascular plant species
    - P – present; 0.5%, 1–10% in increments of 1; then 15%, 20%, 25% etc. in increments of 5%.
- Domin all vascular plant species

2 × 2 m quadrat

- DAFOR all vascular plant species (add additional species to 1 × 1 m quadrat)
- Vegetation height (cm) using direct measurement method below – 3 heights/quadrat
- % cover of: Bare ground, Litter, Bryophytes, Grasses, Forbs, Sedges, Rushes

Figure 3. The arrangement of the quadrat at all field sites.



Vegetation height

The 'direct measurement method' involves placing a card or hand lightly on the vegetation at the level below which about 80% of the vegetation is estimated by eye to be growing (thus ignoring occasional tall stalks), then reading this height on a ruler. This was found to be the most consistent and accurate method in a study comparing sward sticks, drop discs and direct measurement (Stewart *et al.*, 2006).

2.3.7 Botanical data collection – condition assessment

In 2012 a rapid condition assessment (RCA) was carried out using standardised forms for MG3 and for MG8-related (north)(Appendix 1) for non-SSSI sites. To enable comparison with this condition assessment and determine changes in condition over time, the same method was repeated in 2020. For sites that were within SSSI units the field forms published in Robertson & Jefferson (2000) were used to ensure that any additional data required to determine Favourable SSSI condition status was collected: this data could also be used to assess condition against BEHTA G09 criteria and thresholds.

The condition assessment was based on a structured walk intended to give a comprehensive coverage of the mown area of the UHM stand. For the core sample sites the route taken in 2020 (generally a W-shaped walk) followed that of 2012, using copies of the 2012 field maps, with 20 approximately evenly-spaced stops made to record botanical variables. For the enhancement and the non-agreement control sample a new W-shaped walk was carried out recording data at 20 stops as above. Uncut banks were excluded from the condition assessment.

At each point the surveyor recorded the presence of the species listed in the relevant RCA form (Appendix 1; both positive indicators and negative indicators) in an area of 1m radius around the surveyor. The surveyor made an on-site assessment of the NVC community and therefore the most appropriate RCA form to use for the sample stand but also recorded the presence of any additional species listed in the BEHTA tables (Natural England, 2016) for any priority habitat grassland type in order to avoid the loss of information where there was any ambiguity in the identification of the priority grassland or where mosaics between types were present (Appendix 2).

Additional data at the whole stand level was collected on the RCA forms. Data relating to vegetation composition and structure attributes were recorded, including percentage cover of trees and/or scrub, litter, bare ground and percentage cover of target taxa indicative of management or condition variables, required by the grassland BAP habitat-specific BEHTA condition assessment (condition criteria 1 to 6 for G09 in the BEHTA manual).

2.3.8 Soil sample

A soil sample was collected from each stand in every site of each sample group using standard methods (TIN035, Tytherleigh, 2008). A standard pot auger with a corer depth of 7.5 cm was used to take samples at each structured walk point to a minimum total of 20, which in most soils gave a bulked sample of approximately 0.5kg.

Soil samples were analysed by Natural Resource Management Ltd, Bracknell. The analysis package included the following variables: soil pH, available phosphate (Olsen's method mg/l) and total Phosphorus (mg/l), potassium (K; mg/l), magnesium (Mg; mg/l), nitrogen (Total N %), and two measures of organic matter content (loss on Ignition and organic carbon).

2.3.9 Site overview for Pen Portrait

In 2012 a field description of each site in the core sample was recorded during the survey and used, in addition to the results of the quadrat, RCA and soil survey to produce a 'pen portrait' of each site. The field description included notes on the vegetation community within the sampled stand; particularly aspects that would otherwise be missed if the data from the quadrat survey and RCA walk were used alone, such as additional positive or negative indicators, and evidence of management. Notes were also made on features outside the sampled area such as species-rich uncut banks. In 2020 surveyors were asked to update this for the core sample, taking note of any broad changes apparent since the 2012 description. For the enhancement sample and the non-agreement control a new field description was recorded.

2.3.10 Map G09 boundary and vegetation boundaries

In 2012 the boundary of the hay-cut area – the mown G09 feature – was mapped onto a base map and later digitised. Surveyors were asked in 2020 to map boundaries of differing vegetation communities (e.g. MG3, MG8, MG6) to aid in interpreting the botanical data and to contribute to the site overview. It was not intended for digitisation or for determining loss or increase in the G09 feature as exact boundaries are subjective and only useful for analysis if carried out using dGPS in both 'before and 'after' scenarios.

2.4 Data analysis

2.4.1 Data entry, extraction and manipulation

All botanical and stand attribute data available from previous studies (i.e. the ESA botanical monitoring studies 1987–1995, ADAS, 1996; the 2002 partial re-survey, Critchley *et al.*, 2004; and the PAA 2012 study, Hamilton *et al.*, 2014) were extracted from the Environmental Monitoring Database (EMD) by BioEcoSS Ltd as Excel spreadsheets. All botanical and stand attribute data from the 2020 study were quality assessed to determine accuracy and completeness and entered manually from the paper field forms into Excel spreadsheets to match the format of the historical data.

Names of all species were updated across all years to reflect current taxonomy to ensure consistency and eliminate potential errors in analyses. Where two or more species were not separated in any one survey year, where there were inconsistencies in species recorded from one survey year to the next (e.g. *Cardamine* spp.) or where it was felt that identification to species level would have been difficult, taxa were amalgamated across the data set.

Species amalgams used:

Alchemilla vulgaris agg., *Cardamine* sp., *Dactylorhiza* sp., *Euphrasia officinalis* agg., *Juncus acutiflorus/articulatus, Phleum pratense* (*P. pratense + P. bertolonii*), *Poa pratensis* (*P. pratensis* + *Poa humilis*), *Schedonorus pratensis/Schedolium*, and *Taraxacum officinalis* agg.

Further data transformations were performed to provide a series of data tables with raw data, mean values for percentage cover by site, condition parameters and measures of species-richness values. The need to correct analyses for Type 1 errors resulting from multiple comparisons was considered. R offers several adjustment methods including the Bonferroni, Holm, Hochberg and Hommel methods. Use of these methods was not necessary as the number of pairwise comparisons within any independent analysis was small.

2.4.2 Condition assessment against priority grassland attributes and targets

Stand condition – whole sample

The condition of the mown UHM stand within each site was assessed using the data collected in the structured walk to determine its condition in relation to G09 Upland Hay Meadow priority grassland habitat. In the previous 2012 survey the Farm Environment Plan (FEP) method for grassland features coming into the Higher-Level Stewardship scheme was used to carry out the G09 condition assessment (FEP key 2a and b; Natural England, 2010). However, on the inception of the Countryside Stewardship Scheme this method was updated for features coming into Higher Tier (key 2a and 2b; Natural England, 2016). The two methods are nearly identical but in BEHTA there has been a reduction in the number of condition categories from three to two to provide consistency with SSSI assessment; Condition A, which broadly equates to Favourable condition and Condition B, which broadly equates to Unfavourable condition. Although most sites within this study are still under HLS management rather than CS Higher Tier, the updated condition categories as used in BEHTA were used in the 2020 re-survey to reflect current methods as outlined below.

For the 2020 condition assessment analysis, stands were firstly assessed against key 2a (Natural England, 2016) to determine whether the stand was species-rich grassland and likely to be a priority grassland in, or restorable to, Favourable condition. Three key attributes, cover of *Lolium perenne* and *Trifolium repens*; mean species-number; and cover of dicotyledonous species and *Carex spp* determine qualification as:

a. species-rich grassland (priority grassland habitat features G04–10),
b. semi-improved grassland of moderate richness (grassland feature G02 – semi-improved), or
c. species-poor improved grassland (G01).

Stands were then assessed against criteria for upland hay meadow (UHM) G09 priority grassland (key 2b, Natural England, 2016). This was to determine how many stands met priority grassland criteria in both survey years, the condition assessment category of those stands and the change over time from 2012 to 2020.

Stands that were species-rich were assessed to be either G09 in Favourable (G09-A) or Unfavourable condition (G09-B) or G02*, good quality semi-improved grassland that offers potential for restoration to G09 (Natural England, 2016). For those assessed as species-rich grassland, the condition assessment for each stand resulted in a condition category determined by the number of criteria failed (Table 3).

Table 3. Condition assessment category and feature criteria (based on Table 1 in BEHTA Manual, Natural England, 2016). Condition assessment criteria are in Section 2 of the BEHTA Manual and high-value indicator species in Key 2b, Table 2.

Condition assessment category	Grassland type	Assessment passed/failed & Number of missed/failed criteria
G09-A	Species-rich priority grassland habitat: Very good/Favourable condition	Passes assessment for species-rich grassland in key 2a and 2b. 0 fails. Passes assessment for species-rich grassland in key 2a and 2b and all G09 criteria.
G09-B	Species-rich priority grassland habitat: Degraded or Unfavourable condition (Restorable to G09-A)	Passes assessment for species-rich grassland in key 2a and 2b. Fails 1 or more G09 criterion but supports required †number of G09 wildflower indicators.
G02*	Semi-improved grassland: Good quality, moderately species-rich (Potentially restorable to priority grassland)	Passes assessment for species-rich grassland in key 2a and moderately species-rich grassland in key 2b. Fails to meet required number of G09 wildflower indicators but meets wildflower criteria for good semi-improved.
G02	Semi-improved grassland: Species-poor	Fails assessment for species-rich grassland in key 2a. Passes assessment for semi-improved grassland in key 2a.
G01	Improved grassland	Fails all of the above.

†Supports required number but not necessarily at the required frequency

Stands that were not species-rich grassland were assigned to G02 poor semi-improved or G01 improved grassland categories.

The difference in stand condition between sample groups was assessed in relation to:

- Scheme enrolment including HLS/CS option
- Sward enhancement

The 2012 data from the core sample sites that were part of the PAA 2012 study were also assessed using the methods above so that change in condition over time for 2012–2020 could be determined on a site by site basis, and on a stratified sample basis (HK6/GS6[6] sites versus HK7/GS7 sites). The difference between HK7 sites that had received sward enhancement measures and those that had not were also explored for the core sample.

Positive Indicator species analyses – core sample only

Records for positive indicator species were collected during the condition assessment structured walks at each stand in both the 2012 and the 2020 surveys. Surveyors were asked to record positive indicator species for all priority grassland types encountered during the survey (Appendix 2).

For the total condition assessment dataset, the following measures were calculated (for both the composite list for all priority habitat grasslands and for the list restricted to upland hay meadow indicators only):

1. mean number of positive indicator species recorded in 2020;
2. change in number of positive indicator species between the 2012 survey and the 2020 survey;
3. summed frequency of positive indicator species; and
4. changes in summed frequency between the 2012 survey and the 2020 survey were compared between categories of stands of differing agri-environment scheme options.

For each positive indicator species list, the same four measures as above were examined. Analyses were performed using general linear models (GLMs) in the statistical software R (R version 3.02.1, R Core Team 2020) and one-way Analysis of Variance (ANOVA) in MINITAB 17.

Associations between indicator species variables and soil factors were investigated using the regression option of MINITAB.

Results were considered to be significant at $P < 0.05$ and below. Post-hoc Tukey honest significant difference (HSD) tests were performed to determine between-level significances where there were more than two levels for an independent variable, and significance is indicated in the tables by superscript letters; where frequency means differ significantly they do not have a superscript letter in common.

---

[6] Throughout the report, Environmental Stewardship options HK6 and HK7 and Countryside Stewardship options GS6 and GS7 are treated as equivalent and often referred to simply as HK6 and HK7

2.4.3 Botanical data 2002, 2012 & 2020

Determination of NVC communities

Data were recorded in the three (2002 & 2012) or five (2020) quadrats at each site. The 2002 and 2012 survey approach differed from a standard NVC survey as only three quadrats were recorded instead of five, and these were not located in homogeneous stands but were in locations predetermined by previous surveys according to field shape and size. The MATCH routine (Malloch, 1989) was used in all three of these surveys to assist determination of the NVC community. MATCH is now included in the package of vegetation analysis routines MAVIS v1.03 available from the Centre for Ecology and Hydrology (Smart *et al.*, 2016). This is an interpretive tool to assist in the interpretation of vegetation data in conjunction with the published tables and descriptions in Rodwell (1991–2000). Whilst MATCH frequently confirms the surveyor's opinion, the stand type with the highest similarity coefficient is not always considered the correct diagnosis, and other factors can be taken into account by the analyst such as local variation in species composition, the source community where there has been change or where anomalous species may be influencing the data. The final diagnoses of NVC communities are therefore based on examination of the quadrat data with reference to the published vegetation tables (Rodwell, 1992) and with reference to results from MATCH analyses. In the surveys described here, many sites were characterised by extremely heterogeneous vegetation and intermediate NVC types and mosaics were commonly encountered.

Species richness

Several measures of species-richness were calculated from the quadrat data and the condition assessment walk. These are listed together with other measures of vegetation condition in Table 4. These are used as response (or dependent) variables in subsequent analyses. Explanatory (independent) variables related to management and soil chemistry are listed in Table 5.

The statistical software R (R version 3.02.1, R Core Team 2020) was used to investigate parameters of vegetation condition and species-richness in relation to the soil and management variables in Table 5. These analyses used three overlapping datasets: (1) data from the 2020 survey only, (2) data from the core sample , 2012 and 2020, and (3) data from the core sample enhancement sites (HK7 sites in 2002, 2012 and 2020). Further analyses of vegetation change through time used the quadrat data from whole dataset from 1987 to 2020. The linear model function with post-hoc Tukey HSD tests between means was used where response variables were normally distributed and explanatory variables were categorical. The general linear model function with the appropriate error family distribution was used where explanatory variables were continuous or where the model included both continuous and categorical variables. Further details of each analysis are included in the results section.

Table 4. Dependent variables used in analyses of measures of species richness and vegetation condition for 2002, 2012 and 2020: all variables are calculated as mean per site.

Variable (means per site)	Description	Data source
Total species number	Total number of species recorded within quadrats (occurring in at least one quadrat)	Quadrat data
Number of species per m^2	Mean number of species recorded per m^2	Quadrat data
Lolium perenne cover	% cover of *Lolium perenne* per m^2	Quadrat data
Ranunculus repens cover	% cover of *Ranunculus repens* per m^2	Quadrat data
Trifolium repens cover	% cover of *Trifolium repens* per m^2	Quadrat data
Juncus cover	% cover of *Juncus spp* per m^2	Quadrat data
Negative indicator species frequency	% cover of negative indicator spp (large *Rumex* spp, *Senecio spp, Anthriscus sylvestris, Urtica dioica*)	Condition assessment: sward composition
Forb cover	% cover of non-Graminae (broad-leaved species and *Carex spp*)	Condition assessment: sward composition
Positive indicator species – all PHs	Number of positive indicator species recorded from all any/all priority habitat grassland lists in the BEHTA manual	Condition assessment: structured walk frequency counts
Summed frequency of positive indicator species – all PHs	Sum of frequency records of all positive indicator species – species from all priority habitat grassland lists in the BEHTA manual	Condition assessment: structured walk frequency counts
Positive indicator species – UHM only	Number of positive indicator species recorded from the G09 upland hay-meadow priority habitat list in the BEHTA manual	Condition assessment: structured walk frequency counts
Summed frequency of positive indicator species – UHM only	Sum of frequency records of all positive indicator species from the G09 upland hay-meadow priority habitat list in the BEHTA manual	Condition assessment: structured walk frequency counts

Sward composition and environmental variables

The Canoco package (Canoco 5.1, ter Braak & Smilauer, 2018) was used in the analysis of sward composition and relationships between species composition and environmental variables (soil chemistry and management).

Canoco includes several analysis options, two of which, Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA), were used here. The first step in both of these options is the reduction of complex multi-species data, in this case vegetation species lists, to series of numbers in a multi-dimensional space conventionally visualised on several axes. In practice the first two of these axes contain the most useful information. This ordination can then be visually displayed as scatter plots of species and samples using the graphics utilities provided by Canoco. These also enable the colour and symbol coding of categories within the data to highlight groupings and trends within the data.

The second step in analysis followed by CCA is to use supplied environmental variables in an attempt to explain variation in the vegetation data by fitting a regression model. The significance of environmental variables can be determined by use of Monte-Carlo permutation tests, only the significant variables being retained in the final model. Significant environmental variables determined by CCA can be displayed on sample scatter diagrams of species and samples on ordination axes as a visual representation of the model. Categorical variables are displayed as points, while continuous variables are displayed as arrow vectors.

DCA was used initially to visualise the range of data from the 2020 survey and the correspondence of the survey data to the NVC communities identified in the MAVIS MATCH analysis. Subsequent CCA analyses investigated the associations between the 2020 data, soil chemistry and management factors. The soil and management variables included are listed in Table 5. Changes in vegetation characteristics through time were also investigated using CCA, taking 'year' and 'agri-environment scheme option' as environmental variables.

Table 5. Environmental variables used in CCA analyses and linear models.

Variable	Levels	Description
Crop type	Hy	Hay in most years weather permitting
	He	Haylage or silage
	P	Pasture
Closing date	0	No spring grazing
	1	Normally before 30 April
	2	1–9 May
	3	10–15 May
Cutting date	1	15–20 July
	2	Later, depending on weather
Livestock type	A	Traditional cattle (e.g. Galloway, shorthorn) only
	B	Traditional cattle and traditional sheep (e.g. Herdwick, Swaledale)
	C	Traditional cattle and modern sheep (e.g. Texel, mules)
	D	Modern cattle (e.g. Belgian blue, Holstein) only
	E	Modern cattle, any sheep
	F	Traditional sheep only
	G	Modern sheep only
Lime	0	None
	1	Within the previous 10 years
FYM	0	None
	1	Annual applications up to 10t/Ha
	2	Annual applications >10t/ha
NPK	0	None
	1	Any NPK in the previous 10 years
Soil chemistry		
pH		
Phosphate		Available phosphate, Olsen's method
Potassium		
Magnesium		
Total Nitrogen		
Tot phosphorus		
Loss on Ignition		
Total organic Carbon		

Ellenberg's Indicator Values and Suited Species Scores

Ellenberg's Indicator Values or indices and Suited Species Scores (SSS) assign numerical values to species according to their ecological attributes.

Ellenberg indices were originally developed in Germany (Ellenberg, 1988) and have been adapted for UK use (Hill, *et al.*, 1999). Values are assigned to species on 9-point scales for Light (L; ranging from deep shade to full sunlight), Moisture (F; from extreme dryness to completely submerged), Reaction (R; soil pH from extreme acidity to high pH), Nitrogen (N; soil fertility from extremely infertile to highly nutrient-rich), Salt (S; from completely intolerant of saline conditions to characteristic of hyper-saline conditions created by salt-water evaporation.

Suited Species Scores (Critchley *et al.*, 2002) allocate scores of 1, 0 or –1 to individual species according to preferences for acidic soil, calcareous soil, grazed conditions (closed versus open conditions), nutrient level, poaching of grassland and moisture level.

The factors included in these two systems are closely related: Ellenberg Light (L) is related to SSS Grazing Index, Ellenberg Moisture (F) is related to SSS Moisture, Ellenberg Reaction (R) is related to SSS Acidity and Calcareousness, and Ellenberg Nitrogen (N) is related to SSS Nutrient.

The following Ellenberg indicator values were selected for analysis: Light, Moisture, Reaction and Nitrogen. The following SSSs were selected: Grazing Index, Nutrient and Moisture. Total quadrat data from each stand surveyed was used for calculating the EIVs and SSSs in each survey year. For each vegetation stand a summary score was calculated for the whole stand for each Ellenberg value or SSS selected using all species recorded within at least one quadrat on the site to give a potential score for the stand for each variable of 0 to 9 on the Ellenberg Indicator Value system and –1 to 1 on the Suited Species Score system. This was calculated from the 1×1m data only as only 2020 and 2012 (and the validation survey) recorded the wider 2×2m quadrats: 1×1m data provided consistency over the 30 year period. Two values were calculated.

- Mean score where species list per site was used to generate a single value per species and mean score is sum of species scores/number of species (excluding species with no allocated Ellenberg or SSS scores).
- Mean score weighted by frequency across quadrats, where species list per quadrat is used and mean score is therefore sum of species score x number of quadrats in which it occurs/number of records

The first method was used in 2012 (Hamilton *et al.*, 2014) and provides a value for the site but does not reflect the relative contribution each species makes to the character of the site. For example, the score for moisture (F) would be the same whether *Caltha palustris* – a damp-loving species – was local only and occurred in one quadrat, or widespread and present in all five quadrats. In the second method the score is weighted by frequency of occurrence. This second method is therefore more sensitive to reducing the impact on scores of sward heterogeneity.

The EIV and SSS scores were then analysed using a general linear model in R, with post-hoc Tukey HSD tests between means.

An initial analysis was performed on the whole dataset with respect to HLS/CS option, sward enhancement status and agreement status to explore variation in the type of species present in the vegetation in relation to underlying environmental conditions such as wetness or nutrient status.

2.4.4 Botanical data 1987–2020

Longer-term changes in relation to time and management (including sward enhancement) were investigated for all sites where runs of data were available. For the majority of surveys from 1987–1995 vegetation was recorded on the DAFOR scale only. All quadrat data was therefore transformed to presence/absence data. Condition assessment data and management data was also not available for surveys from 1987–2002.

A reduced set of variables were explored for the 1987–2020 analysis of change, all calculated from the transformed data for presence within quadrat.

Two Canonical Correspondence Analyses were performed on this data. In the first, data from all years were included, while in the second, only data from 1987/88 and 2020 were used.

A series of Repeated Measures ANOVAs were performed on the vegetation data to determine the effects of time elapsed since the start of agri-environment programmes in 1987 to 2020. These looked at the effects of year and agri-environment option.

Response variables studied were:

- Ellenberg Indices (EI) Light, F (moisture), Reaction (pH) and Nitrogen
- Suited Species Scores (SSS) Grazing Index, Nutrient and Moisture.
- Mean number of species per site
- Mean number of species per m^2 quadrat at each site
- Mean number of positive indicator species (all Priority Habitats) at each site
- Number of positive indicator species (all Priority Habitats) in each m^2 quadrat

2.4.5 Enhancement sample – positive indicator species analyses

The success or otherwise of carrying out sward enhancement through the introduction of seed (via various methods) in addition to management prescriptions under HLS option HK7 was explored using data from the sites from within the core sample that had also been subject to sward enhancement and also the sites from partner organisation meadow restoration projects. Due to differences in the methods employed for baseline surveys of pre-restoration sites by project partners, a method for transforming all baseline survey data into a form that was directly comparable with the condition assessment data collected in 2020 was designed. As the primary aim of the enhancement activity is to restore meadows to Favourable G09 upland hay meadow, the change in positive indicator species occurrence and frequency prior to (various dates from 2006–2014) and after (2020) enhancement was assessed. All enhancement sites selected for the study had one or more of the following:

1. Frequency data for indicator species present within the stand in the year of, or shortly prior to, restoration – this was usually from a structured walk.
2. Frequency data from the PAA 2012 condition assessment survey (only used where enhancement took place during or after 2012).
3. (For 2 sites) Presence only of species within stand in baseline survey prior to enhancement, weighted by frequency data for the same species as recorded in the 5 quadrats of the 1995 ESA survey.

The project partner baseline data was favoured for this analysis but in some cases the PAA 2012 or a combination of methods (as in 3. above) proved the most accurate if the baseline data lacked frequency data.

In the North Pennine AONB Unit baseline data for their Hay Time project (Starr-Keddle, 2018), frequency of species recorded in the structured walk is provided on a 5-point scale where: 1 = a species is present in 1–4 stops (20%), 2 = presence in 5–8 stops (21–40%), 3 = presence in 9–12 stops (41–60%), 4 = presence in 13–16 stops (61–80%) and 5 = presence in 17–20 stops (81–100%). This is consistent with the use of 'Rare', 'Occasional', 'Frequent' etc. used to quantify frequency in CSM of SSSIs and in the BEHTA assessment of priority grassland habitats (Robertson & Jefferson, 2000; Natural England, 2016). Survey data from other partner organisation projects varied from % occurrence in stops to (in a few cases only) measures of frequency using DAFOR notation only.

The frequency of all PH positive indicator species for the pre- and post-enhancement data was transformed (where required) to a 5-point scale consistent with the 23 sites included in the NP AONB Unit data: this required the transformation of data from 14 sites enhanced by CWT projects, 9 sites enhanced by the YDMT projects and 4 sites enhanced by FoB AONB projects.

3 Results

3.1 The final survey sample

Of the finalized list of 157 sites (103 core, 34 enhancement, 20 non-agreement control), the survey team visited 147 sites (Table 6):

- 95 (of original 103) PAA core sites encompassing
  - 69 former ESA monitoring sites (Indicative, Validation and Extension studies)
  - 26 new 'additional' non-ESA monitoring sites (added by PAA in 2012)
- 18 non-agreement control sites from former ESA monitoring sites

- 34 additional [non-ESA monitoring] 'sward enhancement' HK7 sites from four different partner projects across Cumbria, North Pennine, Yorkshire Dales and Bowland

Of the 95 core sites, 16 had also received sward enhancement through partner projects (Hay time etc.)

Access permission was not gained for eight of the original 103 2012 survey sites, and site ownership could not be found for two of the 20 control sites.

Table 6. The final survey sample for 2020 showing the number of sites in each sample group and the number of sites within each group to be managed under HK6/GS6, HK7/GS7 with no sward enhancement, HK7/GS7 with sward enhancement, and not managed under any agreement.

Sample Group	HK6/GS6	HK7/GS7 No enhancement	HK7/GS7 Sward enhancement	None	Total	% of total sample
Core Sample	29	50	16	0	95	64.6%
Enhancement	0	0	34	0	34	23.1%
Non-agreement	0	0	0	18	18	12.2%
Total	29	50	50	18	147	
% of total sample	19.7%	34.0%	34.0%	12.2%		

3.2 The 2020 Survey

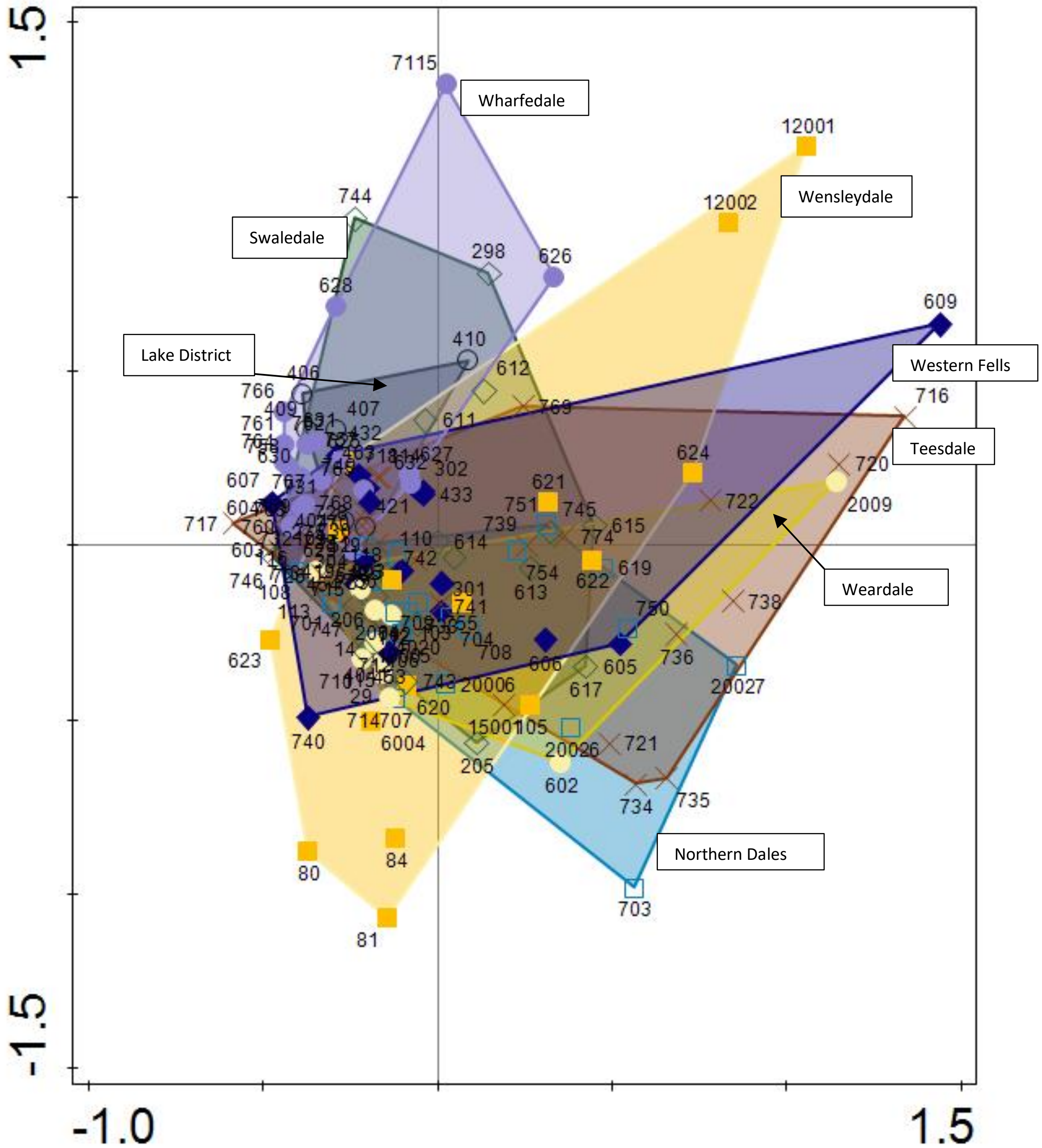
3.2.1 The relationship between vegetation composition and region within the survey area, and exploration of bias between surveyors

The surveyed stands were grouped into geographical regions: Lake District (Cumbria High Fells, Derwent, Uldale), Western Fells (Ribblesdale, Bowland, Lunedale, Howgill Fells, Kirkby Stephen, Tebay, Orton), Northern Dales (Alston, Allendale, Dentdale), Teesdale, Weardale, Wensleydale, Wharfedale and Swaledale. The significance of each region was examined as a categorical variable in a Canonical Correspondence Analysis (CCA). The distribution of sites in relation to region is displayed on a plot of Axis 1 vs Axis 2 of a Detrended Correspondence

Analysis (DCA)(Figure 4). The effects of Wharfedale, Teesdale and the Northern Dales were all significant at $P < 0.01$ and Wensleydale and Swaledale at $P < 0.05$. This suggests that there are geographical differences between the vegetation composition even within the limited area of this survey.

There were also significant effects due to five surveyors, however it is highly likely that these are due to surveyors being allocated sites on a regional basis and therefore mirroring the geographical differences already shown. For example, one surveyor surveyed sites all located in Wensleydale, while another surveyed sites entirely in Wharfedale.

Figure 4. Unconstrained DCA analysis of data for sites grouped by survey regions: key to polygon/symbol – Northern Dales (blue/open squares); Weardale (yellow/circles); Teesdale (brown/crosses); Western Fells (purple/diamonds); Wensleydale (orange/squares); Lake District (blue/open circles); Wharfedale (lilac/circles); Swaledale (green/open diamonds). Significant differences in CCA: Wharfedale, Teesdale, Northern Dales, *P* < 0.01, Wensleydale, Swaledale, P<0.05



3.2.2 Character of the Upland Hay Meadow Sample : National Vegetation Classification (NVC) communities

The determination of NVC community type (Rodwell, 1992) is not an entirely objective process, even with the use of software to provide best fit of sampled vegetation to published data. Vegetation communities are generally on a continuum within and between the published stand data and can occur in mosaics. No attempt is made here to analyse differences between the sampled data and the published accounts. The NVC context is however very useful as a descriptive tool to characterise sites.

NVC communities and sub-communities were determined using a combination of the MATCH routine included in the MAVIS v1.03 (Smart *et al*., 2016) package, and expert opinion, which allows local variation, anomalies and ambiguities to be dealt with more accurately. The majority of stands surveyed fell within the following NVC stand types, although several other vegetation types were also present within the surveyed fields.

- MG3 *Anthoxanthum odoratum–Geranium sylvaticum* grassland
    - MG3a *Bromus hordeaceus* sub-community
    - MG3b *Briza media* sub-community
- MG5 *Cynosurus cristatus–Centaurea* nigra grassland
    - MG5c *Danthonia decumbens* sub-community
- MG6 *Lolium perenne-Cynosurus cristatus* grassland
    - MG6a Typical sub-community
    - MG6b *Anthoxanthum odoratum* sub-community
    - MG6d *Filipendula ulmaria* sub-community (Wallace & Prosser, 2016)
- MG7 *Lolium perenne* leys
- MG8d *Cynosurus cristatus-Caltha palustris* grassland (Wallace & Prosser, 2016)

Results of MATCH analysis for the sampled stand within individual sites are presented in Appendix 3: included within the Table is an indication of the final (single) NVC community to which each stand was assigned. MATCH as included in MAVIS incorporates some additional NVC sub-communities described by Wallace & Prosser (2016).

A summary of the number of stands assigned to each of the above NVC communities is shown in Table 7. Of the 147 stands surveyed the majority (51.7%) had greatest affinities with MG6 grassland, with 23.1% supporting predominantly MG8 and 20.4% supporting MG3 communities, although many sites supported localised areas of another vegetation type or mosaics between these or other stands. Two stands had closer affinities with MG5c – a lowland meadow community – and there were five stands of improved MG7 perennial ley. Unmown banks within fields often supported more species-rich grassland than the main community of the mown area. These were not sampled.

Table 7. Principal NVC stand types in sites surveyed in 2020 (*n* = 147)

NVC Community	NVC Sub-community	Total	
MG3	MG3a	29	19.7%
	MG3b	1	0.7%
MG5	MG5c	2	1.4%
MG6	MG6a	3	2.0%
	MG6b	73	49.7%
MG7		5	3.4%
MG8		34	23.1%
Total Sites		147	

An unconstrained Detrended Correspondence Analysis (DCA: Canoco 5.1, ter Braak & Smilauer, 2018) of the 1m^2 quadrat data collected in the 2020 survey (mean percentage cover for each species) provides a graphic representation of the range of variation within the vegetation and the relationships between the NVC communities identified.

Stands of MG3 upland hay-meadow were clearly separated from other vegetation types on Axes 1 and 2 of the DCA ordination (Figure 5). There is a further separation within these drier grasslands, dividing the few recorded stands of MG5 from MG3.

MG8 stands were less well-defined, but still formed a distinct group. There was a greater range of species diversity and compositions in the MG8d sample. In practice, stands were classified by the MAVIS MATCH algorithm as MG8d on little more basis than the presence of *Caltha palustris*[7] and here included species-poor grasslands which might better be considered as MG6, as well as much richer vegetation. The ordination nevertheless clearly separates MG8d stands from MG3 stands. The residue of less species-rich grasslands corresponded mainly to MG6b, although the species-poor stands of MG7 appear as distinct outliers.

Clustering of the species present at constancy III or more in MG3 and MG8 in O'Reilly's analysis of upland hay meadow communities in the North Pennines (O'Reilly, 2011) is reflected in the distribution of vegetation stands of these communities in the DCA ordination (Figure 6).

[7] Nomenclature of vascular plants follows that of Stace (2019) except where stated.

Figure 5. Unconstrained DCA analysis of 2020 quadrat data, showing the main NVC community at each site: MG3, red triangles; MG5, orange stars; MG6, light blue circles; MG7, dark blue circles; and MG8, green squares.

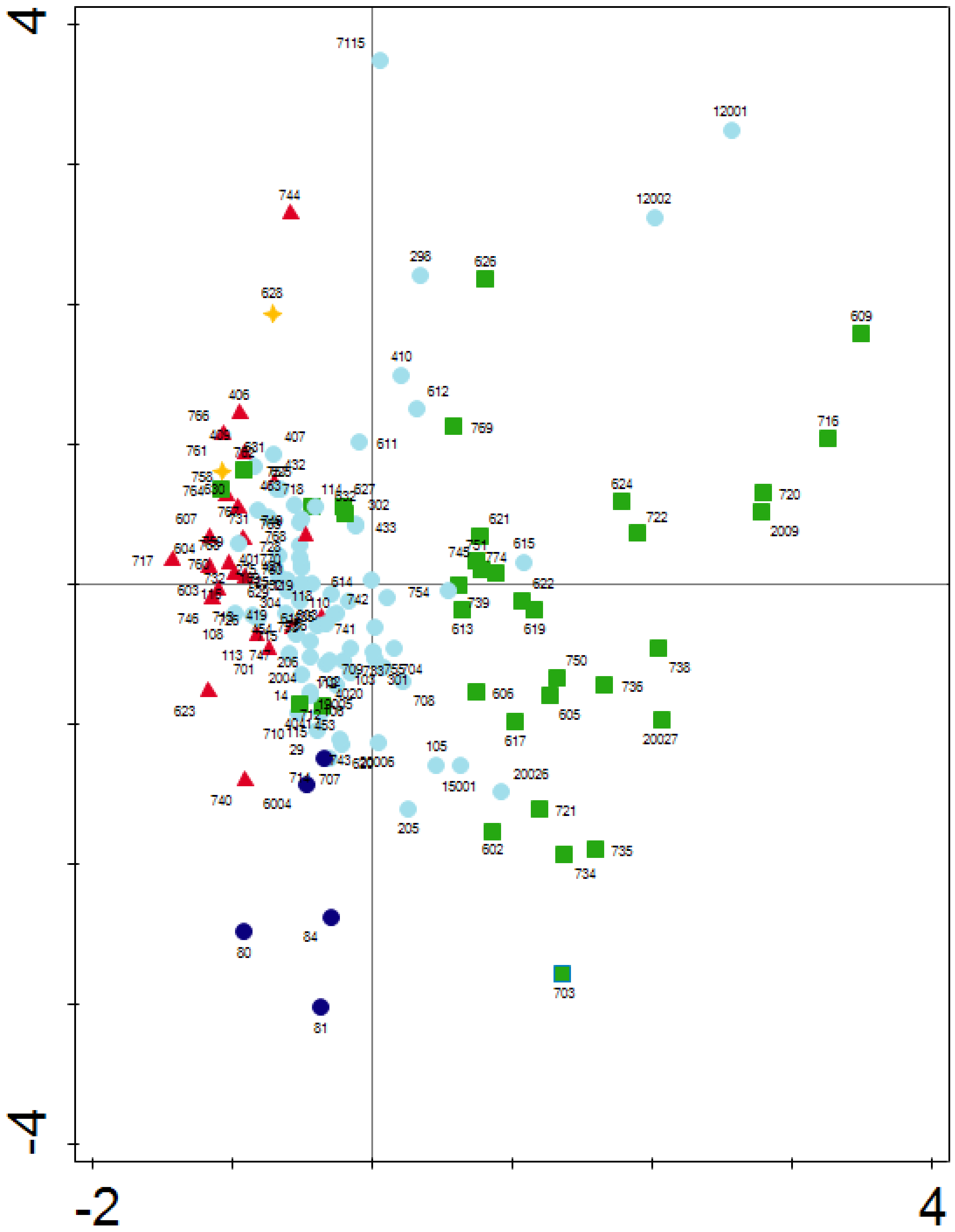
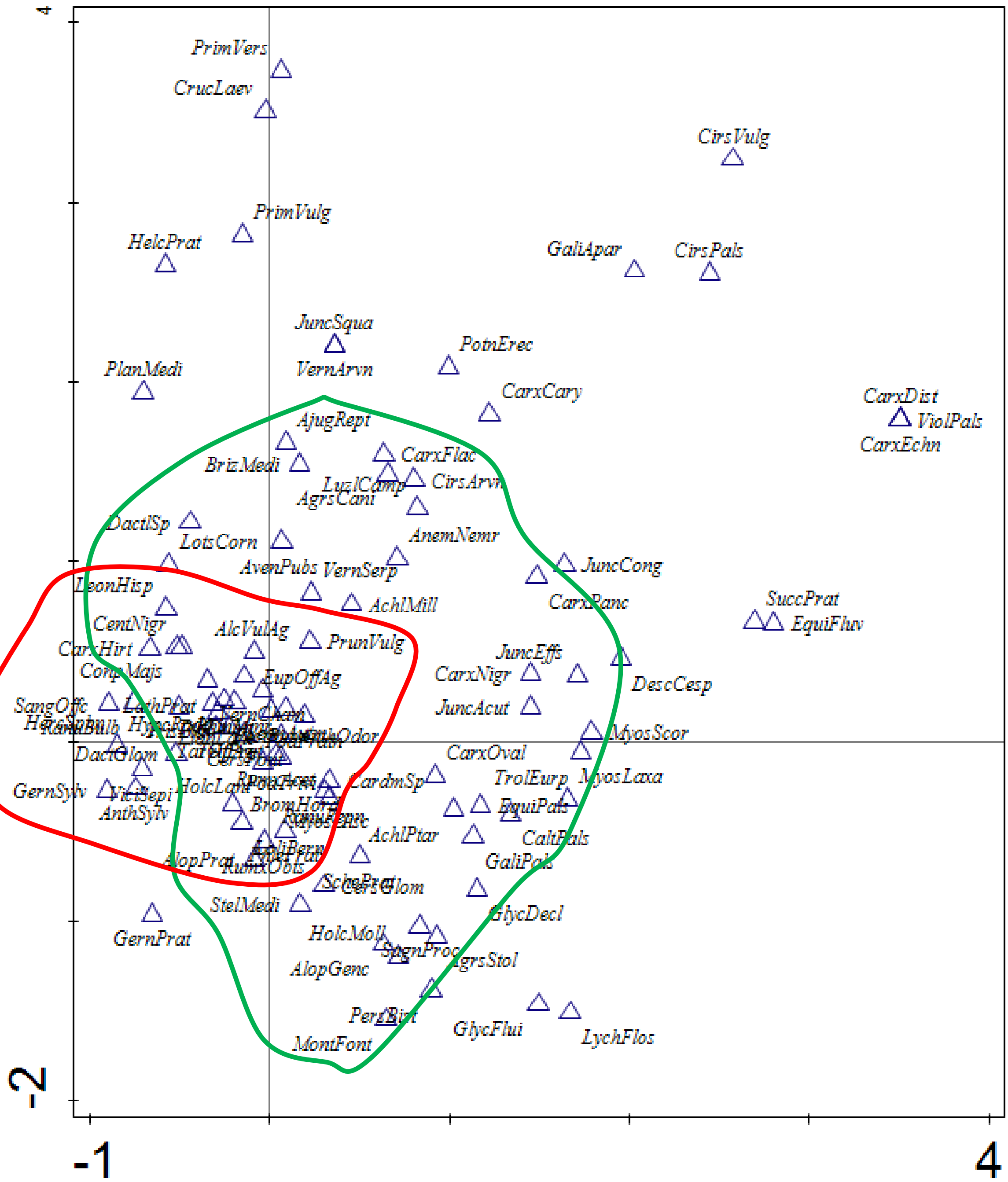


Figure 6. Unconstrained DCA analysis of 2020 quadrat data: the green polygon encloses species of constancy V or IV in MG8d; and the red polygon encloses species of constancy V or IV in MG3 (Teesdale data after O'Reilly, 2011).



MG3 *Anthoxanthum odoratum–Geranium sylvaticum* grassland and MG5 *Cynosurus cristatus-Centaurea nigra* grassland (*n* = 30)

Where MG3 was the main stand type within the site, this was largely represented by the more species-poor, semi-improved MG3a *Bromus hordeaceus* sub-community with much reduced cover of the typical MG3 associates *Geranium sylvaticum, Sanguisorba officinalis* and *Alchemilla vulgaris* agg. More species-rich stands either had affinities to MG3b *Briza media* sub-community, or, where MG3 associates were sparse but MG5 associates such as *Centaurea nigra* were abundant, to MG5. Using data from the condition assessment structured walk, Figure 7a shows the percentage of MG3a,b and MG5 stands combined (*n* = 32) which supported individual positive indicator species (combined list from all Priority Habitat lowland grasslands; BEHTA manual 2018). Figure 7b shows the percentage of the total number of stops (*n* = 640) across the sample in which each of these indicator species occurred. While the typical MG3 species *Sanguisorba officinalis* and *Conopodium majus* were present in 73% of stands, they were present in fewer than 30% of condition assessment stops, *Alchemilla vulgaris* agg. was present in in 53% of stands and *Geranium sylvaticum* in 43%, but were present in only 11% and 13% respectively of condition assessment stops. The heterogeneous character of the meadows is shown by the presence in MG3/5 stands of *Caltha palustris* in 15% of stands, and most stands had damp or flushed areas with MG8-related vegetation.

MG5 *Centaurea nigra-Cynosurus cristatus* grassland (*n* = 2)

Two species-rich stands that largely lacked typical MG3 associates apart from rare *Alchemilla vulgaris* agg., but supported high frequency *Centaurea nigra, Rhinanthus minor* and *Filipendula ulmaria* were assigned to MG5c *Danthonia decumbens* sub-community.

MG6 *Lolium perenne-Cynosurus cristatus* grassland (*n* = 76)

Agriculturally improved stands that supported typical MG3 or MG8 associates at low frequencies and were less species-rich were assigned to MG6; although there was a wide range of vegetation within these sites. Very species-poor sites (three sites) were assigned to MG6a but most had greater affinity to MG6b *Anthoxanthum odoratum* sub-community. The MG6b stands ranged from vegetation of low diversity to that which approached Priority Habitat grassland (see Section 3.2.2). O'Reilly (2011) described three variants of MG6b (MG6bi *Rumex obtusifolius-Ranunculus repens* variant; MG6bii *Festuca rubra-Veronica chamaedrys* variant; and MG6biii *Trifolium pratense-Rhinanthus minor* variant) for North Pennine upland hay meadows, reflecting the continuum from species-poor (MG6bi) to species-rich (MG6biii) within this heterogeneous vegetation community. MG6biii can be intermediate between MG6 and MG3, supporting some MG3 differential species at low frequency. Whilst occasional plants of typical MG3 associates were recorded on unmown banks or on the margins of the MG6b stands in this project, the main stands rarely supported these species other than as the occasional plant. More than 50% of MG6 stands (Figure 8a) supported the more widespread positive indicator species *Rhinanthus minor, Euphrasia* *vulgaris* agg (mainly *E. arctica*) and *Leontodon* spp.[8], while *Conopodium majus* was present in 44% and *Lathyrus pratensis, Filipendula ulmaria* and *Centaurea nigra* in over 30%. However, the frequency of these species within stands was low (Figure 8b) with only *R. minor* occurring in >50% of condition assessment stops; *Leontodon* and *C. majus* in 15% and 25%, respectively, and *L. pratensis, F. ulmaria* and *C. nigra* in 5 or 6% of stops.

Filipendula ulmaria was unusually abundant in some of the stands in which it occurred and these are thought more likely to represent degraded forms of MG8 than MG3. Wallace and Prosser (2014) described a new sub-community, MG6d *Filipendula ulmaria* sub-community, in their assessment of floodplain grasslands. There are affinities with MG6d in some of these MG6b stands, and this can be seen in the NVC MAVIS analysis table in Appendix 3.

MG7 *Lolium perenne* leys and related grasslands (*n* = 5)

Five stands within the control sample were species-poor with low cover of wildflowers and sedges (< 10%) and high cover of *Lolium perenne* with *Holcus lanatus* and *Dactylis glomerata*. *Alopecurus pratensis* was frequent in some of the stands and *Poa trivialis* in others. Fine-leaved grasses were occasional such as *Agrostis capillaris, Agrostis stolonifera* and *Festuca rubra.* Forbs included low frequency *Ranunculus repens, Ranunculus acris, Trifolium repens* and *Rumex acetosa.* Four were meadows but the fifth (formerly a meadow) was permanent sheep pasture. These stands had closest affinities with MG7b *Lolium perenne–Poa trivialis* leys and MG7d *Lolium perenne–Alopecurus pratensis* grassland.

MG8 *Cynosurus cristatus-Caltha palustris* grassland (*n* = 34)

Stands with frequent *Caltha palustris* together with *Scorzoneroides autumnalis* and *Filipendula ulmaria* showed closest affinities to the northern variant, MG8d (Prosser & Wallace, 2016). *Rhinanthus minor* and *Euphrasia* were also recorded in most MG8 stands. Figure 9a shows the frequency of the 23 positive indicator species recorded in >10% of the 34 surveyed stands of MG8. Species such as *Carex nigra, Carex panicea, Achillea ptarmica, Lychnis flos-cuculi, Trollius europaeus, Succisa pratensis, Dactylorhiza* orchids (particularly *D. purpurella*) and *Crepis paludosa* were associated with the MG8 sample. However, the frequency of occurrence of these species was again low (Figure 9b), with only *C. palustris, R. minor* and *Euphrasia* occurring in more than 40% of condition assessment stops.

[8] Includes all *Leontodon* spp. plus *Scorzoneroides autumnalis* (syn. *Leontodon autumnalis*)

Figure 7. Positive indicator species associated with MG3 (& two MG5) stands within the 2020 sample: (a) the proportion of MG3 sites in which the species occurred (species occupying >10% of sites only shown); and (b) the proportion of condition assessment stops in which the species was recorded. *n* = 32

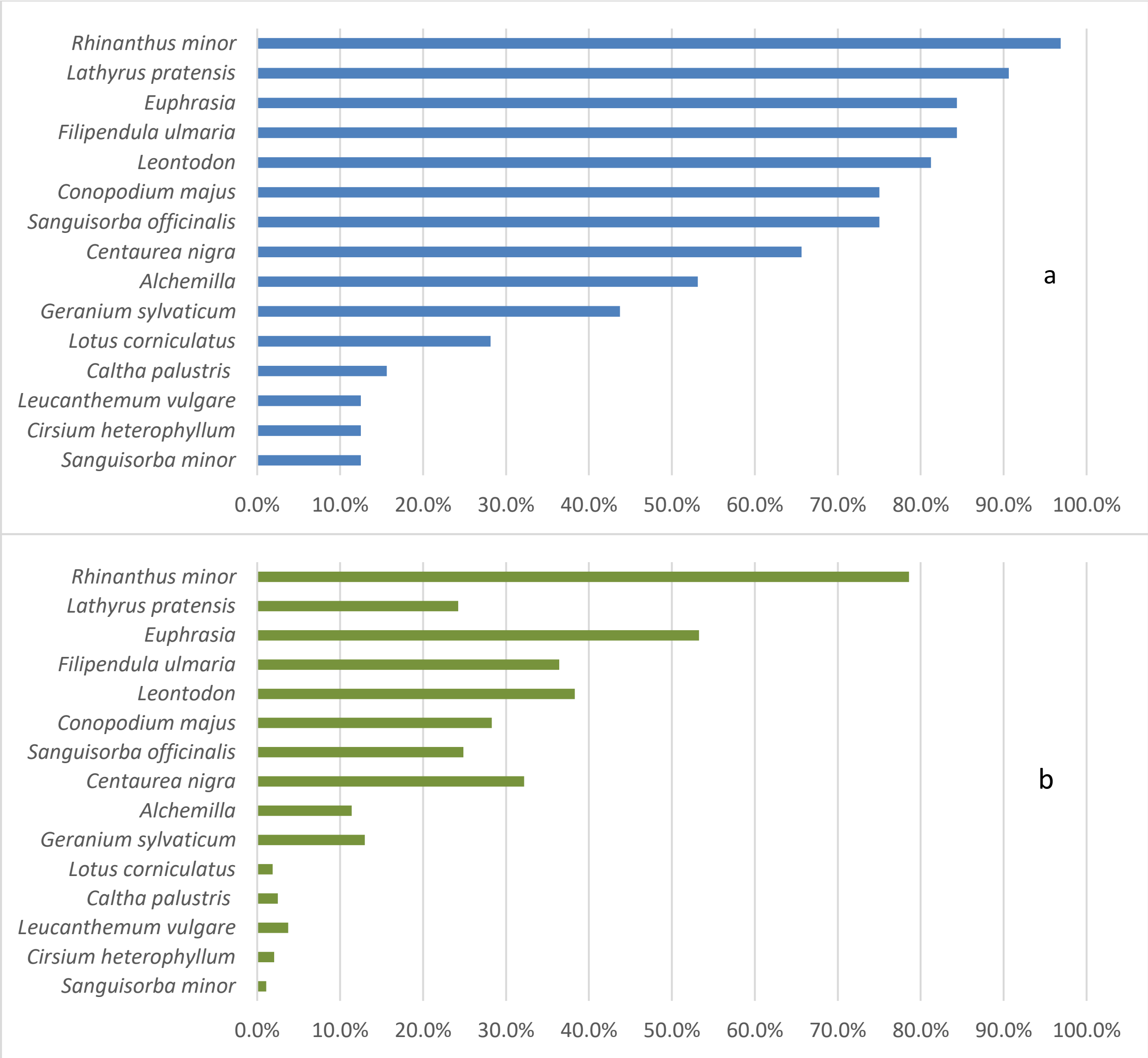


Figure 8. Positive indicator species associated with the MG6 stands within the 2020 sample: (top) the proportion of MG6 sites in which the species occurs (species occupying >10% of sites only shown); and (bottom) the proportion of condition assessment stops in which the species was recorded (e.g. occurrence in 5% of stops would be 1 stop in 20). *n* = 76

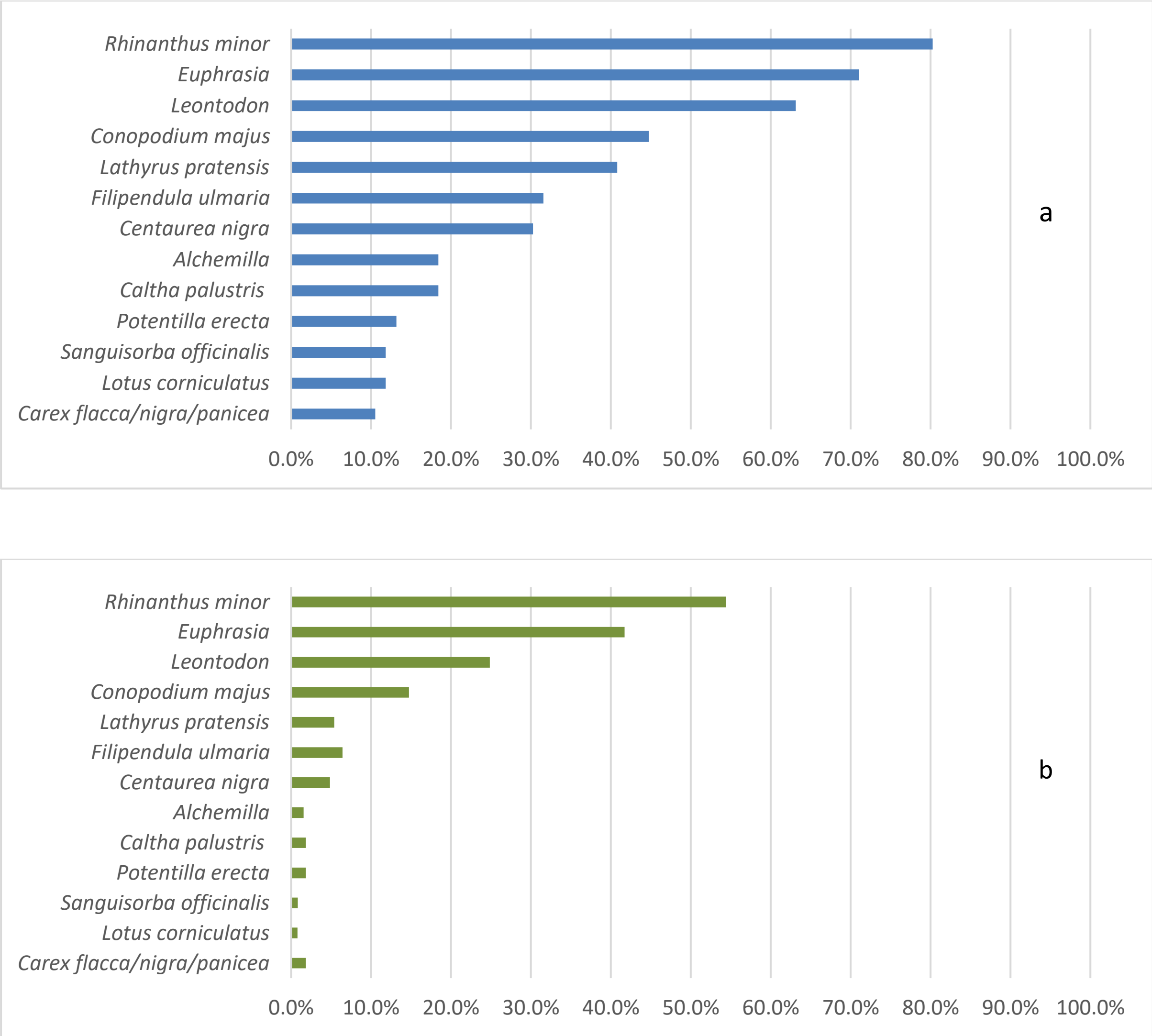
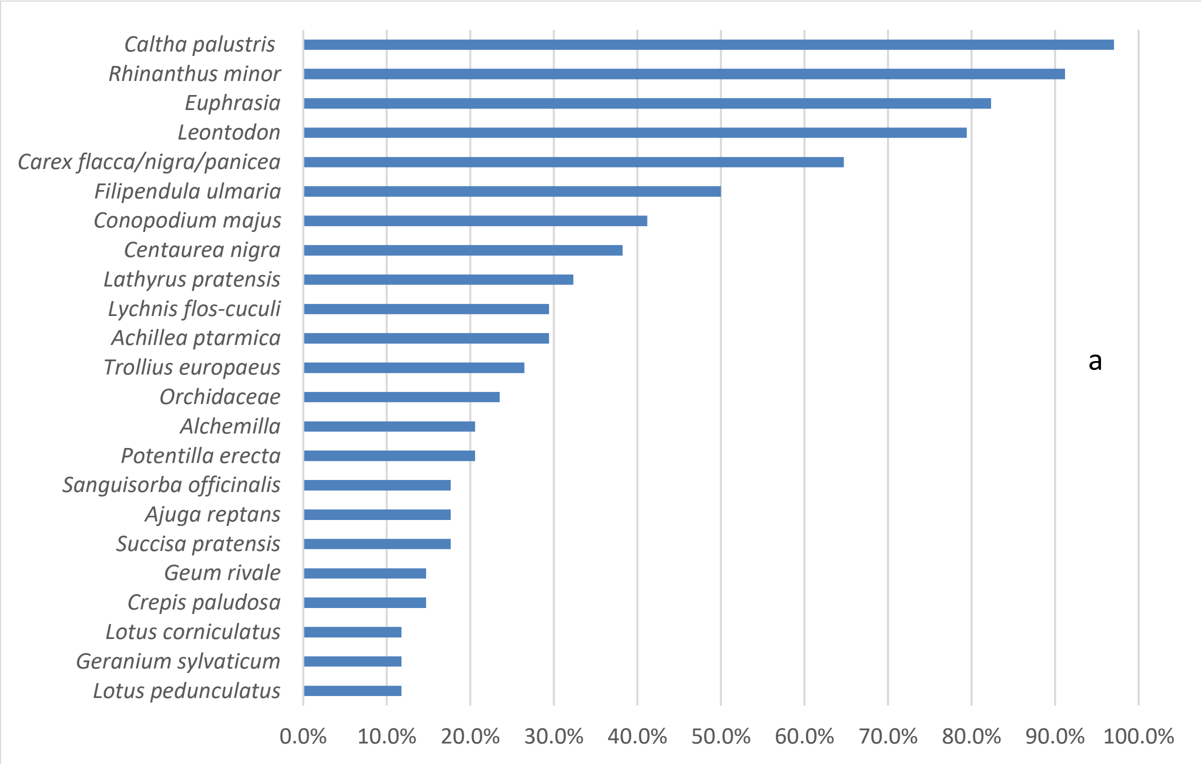
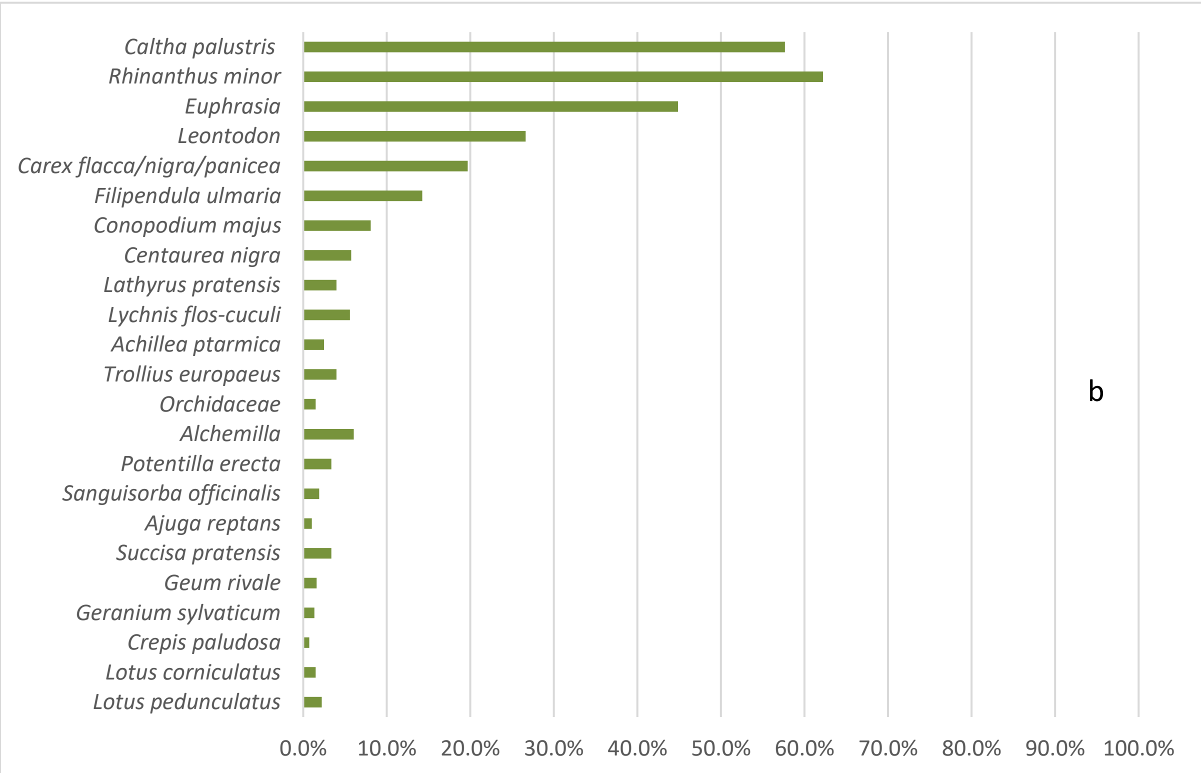


Figure 9. Positive indicator species associated with the MG8 stands within the 2020 sample: (top) the proportion of MG8 sites in which the species occurs (species occupying >10% of sites only shown); and (bottom) the proportion of condition assessment stops in which the species was recorded (e.g. occurrence in 5% of stops would be 1 stop in 20). *n* = 34





3.2.3 Species richness and NVC Community

Number of species

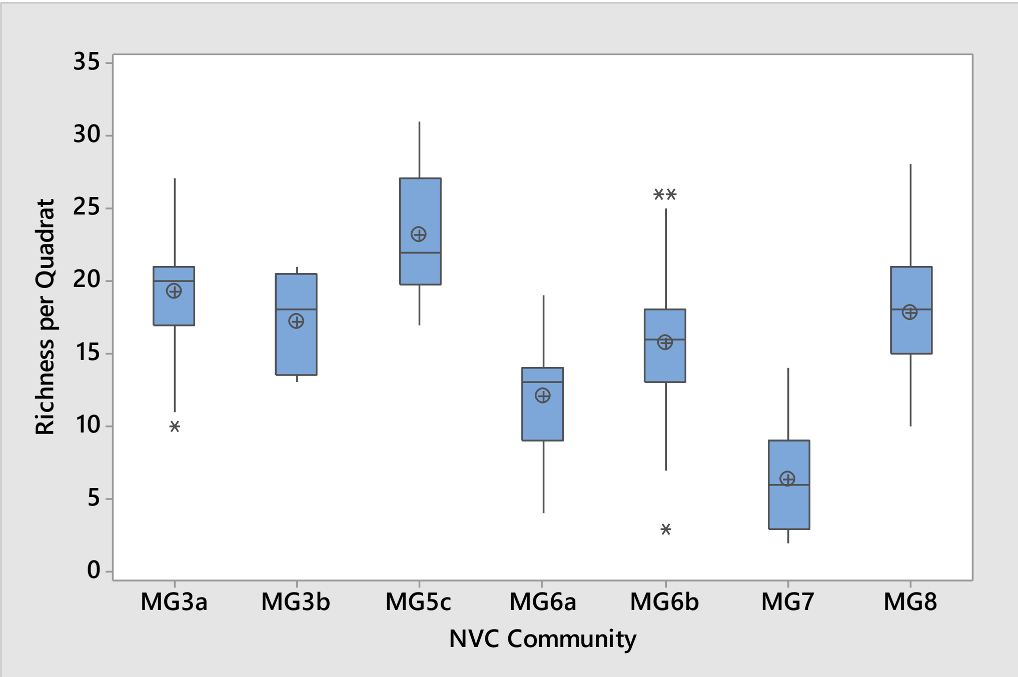
The number of vascular plant species was calculated from the quadrat data. Total number of species was significantly higher in stands of MG3 (including two stands of MG5) and MG8 than stands of MG6 and MG7 sites ($P > 0.001$, Table 8).

Mean number of species per m^2, calculated from quadrat data, shows (Table 8) that MG3/MG5 had significantly more species per m^2 on average than MG8, which was significantly richer than MG6 and MG7 ($P > 0.001$). The two stands of MG5c had the highest mean number of species per m^2 (Figure 10).

Table 8. Number of species by NVC community type. One-way Analysis of Variance (ANOVA) with post-hoc Tukey pairwise comparisons with 95% CI, means that do not share a letter are significantly different.

Variable (mean value ± SD)	MG3/MG5	MG8	MG6	MG7	*P*
Total number of species (df 3,146)	$31.250^{a} \pm 4.103$	$31.676^{a} \pm 5.290$	$26.158^{b} \pm 5.369$	$13.20^{c} \pm 5.40$	***
Number of species per m^2 (df 3,734)	$19.500^{a} \pm 3.378$	$17.841^{b} \pm 3.666$	$15.613^{c} \pm 3.634$	$6.400^{d} \pm 3.291$	***

Figure 10. Boxplot plot of species per m^2 for the NVC sub-community types in the sample: mean, median, quartiles and outliers are shown. All differences are significant (*P > 0.001*) with the exception of MG3b.



Positive Indicators species

Positive indicator measures were calculated from the rapid condition assessment structured walk data (RCA). Stands of MG3 were richest in both total number of positive indicator species (Table 9), and frequency of positive indicator species ($P > 0.001$) and on average supported more than 3 frequent (present in more than 9 condition stops in a field) positive indicators, significantly more than for MG8, and for all measures compared with MG6 and MG7 (Table 9).

Table 9. Positive indicator frequency data for sites by NVC community type. Analysis of Variance (ANOVA) of mean values with post-hoc Tukey pairwise comparisons with 95% CI, means that do not share a letter are significantly different at $P < 0.05$.

Variable (mean value ± SD)	MG3/MG5	MG8	MG6	MG7	*P*
(A) No. positive indicators per site. df 3,146	$9.313^{a} \pm 2.967$	$8.765^{a} \pm 3.429$	$4.947^{b} \pm 2.678$	0.000^{c}	***
(B) Summed frequency of positive indicators per site. df 3,146	$72.16^{a} \pm 24.15$	$56.50^{b} \pm 23.91$	$33.28^{c} \pm 17.54$	0.000^{d}	***
(C) No. positive indicators that are frequent (in ≥9 stops out of 20) per site. df 3,146	$3.813^{a} \pm 1.533$	$2.618^{b} \pm 1.393$	$1.592^{c} \pm 1.110$	0.000^{d}	***

3.2.4 Scheme option and NVC Community

For sites under scheme management (129 sites), those under ‘maintenance’ options HK6 or GS6 were most frequently found to support MG8-related communities in the main stand (41.4%) with the target community of MG3-related hay meadow (and one case of MG5) in 27.5% of sites and 31% supporting less species-rich, semi-improved MG6 vegetation (Table 10).

Of sites under ‘restoration’ options HK7 or GS7, 55% were predominately MG6b. When these were sub-divided into sites that had and had not been subject to sward enhancement they comprised 76% and 36% respectively of the total HK7/GS7 sample. Stands that had not been subject to sward enhancement included a greater proportion of MG3 (30%) and MG8 (30%) than sites that had been enhanced (MG3, 14% and MG8 10%).

The non-agreement sites included one MG3 and two MG8 sites of higher quality. More than half of these sites were MG6b with the remaining five being species-poor semi-improved and improved perennial ley MG7 (28%).

Table 10. NVC communities recorded in the UHM sample by scheme option and enhancement status – numbers and percentages.

NVC Community	NVC Sub-community	HK6/GS6		HK7/GS7 No enhancement		HK7/GS7 Sward enhancement		None		Total	
MG3	MG3a	7	24.1%	14	28.0%	7	14.0%	1	5.6%	29	19.7%
	MG3b	0	0.0%	1	2.0%	0	0.0%	0	0.0%	1	0.7%
MG5	MG5c	1	3.4%	1	2.0%	0	0.0%	0	0.0%	2	1.4%
MG6	MG6a	1	3.4%	1	2.0%	0	0.0%	1	5.6%	3	2.0%
	MG6b	8	27.6%	18	36.0%	38	76.0%	9	50.0%	73	49.7%
MG7		0	0.0%	0	0.0%	0	0.0%	5	27.8%	5	3.4%
MG8		12	41.4%	15	30.0%	5	10.0%	2	11.1%	34	23.1%
Total Sites		29		50		50		19		148	

3.3 Condition of the upland hay meadow sample in 2020

3.3.1 Stand condition and NVC community

All of the 147 sites in the 2020 survey were assessed against condition assessment criteria described in the BEHTA manual (Natural England, 2016). The sample of 147 sites included: Favourable condition Upland Hay Meadow priority habitat (PH) grassland (G09-A); Unfavourable condition UHM PH (G09-B); moderately species-rich and restorable non-PH grassland (G02*); species-poor non-PH grassland (G02); and improved grassland (G01).

Figure 11 shows the condition of grasslands within each NVC (sub)community type. The majority of MG3 and MG8, and both MG5 stands were Favourable or Unfavourable condition priority habitat grasslands rather than G02*/G02 semi-improved,. Some MG6 stands however also qualified as G09 priority grasslands (condition A or B). These are likely to be degraded stands of MG3 and MG8 with lower levels of agricultural improvement. Parameters of species-richness contribute to the condition assessment: consequently mean species number m^{-2}, number of positive indicator species m^{-2} and summed frequency of positive indicator species were all significantly associated with stand condition (0). Favourable condition G09 had just over two extra species per m^2 than Unfavourable condition G09 and three additional positive indicator species. Both condition classes exceeded the requisite four positive indicators (with means of 9.917 and 6.773 positive indicators respectively in Favourable and Unfavourable G09 grassland), as did the G02* good semi-improved grasslands at an mean of 4.152 positive indicators indicating that stands failed more on the frequency of indicators than on a lack of indicators. There were no significant differences in number of positive indicator species between G02* good semi-improved and G02 poor semi-improved, but there were significant differences in the summed frequencies of these indicators between these (and all other) condition classes.

The criterion most frequently failed in the condition assessment was frequency of positive indicator species (55% of all stands) followed by cover of qualifying wildflower (and *Carex*) species (25%). Only 2% of stands failed on negative indicator criteria. No stand failed on cover of *Juncus* species.

Figure 11. Results of the condition assessment stratified by the main NVC (sub)community of the UHM stand sampled, with the number of sites in each condition category per community type. G09-A, Favourable condition G09 UHM; G09-B, Unfavourable condition G09 UHM; G02*, good semi-improved G02 grassland; G02, poor semi-improved G02 grassland; and G01, improved G01 grassland.

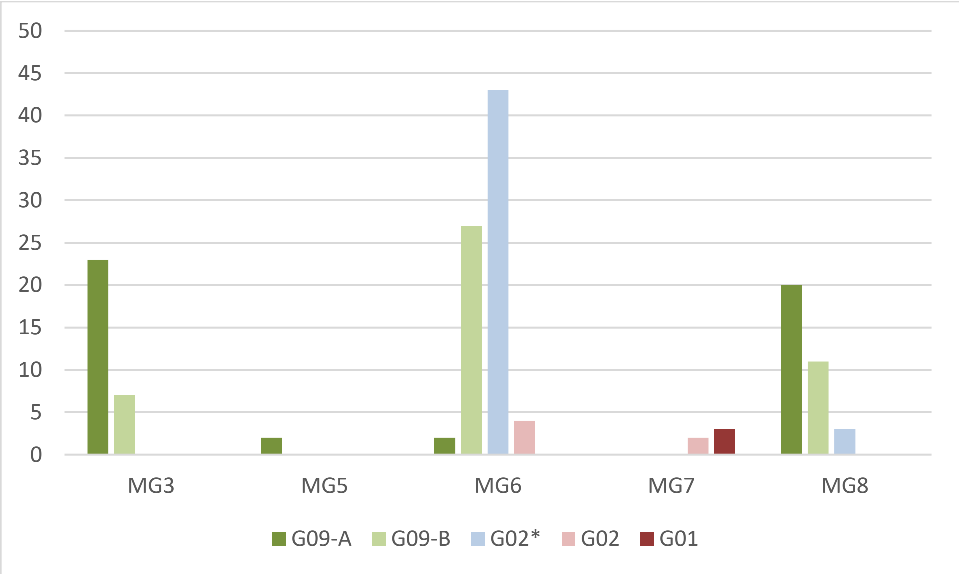


Table 11. Measures of species richness within the 2020 sample stratified by stand condition category. ANOVA with post-hoc Tukey Pairwise comparisons. Means that do not share a letter are significantly different. Significance *** is *P* > 0.001

Condition	No. species per m^2	No. positive indicator species per site	Summed frequency of positive indicator species per site
G09-A	19.450 ^{a} ± 2.570	9.917 ^{a} ± 2.85	75.90 ^{a} ± 18.43
G09-B	17.245 ^{b} ± 2.270	6.773 ^{b} ± 2.761	43.80 ^{b} ± 13.13
G02*	14.809 ^{c} ± 2.489	4.152 ^{c} ± 2.033	25.11 ^{c} ± 11.18
G02	10.767 ^{d} ± 1.675	1.167 ^{c} 1.472	5.67 ^{d} ± 7.23
G01	4.267 ^{e} ± 0.231	0.000 ^{c} ± 0.000	0.00 ^{e} ± 0.00
P	***	***	***

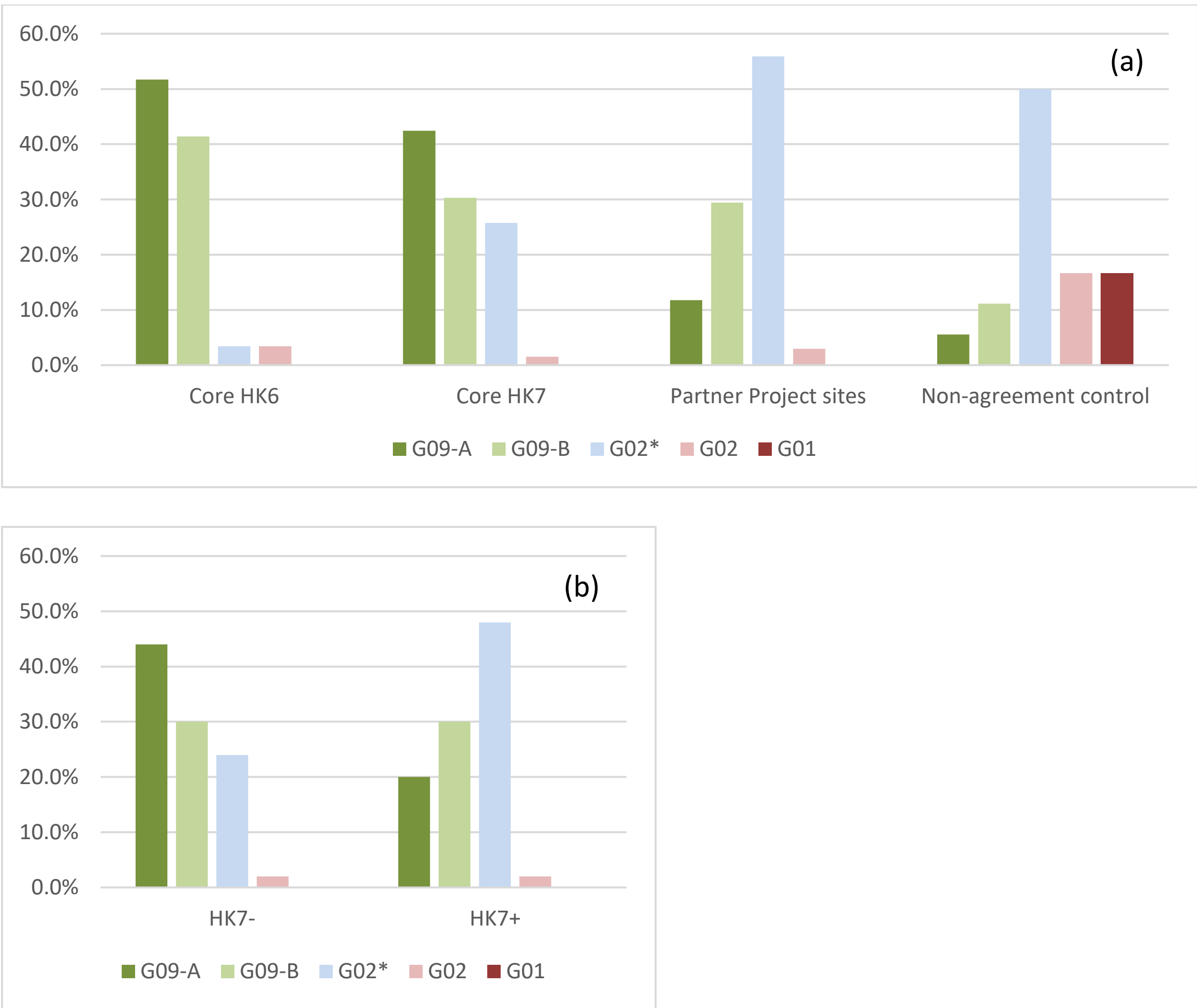
3.3.2 Stand condition, agri-environment scheme option and enhancement measures

Within the 2020 survey there were the following types of sites:

- Core sample HK6 sites (also surveyed in 2012) *n* = 29
- Core sample HK7 sites (also surveyed in 2012) *n* = 66, comprising:
  - Core sample HK7 sites without enhancement (also surveyed in 2012) *n* = 50
  - Core sample HK7 sites with enhancement (also surveyed in 2012) *n* = 16
- Partner project HK7 sites with enhancement (not surveyed in 2012) *n* = 34
- Control sites not in agri-environment agreements (not surveyed in 2012) *n* = 18

The condition of sites within each of these groups is illustrated in Figure 12.

Figure 12. Results of the condition assessment stratified by the sample group, showing the percentage of sites in each condition category per group. (a) Core HK6 sites; Core HK7 sites; Partner Project enhancement sites. (b) HK7 sites stratified by enhancement status: HK7-, HK7 sites with no sward enhancement; HK7+, HK7 sites with sward enhancement.



Core sample

All of the 95 sites in the core sample were managed within the Environmental Stewardship or Countryside Stewardship schemes. Of these, 79% were assessed as G09 Upland Hay-Meadow priority grassland habitat, 45% in Favourable condition (G09-A) and 34% in Unfavourable condition (G09-B). A further 19% were considered to be of insufficient quality to be G09 but were moderately species-rich and restorable (G02*). Two sites were G02 species-poor grassland.

93% of HK6 sites in the core sample were G09 priority habitat, although only 51.7% were in Favourable condition. One site under option HK6 supported species-poor semi-improved G02 grassland. 73% of HK7 were assessed as G09 with 42% in Favourable condition.

Enhancement sample – Partner organisation project sites

All 34 sites of the enhancement sample, drawn from partner organisation hay meadow restoration projects, are currently managed under option HK7. More than half of these supported G02 semi-improved grassland rather than G09 Upland Hay-Meadow.

HK7 restoration option sites with and without enhancement

The 50 sites under an HK7 restoration management option that were selected for sward enhancement ('HK7+'), whether part of the core sample (16 sites) or a partner project (34 sites) tended to be in poorer condition than the 50 HK7 ('HK7-') sites within the core sample that were <u>not</u> selected for sward enhancement.

Non-agreement control sample

Most sites in the non-agreement control were good semi-improved (Figure 12).

3.3.3 Stand condition and statutory designation (SSSI)

Of the 95 core sample sites resurveyed in 2020, 22 were within SSSIs. Eight contained stands of MG3 (or in the case of one site, a flood-damaged former MG3) and 14 contained stands of MG8. Six were managed under HK6 and 16 under HK7.

When assessed using BEHTA (Natural England, 2016) criteria for the condition assessment of G09 upland hay meadow priority grassland habitat, 18 of 22 were in Favourable condition passing all criteria and attribute thresholds (Figure 13). If however the more stringent criteria for SSSI grasslands (MG3 <u>or</u> MG8-related/MG3-related, wet northern meadow)(Robertson & Jefferson, 2000) are applied, only 5 of 22 were in Favourable condition. This difference in status was due to the requirement for a greater frequency of positive indicator species in statutorily designated grassland. For MG3 stands, three frequent and three occasional species are required for Favourable condition, whilst in MG8-related/MG3-related two frequent and four occasional species are required for Favourable condition in SSSIs. In non-SSSI G09 grasslands only two frequent plus two occasional species are required.

Stands of grassland within SSSIs had significantly more species per m^2 in the quadrats, significantly greater percentage cover of wildflowers and sedges (non-Gramineae) and a significantly greater mean number of positive indicator species (Table 12). They also had greater summed frequency of positive indicator species (63.14) compared with non-SSSI stands (50.96) but this was not statistically significant

Figure 13. The number of stands within SSSI units to be assessed as in Favourable condition or Unfavourable condition when assessed against: BEHTA G09 PH criteria (blue) and SSSI attributes and thresholds (green).

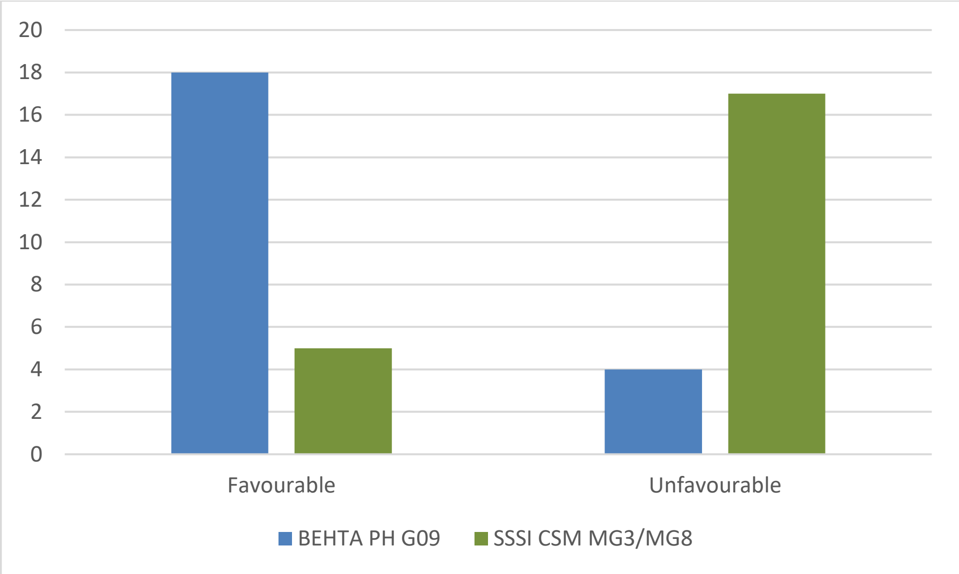


Table 12. Measures of species richness within the 2020 sample: Analysis of Variance (ANOVA) of mean values with post-hoc Tukey pairwise comparisons with 95% CI for stands within a SSSI unit compared with stands that were not within a SSSI unit. Significance levels: *** *P* < 0.001, ** *P* < 0.01, * *P* < 0.05.

	SSSI *n* = 22	Non-SSSI *n* = 73	*P*
Mean number of species per m^2	19.10	16.95	**
Mean % cover of non-Graminae	60.55	48.33	**
Mean number of positive indicator species (all PHs)	10.23	7.07	***
Mean summed frequency of positive indicator species (all PHs)	63.14	50.96	ns

3.4 Explanatory variables for stand condition

Data from the botanical survey, the whole stand condition assessment, the soil survey, the enhancement status of sites, and the management questionnaire for all sites surveyed in 2020 were used to investigate relationships between vegetation composition and stand condition in 2020 and explanatory environmental variables. The aim was to determine which environmental variables contributed most to vegetation composition and condition.

3.4.1 CCA analysis of associations between vegetation composition, stand condition and explanatory environmental variables

The Canonical Correspondence Analysis (CCA) function in Canoco 5.1 (Smilauer & ter Braak, 2018) was used to investigate relationships between vegetation composition in 2020 and explanatory environmental variables. The final fitted model was constructed by forward selection of variables, the significance of which was determined using the Monte-Carlo Permutation Test with 500 permutations. These environmental variables included the suite of soil chemical characteristics; pH, available phosphate (Olsen's method), magnesium, potassium, total phosphorus, total nitrogen, loss on ignition, and total carbon. The responses provided for the management questionnaire varied by farmer in accuracy and detail but the results were interpreted to provide a series of simple variables which could be used in the analyses (Table 13).

Significant associations were found between vegetation composition and the explanatory variables: available phosphate, magnesium, potassium, pH, designation as a SSSI, enhancement (restoration) management, agri-environment scheme enrolment option, application of lime and use of traditional livestock breeds. The relationships of these variables to different categorisations of sites are shown in 0–18 and explored in more detail in the following sections: each of these figures relate to the same CCA analysis, but each Figure 14–17 has a different classification of samples highlighted. Figure 18 looks at species. Table 14 provides the percentage of variation explained by the axes (and eigenvalues) for Figures 14–18.

In 0 with sites classified by NVC type, stands of MG3 appear to be associated with relatively high pH but low levels of nutrients especially available phosphate but also magnesium and potassium. Sward enhancement was concentrated on the drier MG3 and MG5 grasslands rather than the wetter MG8, but MG8 grasslands are more typical of SSSIs. MG8 grasslands are present over a wide range of available phosphate levels, possibly reflecting the wide range of floristic variation within this community, and also favour a higher level of potassium but lower pH.

The main environmental factor associated with site condition (Figure 15) was available phosphate. Sites with higher phosphate levels were in poorer condition, while lower phosphate level was associated with better condition. Vegetation in SSSIs was generally in Favourable condition (under BEHTA PH criteria), although many sites outside SSSIs were also in Favourable condition.

Table 13. Explanatory variables used in CCA analysis of vegetation surveyed in 2020. Variables in the final model chosen by forward selection: significance $P < 0.05$ *, $P < 0.01$ **.

Variable: Soil chemistry		*P*
pH		*
Available phosphate	Olsen's method	**
Magnesium		**
Potassium		*
Total Phosphorus		
Total Nitrogen	Available and organic	
Loss on ignition	Indicative of organic matter content in non-limestone soils	
Total Carbon		
Variable: Management		
Crop	a. Hay in most years b. Haylage/silage in most years	
Closing date	a. Before 15th April b. 15th April–7th May c. 7th May–15th May	
Cutting date	a. 15th July–20th July, b. after 20th July or weather dependent	
Livestock type	A. traditional cattle only B. traditional cattle and traditional sheep C. traditional cattle and modern sheep D. modern cattle only E. modern cattle, any sheep F. traditional sheep only G. modern sheep only	B * F *
Lime	Any application since 2010	*
NPK	Any application since 2010	
FYM	a. None b. <10T/ha c. >10T/ha	
Enhancement		
Scheme option	a. HK6 b. HK7 c. None	HK6 * HK7 * None *

Table 14. Canonical Correspondence Analysis of Core sample sites surveyed from 1987 to 2020 (Figs 14-18). Eigenvalues and percentage of variation explained by axes. Significant terms tabulated below.

Significant terms		Significance
Soil	Available phosphate	$P < 0.002$
	pH	$P < 0.020$
	Mg	$P < 0.026$
	K	$P < 0.032$
Management	Lime application in previous 10 years	$P < 0.008$
	Stock – traditional sheep	$P < 0.016$
	Stock – traditional cattle and sheep	$P < 0.022$
Status	HK7 with enhancement	$P < 0.002$
	SSSI	$P < 0.004$
	HK7 without enhancement	$P < 0.018$
	HK6	$P < 0.018$

Axis	% of variation explained by the ordination axes (cumulative)	Eigenvalues
Axis 1	3.72	0.0779
Axis 2	6.58	0.0598
Axis 3	8.40	0.0380
Axis 4	10.10	0.0356

There was an association between the use of traditional cattle (tc) and sheep (ts) and better condition sites. Sites under the HK7 option tended to be in less good condition than those in the HK6 option, but sites not under any agri-environment agreement were in poorer condition than sites in either HK6 or HK7. This was also shown by Figure 17.

No sites enhanced by addition of plant material (Figure 16) were in SSSIs, and most, but not all had a relatively low levels of available phosphate and potassium. These sites were associated with the restoration vector and the HK7 option centroid, but were not associated with the use of traditional livestock breeds.

Available phosphate was also the main factor associated with scheme option (Figure 17). HK6 sites tended to have lower levels than HK7 sites, while sites not in an agri-environment scheme had the highest phosphate levels. G09 grassland indicator species (Figure 18) were associated with low phosphate and potassium levels, traditional livestock and agri-environment scheme options.

Figure 14. Unconstrained DCA analysis of sites surveyed in 2020 with variables identified by CCA analysis as significant fitted as supplementary variables. Sites classified by NVC stand type. MG3, red triangles; MG5c, orange stars; MG6, light blue circles; MG7, dark blue circles; MG8, green squares. Significant variables: Available phosphate Olsen's method, pH, K (potassium), HK6, HK7, no A-E agreement, Lime application in previous 10 years, Rest (sward enhancement), tcts (Traditional cattle, traditional sheep), ts (traditional sheep).

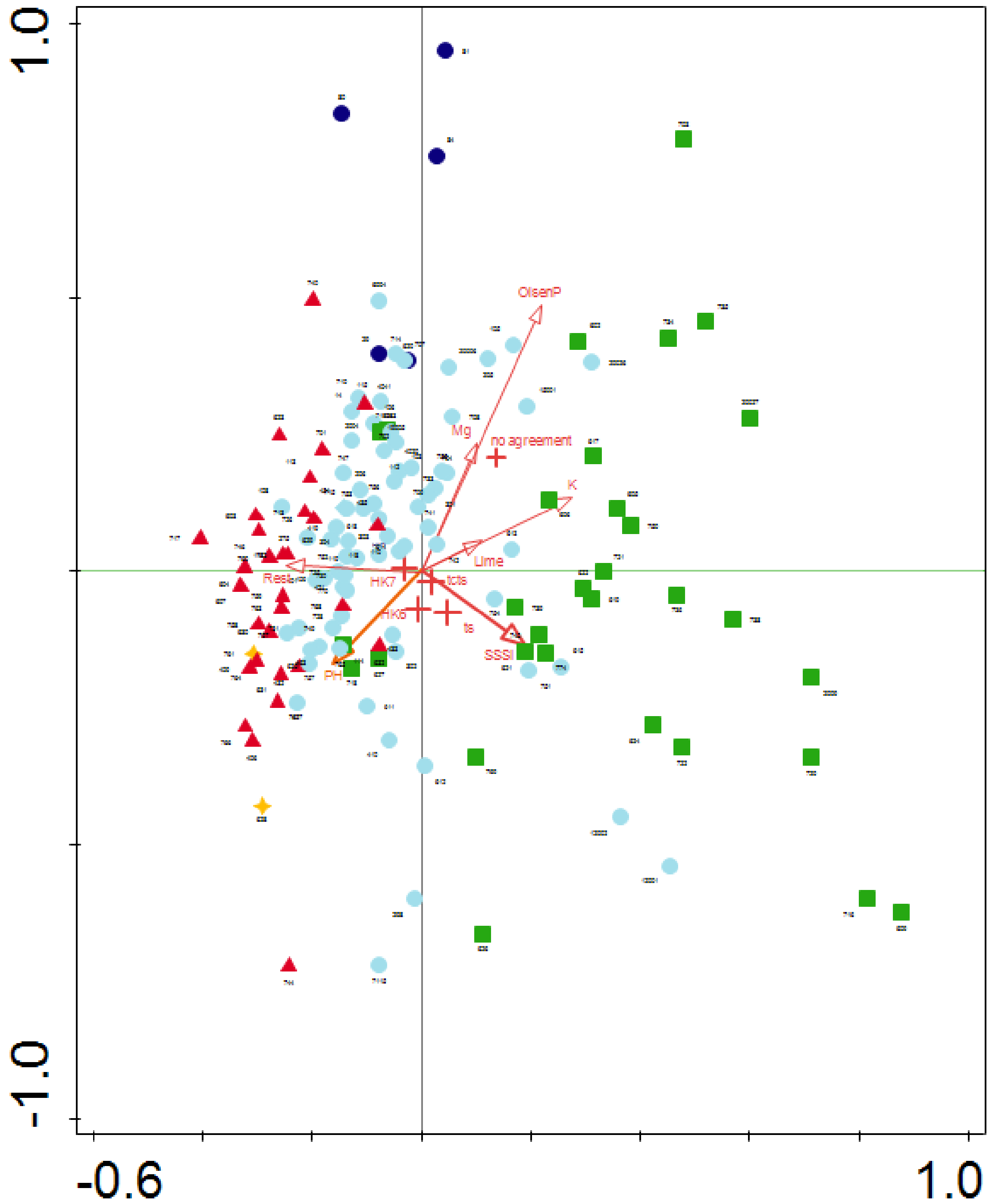


Figure 15. Unconstrained DCA analysis of sites surveyed in 2020 with variables identified by CCA analysis as significant fitted as supplementary variables. Sites classified by condition: G09-A, green squares; G09-B, beige circles; G02* good semi-improved, light blue diamond; G02 poor semi-improved, dark blue square; G01 improved, navy blue circle. Significant variables: Available phosphate Olsen's method, pH, K (potassium), HK6, HK7, no A-E agreement, Lime application in previous 10 years, Rest (sward enhancement), tcts (Traditional cattle, traditional sheep), ts (traditional sheep).

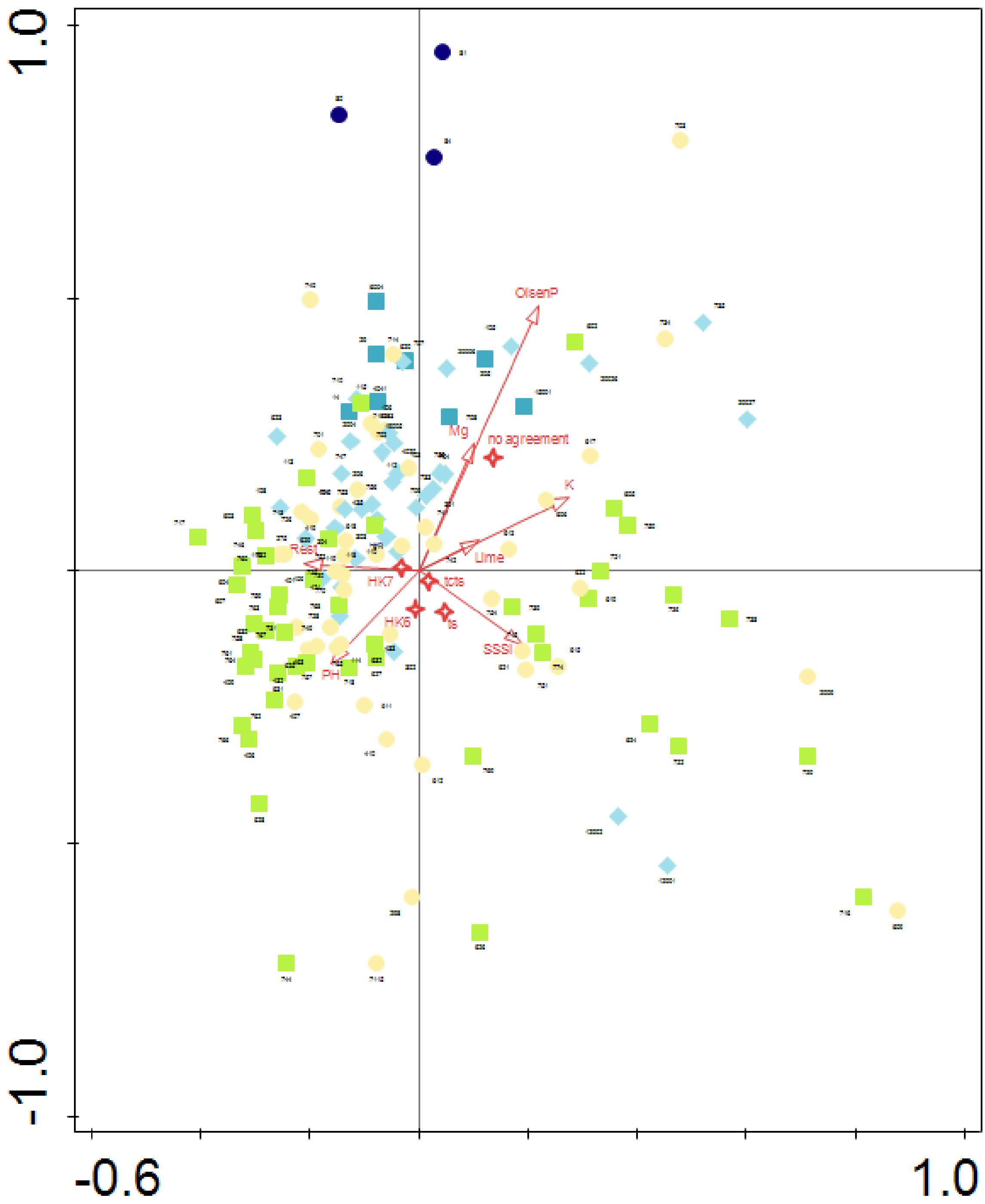


Figure 16. Unconstrained DCA analysis of sites surveyed in 2020 with variables identified by CCA analysis as significant fitted as supplementary variables. Sites classified by enhancement: sward enhancement sites (HK7+), purple circles; no sward enhancement sites (HK6, HK7–), orange squares. Significant variables: Available phosphate Olsen's method, pH, K (potassium), HK6, HK7, no A-E agreement, Lime application in previous 10 years, Rest (sward enhancement), tcts (Traditional cattle, traditional sheep), ts (traditional sheep).

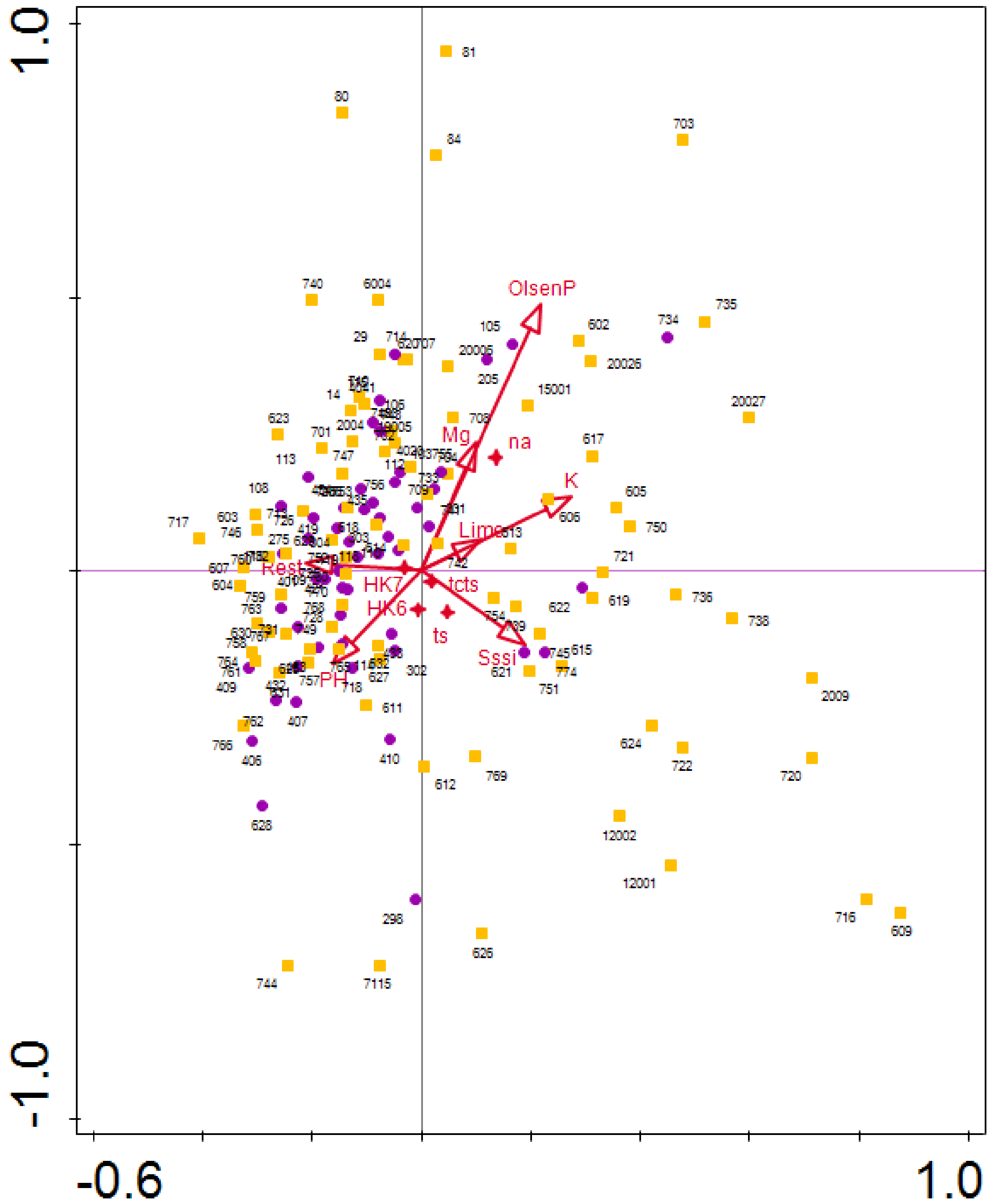


Figure 17. Unconstrained DCA analysis of sites surveyed in 2020 with variables identified by CCA analysis as significant fitted as supplementary variables. Sites classified by scheme option: HK6, violet circles; HK7 orange squares; and No agri-environment agreement, light blue diamonds. Significant variables: Available phosphate Olsen's method, pH, K (potassium), HK6, HK7, no A-E agreement, Lime application in previous 10 years, Rest (sward enhancement), tcts (Traditional cattle, traditional sheep), ts (traditional sheep).

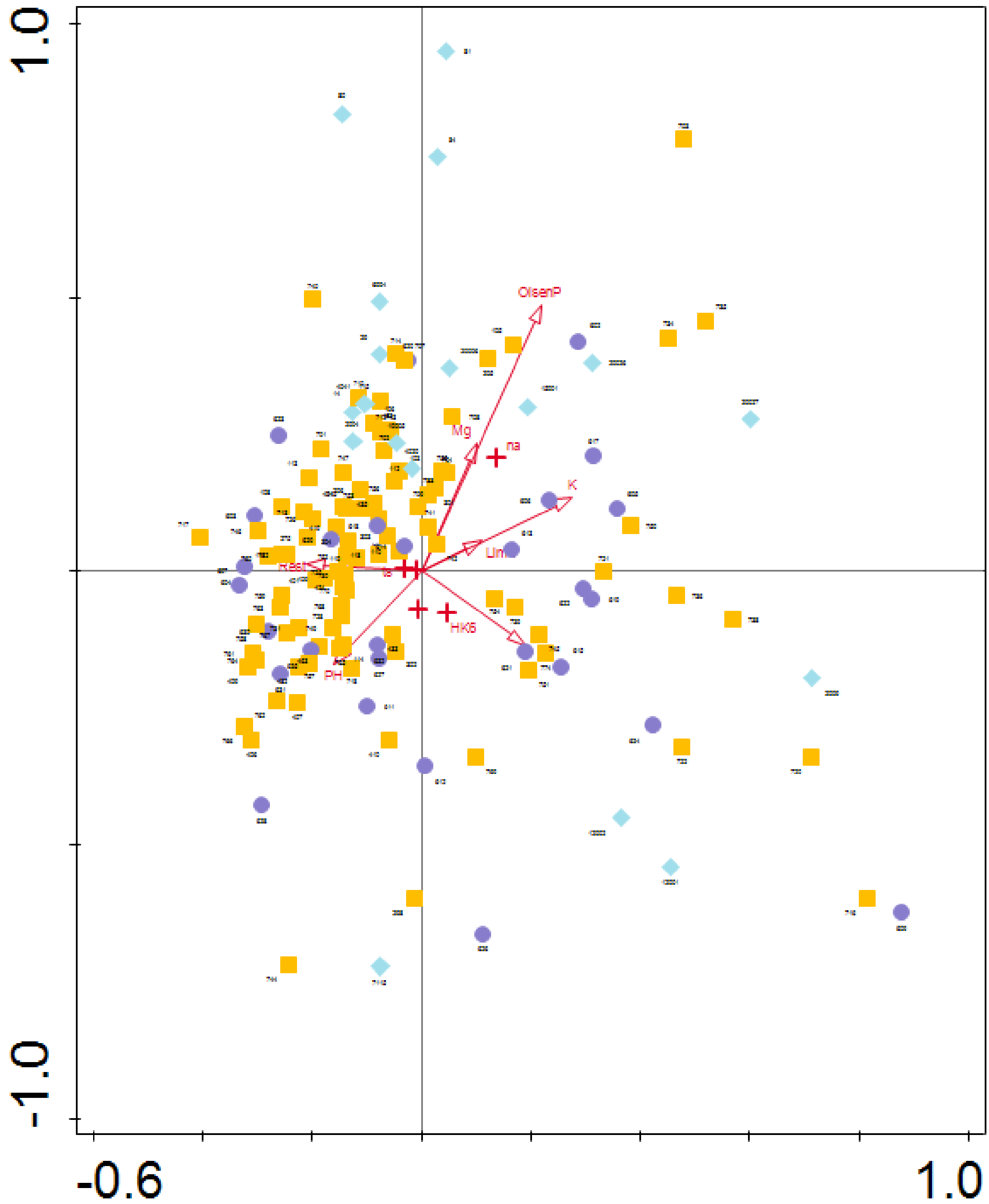
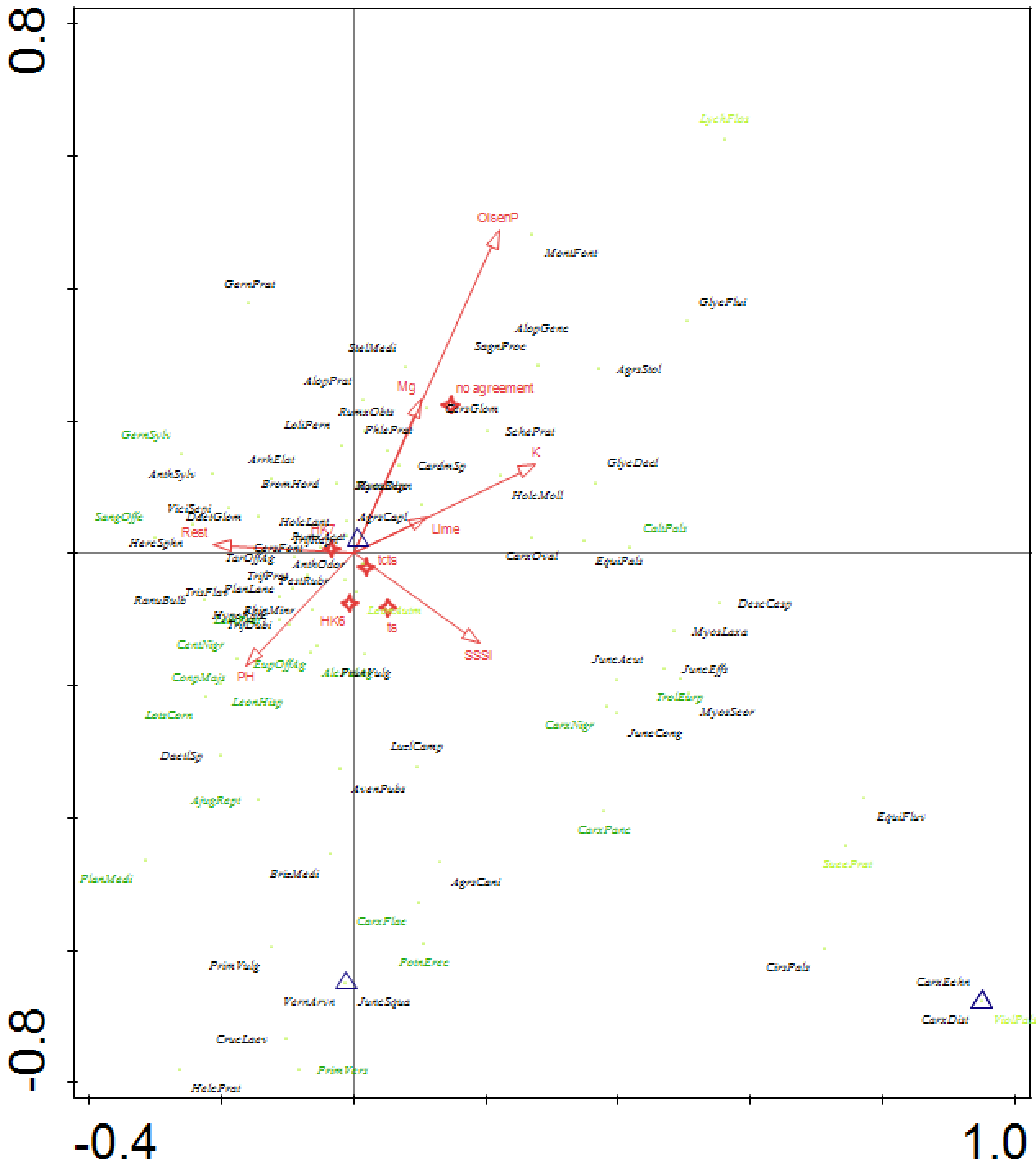


Figure 18. Unconstrained DCA analysis of sites surveyed in 2020 with variables identified by CCA analysis as significant fitted as supplementary variables. Species. Positive indicator species for G09 grasslands in green. Significant variables: Available phosphate Olsen's method, pH, K (potassium), HK6, HK7, no A-E agreement, Lime application in previous 10 years, Rest (sward enhancement), tcts (Traditional cattle, traditional sheep), ts (traditional sheep).



3.4.2 Soil chemistry and management variables including agri-environment scheme enrolment, option and sward enhancement measures

Sites that were assessed as Favourable condition G09 upland hay meadow priority grassland habitat in 2020 had significantly lower levels of available phosphate than stands assessed as non-priority grassland (Table 15). Unfavourable condition G09 had significantly lower levels of available phosphate than stands assessed as poor semi-improved or improved non-priority grassland (G01, G02). Most (98%) of Favourable condition G09 had an Index P of 1 or 0 (Olsen's P of 1–15 mg/l), compared with 81% of Unfavourable stands and 55% of non-priority grasslands (data not shown). There was a weak positive relationship between stand condition and total nitrogen.

There was no significant relationship between stand condition and total phosphate, potassium, magnesium, loss on ignition, or organic carbon.

Table 15. ANOVA with post-hoc Tukey pairwise comparisons for soil chemistry variables and stand condition – mean values shown. Significance: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$. Means that do not share a letter are significantly different.

Condition	Olsen's P	Total P	K	Mg	N	LoI	OC
G09-A	10.42^{a}	1340.50	108.96	159.73	0.84^{a}	17.46	7.68
G09-B	12.41^{ab}	1273.40	120.75	145.86	0.79^{ab}	16.14	7.30
G02*	14.13^{bc}	1223.60	131.52	172.28	0.72^{b}	15.54	6.96
G02	20.83^{d}	1478.00	137.80	172.50	0.69^{ab}	15.35	7.12
G01	21.00^{cd}	1356.00	132.70	170.67	0.67^{ab}	14.23	5.53
P	***	ns	ns	ns	*	ns	ns

Several measures of species-richness and species-related condition attributes were examined in relation to soil and management variables using the generalised linear model (GLM) routines available in R. These measures were: mean number of species per m^2, mean cover of *Lolium perenne,* mean cover of dicotyledonous and *Carex* species, mean cover of dicotyledonous species minus *T. repens* and *R. repens,* mean cover of negative indicator species, mean cover of *Juncus* spp, number of positive indicator species (all priority grasslands), summed frequency of positive indicator species (all priority grasslands), number of positive indicator species (Upland Hay-meadows only) and summed frequency of positive indicator species (Upland Hay-meadows only)(Table 16a).

The management variables used in these GLMs were categorical and qualitative only. It was therefore considered that to refine the models by stepwise procedures would introduce a misleading impression of accuracy. These models are therefore not intended to give a complete assessment of factors determining vegetation composition or to be usable predictively. The results of these and subsequent GLMs are only indicative and should be used in combination with the other analyses described in this report.

The total number of species m^{-2} was positively related to available phosphate (Olsen's P), as were cover of *Lolium perenne* and negative indicator species. The cover of dicotyledonous species and *Carex* (with or without *Trifolium repens* and *Ranunculus repens*) – and all positive indicator species measures were however negatively related to Olsen's P. This is considered further below in relation to site condition. Other significant soil variable effects were pH which was positively associated with *Lolium perenne* cover, but also positively associated with three out of four positive indicator species measures, and negative indicator species cover which was positively associated with magnesium level. *Lolium perenne* cover increased with loss on ignition.

Mean cover of dicotyledonous and *Carex* species, mean cover of dicotyledonous and *Carex* species minus *T. repens* and *R. repens,* mean cover of negative indicator species, and summed frequency of positive indicator species (all PHs and UHM) were all associated with later cutting dates (Table 16a). Frequency of positive indicator species (all PHs) and summed frequency of positive indicator species (UHM only) were lower where fields were grazed by modern sheep breeds in the absence of any cattle.

Number of species m^2 and cover of dicotyledonous species and *Carex,* and all measures of positive indicator species were lower where artificial fertiliser (NPK) had been applied (Table 16b).

For all tested measures of species-richness: mean number of species m^{-2}, cover of dicotyledonous species and *Carex* (with and without *Trifolium repens* and *Ranunculus repens*), frequency and summed frequency of positive indicator species (all Priority Habitats and Upland Hay Meadow only), numbers and percentage covers were significantly lower in fields not enrolled in agri-environment schemes (Table 17). All measures of species-richness were slightly higher in the HK6/GS6 sample than the HK7/GS7 sample, but the only significant difference was in numbers of positive indicator species (all habitats and UHM only), which were significantly greater in HK6 samples than in HK7 samples (Table 17).

Fields which had been enhanced by the addition of plant material in the form of seed, green hay or plug plants (HK7+) had significantly lower numbers of positive indicator species for all priority habitats and Upland Hay Meadows, and lower summed frequency of Upland Hay Meadow indicators than those sites that had not been enhanced (HK7-)(Table 18). Further analysis of core sample sites together with data from partner project sites is described in section 3.5.

Table 16. **(a)** Relationships between soil and management factors and species richness and cover variables. General Linear Model analysis: number of species m^{-2} and % cover of non-grass species – inverse gaussian model; all other variables – quasipoisson model. **Coefficients** ± standard errors. Significant results only shown. Significance levels: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$

Botanical variables	Soil variables				Management variables		
	pH	Olsen's P	Mg	Loss on Ignition	Cutting date	Livestock (modern sheep)	Intercept
Number of species per m^2		** 1.57×10^{-4} ± 5.67×10^{-5}					0.0145 ± 0.0045
Percentage cover of non-Graminae					* 0.199 ± 0.0778		3.657 ± 0.807
Percentage cover of *Lolium perenne*	** 0.837 ± 0.298	*** 0.178 ± 0.0269		* 0.167 ± 0.0792			
Percentage cover of non-grass species other than *Trifolium repens* and *Ranunculus repens*		** −0.0454 ± 0.0134			* 0.216 ± 0.0914		3.675 ± 0.964
Percentage cover of negative indicator spp		*** 0.118 ± 0.0204	** 0.0036 ± 0.00122		*** 0.695 ± 0.156		
Number of positive indicator species (all habitats)	* 0.268 ± 0.133	* −0.035 ± 0.0156				** −0.882 ± 0.332	
Summed frequency of positive indicator species (all habitats)	* 0.272 ± 0.130	* −0.0559 ± 0.0143			** 0.308 ± 0.0966		
Number of positive indicator species (UHM only)		* −0.0343 ± 0.0135				* −0.808 ± 0.326	
Summed frequency of positive indicator species (UHM only)	* 0.264 ± 0.130	*** −0.055± 0.0142			** 0.313 ± 0.096		

Table 16 **(b)** Relationships between artificial fertiliser (NPK) addition and species richness and cover variables. General Linear Model analysis: number of species m^{-2} and % cover of non-grass species with fertiliser as a categorical variable with two levels – Gaussian model. **Coefficients** ± standard errors. Significant results only shown. Significance levels: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$. df 146:144

Botanical variables	Without fertiliser	With fertiliser	Intercept
Number of species per m^2		** –3.63 ±1.30	*** 15.80 ±0.82
Percentage cover of non-Graminae		*** –23.67 ±6.46	*** 43.83 ±4.09
Percentage cover of non-grass species other than *Trifolium repens* and *Ranunculus repens*		*** –20.87 ±5.84	*** 29.69 ±3.69
Number of positive indicator species (all habitats)	** 2.61 ±0.89		*** 4.61 ±0.83
Summed frequency of positive indicator species (all habitats)	** 20.38 ±6.26		*** 31.22 ±5.83
Number of positive indicator species (UHM only)	** 2.39 ±0.81		*** 4.50 ±0.75
Summed frequency of positive indicator species (UHM only)	** 19.77 ±6.18	* –18.03 9.09	*** 31.11 ±5.75

Table 17. Differences between sites managed under HK6 (GS6), HK7 (GS7) or under no agri-environment scheme agreement in 2020. Analysis of variance, 2:144 degrees of freedom.

Botanical variable	*P*	HK6	HK7 (all)	None
Number of species per m^2	***	18.30 [a]	16.84 [a]	13.12[b]
Percentage cover of non-Graminae	***	49.86 [a]	48.81 [a]	23.72 [b]
Percentage cover of non-grass species other than *Trifolium repens* and *Ranunculus repens*	***	37.99 [a]	36.26 [a]	12.78 [b]
Number of positive indicator species (all habitats)	***	8.56 [a]	6.64 [b]	3.28 [c]
Summed frequency of positive indicator species (all habitats)	***	58.66 [a]	48.14 [a]	13.56[b]
Number of positive indicator species (UHM only)	***	8.28 [a]	6.33 [b]	3.11 [c]
Summed frequency of positive indicator species (UHM only)	***	57.79 [a]	47.54 [a]	13.33 [c]

Table 18. Differences between HK7 (GS7) sites in 2020: HK7- no enhancement, i.e. no addition of plant material; and HK7+ enhanced, with addition of plant material (green hay, seed or plug plants). ANOVA 2:144 degrees of freedom. Significance: ** $P > 0.01$

	P	HK7-	HK7+
Mean number of species per m^2		16.64	17.08
Percentage cover of non-Graminae species		45.28	48.38
Percentage cover of non-grass species other than *Trifolium repens* and *Ranunculus repens*		34.22	34.35
Number of positive indicator species (all habitats)	**	7.47	5.56
Summed frequency of positive indicator species (all habitats)		49.45	43.67
Number of positive indicator species (UHM only)	**	7.12	5.33
Summed frequency of positive indicator species (UHM only)	**	48.80	43.06

3.4.3 Ellenberg indicator values and Suited Species Scores (SSS)

Significant associations (GLMs in R) were detected between Ellenberg indices and Suited Species Scores (SSS) calculated for the hay meadow sites and some soil/management variables: these are presented in Appendix 4 as, whilst of interest, they contribute little to our understanding of the results.

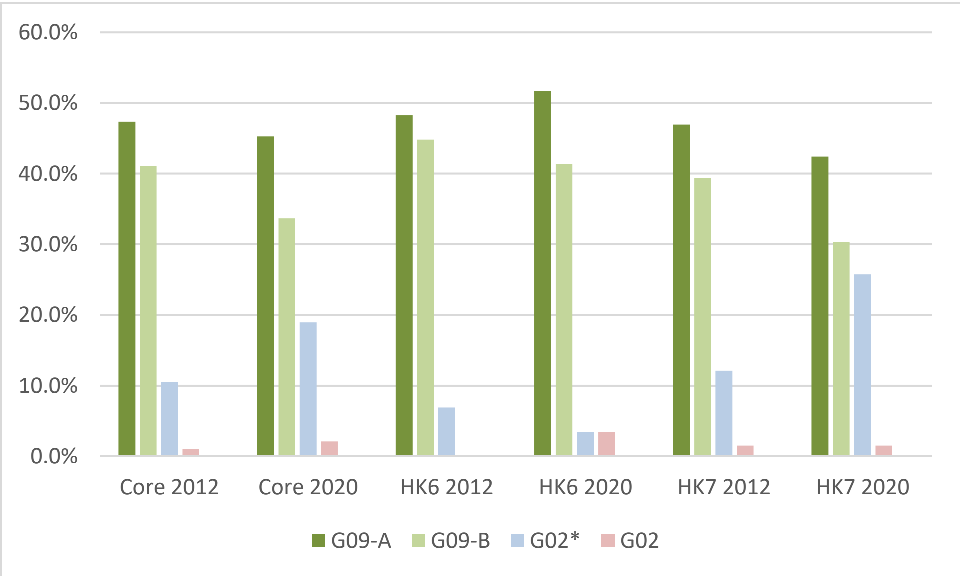
3.5 Changes in the core sample from 2012 to 2020

Data from the core sample (sites surveyed in both 2012 and 2020) were compared in order to determine any changes that had occurred since the previous survey in 2012 and any differences between meadows managed under HLS options for maintenance and restoration (HK6 and HK7).

3.5.1 BEHTA condition assessment

Figure 19 shows the results of the condition assessment using BEHTA guidelines and criteria (Natural England, 2016) for the 95 sites in the core sample that were surveyed in both 2012 and 2020. There has been a small decrease (from 47.4% in 2012 to 45.3% in 2020) in the proportion of sites that are assessed as G09 priority habitat (any condition) for the sample, when considered as a whole. There has been an increase in the proportion of sites in scheme option HK6/GS6 from 48.3% in 2012 to 51.7% in 2020 that are in Favourable condition. In the HK7/GS7 sample condition has declined with fewer sites in Favourable condition and a greater proportion assessed as good semi-improved (12.1% G02* good semi-improved in 2012 compared with 25.8% in 2020). Losses and gains between these condition categories are considered in Table 19.

Figure 19. Results of the condition assessment for the core sample (n = 95) stratified by year and scheme option, showing percentage of sites in sample group in each condition category.



HK6/GS6 – Maintenance of species-rich grassland

Of 14 sites in Favourable condition (G09-A) in 2012, nine had maintained condition in 2020 while five had declined and were Unfavourable (G09-B, 4 sites) or were no longer species-rich grassland (G02*, 1 site). Of 13 sites in Unfavourable G09 condition (G09-B) in 2012, six had improved, achieving Favourable condition while the remaining seven demonstrated no change (remained as G09-B Unfavourable). Of the two G02* good semi-improved sites under HK6 in 2012, one improved (G09-B) and one deteriorated (G02 – poor SI) by 2020.

HK7/GS7 – Restoration of species-rich grassland without and without enhancement

Of 31 sites in Favourable G09 condition (G09-A) in 2012, 23 maintained Favourable condition by 2020 while eight deteriorated to the point where they no longer achieved Favourable status. Of 26 sites in Unfavourable condition (G09-B) in 2012, five achieved Favourable condition, 14 showed no change (stayed as G09-B Unfavourable), while seven deteriorated and were no longer priority habitat. There were nine G02* good semi-improved stands in the 2012 HK7 sample. None of these had undergone a change of status by 2020.

The fate of the 16 sites in the core sample of HK7 sites that had received sward enhancement measures (HK7+) was compared with the 50 sites that had not been enhanced (HK7-). Although numbers in the enhancement sample were small, the non-enhanced HK7- sample fared better, with a greater proportion maintaining good condition and a lower proportion deteriorating (Table 20).

These results can be summarised in terms of the impact of HLS management: a 'Good' outcome would be maintaining G09-A, or increasing (restoring) condition by one or more categories. A 'Neutral' outcome would be maintaining Unfavourable condition G09, as it is at least maintaining the grassland feature albeit at a sub-optimal condition (B-B only). A 'Bad' outcome would be losing condition by one or more categories or maintaining non-G09 grassland (i.e. good/poor semi-improved) rather than restoring to G09. These categories are shown in the 'Outcome' column in Tables 19 and 20.

More sites in all three option categories (Table 21) had a greater proportion of sites with a good outcome than a neutral or a poor outcome, and good plus neutral outcomes exceeded bad outcomes in all categories. The behaviour of sites that have been enhanced is further explored for the whole data set including partner project enhancement sites in section 3.6.

Stands within SSSIs regardless of scheme option type, demonstrated more positive outcomes than non-SSSI stands (any option) (Table 21). Fifteen of the 22 SSSI stands were in the A-A outcome category, with a further stand in B-A. Of the three with a poor outcome, one was flood damaged.

Table 19. A summary of the fate of individual sites within the core sample: proportions of sites within each condition class in 2012 maintaining their condition class, declining in condition or improving condition.

Condition 2012–2020	CORE ALL *n* = 95	CORE HK6 *n* = 29	CORE HK7 *n* = 66	Description of change	Outcome
A–A	71.1%	64.3%	74.2%	Maintained G09 Fav. Condition	Good
A–B	22.2%	28.6%	19.4%	Decline from G09 Fav to Unfav cond	Bad
A–G02*	6.7%	7.1%	6.5%	Decline from G09 Fav to Good SI only	Bad
B–A	28.2%	46.2%	19.2%	Restored to G09 Fav. condition	Good
B–B	53.8%	53.8%	53.8%	Maintained G09 Unfav condition	Neutral
B–G02*	17.9%	0.0%	26.9%	Decline from G09 Unfav to Good SI only	Bad
G02*–B	10.0%	50.0%	0.0%	Restored from Good SI to G09 Unfav	Good
G02*–G02*	70.0%	0.0%	87.5%	Maintained Good SI	Bad
G02*–G02	20.0%	50.0%	12.5%	Decline from Good SI to Poor SI	Bad
G02–G02*	100.0%	0.0%	100.0%	Restored from Poor SI to Good SI	Good

Table 20. A summary of the fate of individual sites within the core HK7/GS7sample: proportions of sites within each condition class in 2012 to maintain their condition class, deteriorate or be restored to better condition, stratified by enhancement (HK7- versus HK7+)

Condition 2012–2020	HK7 ALL *n* = 66	HK7- *n* = 50	HK7+ *n* = 16	Description of change	Outcome
A-A	74.2%	76.0%	66.7%	Maintained G09 Fav. Condition	Good
A-B	19.4%	16.0%	33.3%	Decline from G09 Fav to Unfav cond	Bad
A-G02*	6.5%	8.0%	0.0%	Decline from G09 Fav to Good SI only	Bad
B-A	19.2%	16.7%	25.0%	Restored to G09 Fav. condition	Good
B-B	53.8%	61.1%	37.5%	Maintained G09 Unfav condition	Neutral
B-G02*	26.9%	22.2%	37.5%	Decline from G09 Unfav to Good SI only	Bad
G02*-B	0.0%	0.0%	0.0%	Restored from Good SI to G09 Unfav	Good
G02*-G02*	87.5%	85.7%	100.0%	Maintained Good SI	Bad
G02*-G02	12.5%	14.3%	0.0%	Decline from Good SI to Poor SI	Bad
G02-G02*	100.0%	0.0%	100.0%	Restored from Poor SI to Good SI	Good

Table 21. Good, neutral and bad outcomes for the core sample stratified by scheme option and by no enhancement (HK7-) or with enhancement (HK7+). Values are percentage of the total number of sites in 'Option' category.

Option	Good outcome	Neutral outcome	Bad outcome
	A-A, B-A, G02*-B, G02-G02*	B-B	A-B, A-G02*, B-G02*, G02*-G02*, G02*-G02
HK6	55.2%	24.1%	21.2%
HK7-	44.0%	22.0%	34.0%
HK7+	43.8%	18.8%	37.5%
SSSI	81.8%	4.6%	13.6%

3.5.2 Changes in vegetation composition and diversity

Species richness and positive indicators

Change in mean number of species per m^2 quadrat per site in the core sample meadows from 2012 to 2020 was explored using paired T-tests (95% CI, Minitab 17). There was a significant decrease in mean number per $1m^2$ (Table 22). When stratified by scheme option, mean richness per quadrat was also significantly higher for the HK6/GS6 sample in 2012 than 2020 and for the HK7/GS7 sample.

Data on positive indicator species was collected from a single 20-stop walk across each site, in both 2012 and 2020. The change in the number of positive indicator species could therefore be directly compared between years using paired T-tests (95% CI; Minitab 17). Whilst there was a small decrease in number of positive indicators from 2012 to 2020 this change was not significant for the whole core sample, or when stratified by scheme option. A decrease in summed frequency of positive indicators from 2012 to 2020 was however significant (P > 0.01) and when stratified by scheme option the HK7 sample had a significant decrease in summed frequency (Table 23).

Table 22. Core sample: changes in mean number of species m^{-2} between 2012 and 2020. Paired T-Test, Minitab 17. Significance: *** P < 0.001

Option	2012	2020	*P*	*n*
HK6 and HK7	21.48	17.45	***	95
HK6 only	22.14	18.29	***	29
HK7 only	21.19	17.07	***	66

Table 23. Core sample: changes in (a) mean number of positive indicators per site and (b) mean summed frequency per site between 2012 and 2020. Paired T-Test, Minitab 17. Significance: *** P < 0.001, ** P < 0.01, * P < 0.05.

(a) Option	2012	2020	*P*	*n*
HK6 and HK7	8.17	7.80	ns	95
HK6 only	9.17	8.59	ns	29
HK7 only	7.28	7.46	ns	66

(b) Option	2012	2020	*P*	*n*
HK6 and HK7	60.99	53.78	**	95
HK6	66.93	58.66	ns	29
HK7	58.38	51.64	*	66

The change in parameters of species richness were explored in relation to condition outcomes (good, neutral or bad outcomes) over time to investigate which variable or variables of species diversity contributed to change in BEHTA condition category over time. Whilst the good outcome sites saw an increase in the number and frequency of positive indicator species, which was significantly different to the losses seen in the bad outcome sites (Table 24), the mean change was very low and species richness within the good outcome sites decreased.

Table 24. ANOVA with post-hoc Tukey pairwise comparisons (95% CI) of species richness variables contributing to change in condition (condition outcome) from 2012 to 2020, shown as mean change (± SD) from 2012–2020. Good outcome: A-A, B-A, G02*-B, G02-G02*; Neutral outcome: B-B ; Bad Outcome: A-B, A-G02*, B-G02*, G02*-G02*, G02*-G02. Means that do not share a letter are significantly different. Significance: ** *P* > 0.01, *** *P* > 0.001.

	Change in mean from 2012 to 2020		
Condition outcome	Number of species per m^2	Number of positive indicators per site	Summed frequency of positive indicators per site
Good outcome	−3.321 ± 2.959	0.689 ^{a} ± 2.653	1.96 ^{a} ± 30.40
Neutral outcome	−4.143 ± 3.798	−0.762 ^{ab} ± 3.113	−11.33 ^{ab} ± 19.75
Bad outcome	−5.064 ± 3.252	−1.759 ^{b} ± 2.099	−18.45 ^{b} ± 17.41
P	ns	**	***

3.5.3 Explanatory variables for change in stand condition over time

There were few associations between soil chemistry and change in species richness (Table 25). The largest was for sites with high pH to show an increase in summed frequency of positive indicator species. There were weak and contradictory associations between summed frequency and total number of species m^{-2} and potassium, and an increase in positive indicator species at higher nitrogen levels.

No significant relationship between phosphate and change in species richness was found in this analysis: however, when the relationship between Olsen's P and stand condition noted in section 3.3 was explored with regard to condition 'outcome' categories, sites with a neutral or good outcome had significantly lower levels of Olsen's P than those with a bad outcome (Figure 20). There was also a moderately significant association between stand condition outcomes and soil potassium, with significantly lower potassium in stands with a good outcome. No other significant associations between condition outcome and soil chemistry variables were identified.

There was a positive association between an increase in number of positive indicator species and summed frequency of positive indicators and cutting for hay, relatively late cutting date and cattle grazing .

Table 25. Associations between changes in parameters of species-richness and soil and management variables in core sample sites between 2012 and 2020. Probabilities, coefficients and standard errors, GLM, Gaussian model. df = 83:61. Significant variables only shown. Significance levels: *** *P* < 0.001, ** *P* < 0.01, * *P* < 0.05

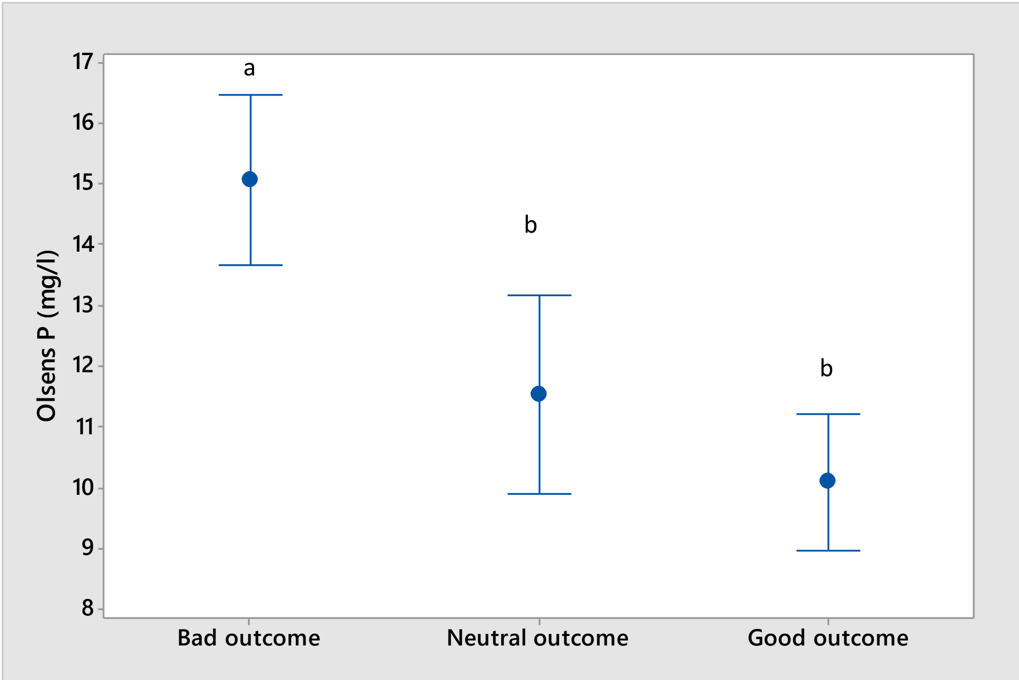
	pH	K	N	Crop (hay)	Cutting date	Stock (modern cattle)	Intercept
Change in number of species m^{-2}		* 0.002 ± 0.0007					* –13.37 ± 6.60
Change in total number of +ve indicator species (all priority habitats)			* 2.80 ± 1.22	* 1.59 ± 0.65		*** 9.86 ± 2.85	
Change in summed frequency of +ve indicator species (all priority habitats)	* 15.3 ± 7.21	* –0.116 ± 0.052		* 13.10 ± 6.50	* 14.55 ± 5.55		* –122.8 ± 47.8

3.6 Changes in the sward enhancement sample from pre- to post-enhancement 2006–15 to 2020

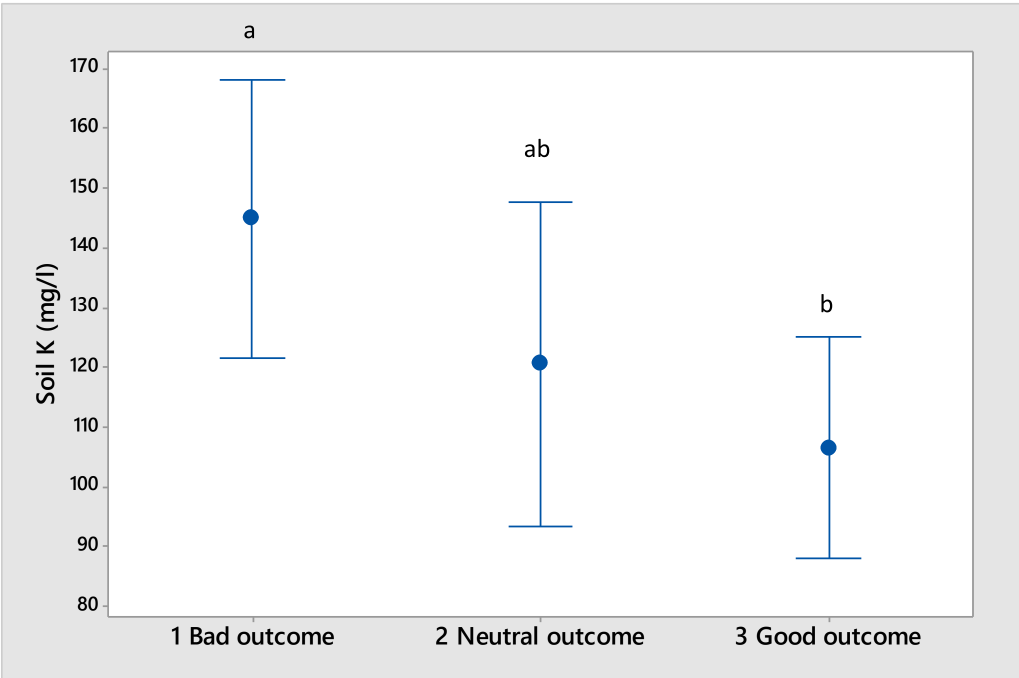
Results already reported in earlier sections for the 'enhancement' sample refer to their condition in 2020; and for the 16 sites in the core sample that had received sward enhancement, refer to change between 2012 and 2020. The results for the enhancement sites in 2020 show them to be of lower condition than the core sample sites – HK6 and unenhanced HK7 sites. The following analyses explore the project partner sites as a stand-alone sample and use the baseline data collected by those projects prior to sward enhancement (2006–2015, variously): the timing of these baseline surveys and subsequent sward enhancement activity. This data set is composed of the 32 of the 34 project partner sites (baseline data from 2 sites not available) plus the 16 sites in the core sample that were also part of a previous partner organisation's enhancement project and explores change within this sample relative to their starting point prior to enhancement.

Paired T-tests (95% CI; Minitab 17) were carried out to explore the change in variables within and between the 48 enhancement sites. There was a significant increase (*P* > 0.001) in the mean number of positive indicator species recorded within each site in the resurveyed sample in 2020 (5–14 years after enhancement: 5.72 ± 2.97 SD) compared with the same sites in the baseline survey prior to enhancement measures (mean 4.14 ± 2.58 SD) (Figure 21). There was also a significant increase in the summed frequency (frequency per species per site on a 5-point scale) of positive indicators within sites (mean 8.50 ± 5.41 SD compared with 13.77 ± 5.65 SD after enhancement (*P* > 0.001) (Figure 22). Overall, 60% of sites saw an increase in the number and 90% of sites saw an increase in the summed frequency of positive indicator species on their pre-enhancement baseline survey. The change in total number and summed frequency of positive indicator species was also investigated in relation to time elapsed since enhancement: no significant differences were found.

Figure 20. Interval plot of mean (a) Olsen's P (mg/l) and (b) soil Potassium (K mg/l) for categories of condition outcome (with 95% CI bars) in core sample from 2012 to 2020: Tukey Pairwise comparisons. Means that do not share a letter are significantly different.



(a)



(b)

Figure 21. Boxplot showing the distribution of data for positive indicator species (total number of positive indicators per site in W-walk) in the baseline survey prior to sward enhancement and for the 2020 resurvey ≥ 5 years after sward enhancement: mean, median, quartiles and outliers are shown.

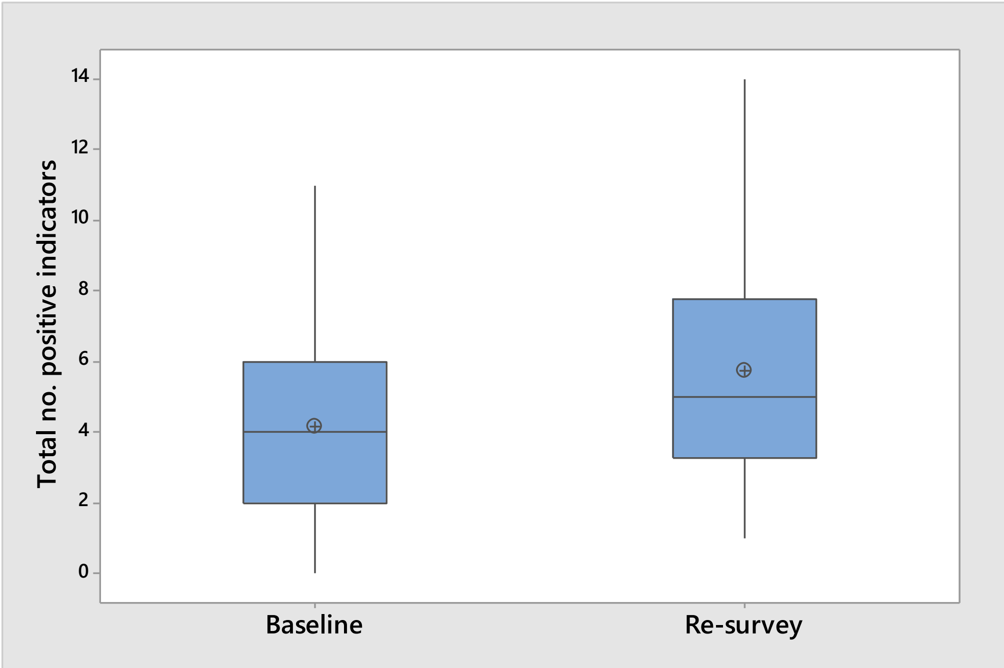
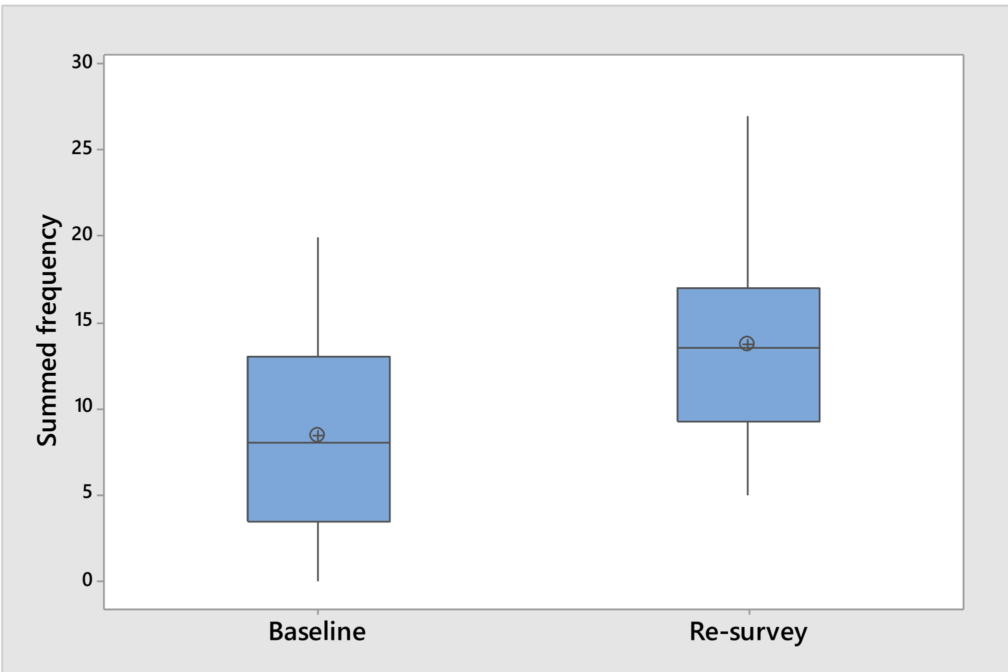


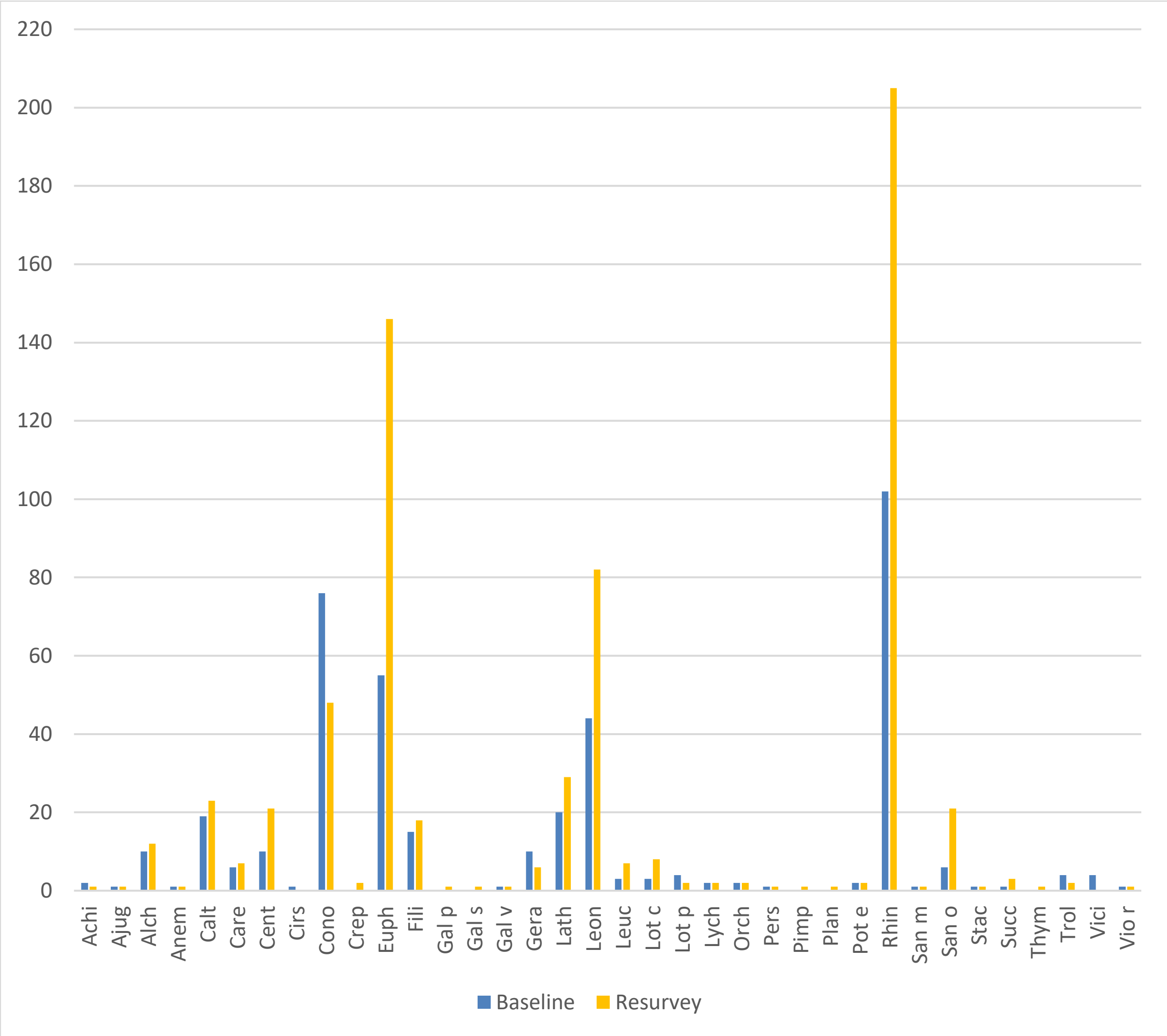
Figure 22. Boxplot showing the distribution of data for positive indicator species (summed frequency of all species per site in W-walk) in the baseline survey prior to sward enhancement and for the 2020 resurvey ≥ 5 years after sward enhancement: mean, median, quartiles and outliers (*) are shown.



Paired T-tests were also employed to explore the change in occurrence and frequency of individual species within sites over time (pre- and post-enhancement). Figure 23 shows the summed frequency of individual wildflower indicator species recorded within the enhancement sample prior to (baseline) and post-enhancement (resurvey). Whilst *Rhinanthus minor, Euphrasia vulgaris* agg. and *Leontodon* spp. showed clear increases in summed frequency across the whole sample, the change in summed frequency for individual species within the sample, when considered as a whole was not significant (Paired T-Test, 95% CI, $P = 0.086$; Minitab 17) – many individual species saw minor changes and most were infrequent. However, when the number of sites occupied by individual positive indicator species was explored, regardless of frequency within the site, the change from baseline to resurvey in number of sites supporting a species was significant (mean occurrence of indicator within site per species was 4.23 ± 7.82 compared with 5.85 ± 10.68 SD Paired T-Test, 95% CI, $P = 0.021$). Figure 24 shows the relative gains/losses for individual species. Whilst some species (*Geranium sylvaticum, Conopodium majus, Achillea ptarmica* and *Trollius europaeus*) were lost from some sites following the baseline survey and subsequent enhancement, the majority saw positive change in the number of sites occupied. Whilst *Rhinanthus minor* had the greatest summed frequency for the whole sample in 2020, *Euphrasia* was the most successful in colonising new sites.

Note: As the source of the plant material (hay, seed or plugs) varied by project, by collection date and by site, the positive indicator species 'available' within the plant material used to inoculate the site also varied, so the failure of any given species to colonise a site should be viewed with caution. For example, plants of *Geranium sylvaticum* – a species that is relatively late in the season to set seed – may have been present in a donor meadow but ripe seed may not be present in a hay cut.

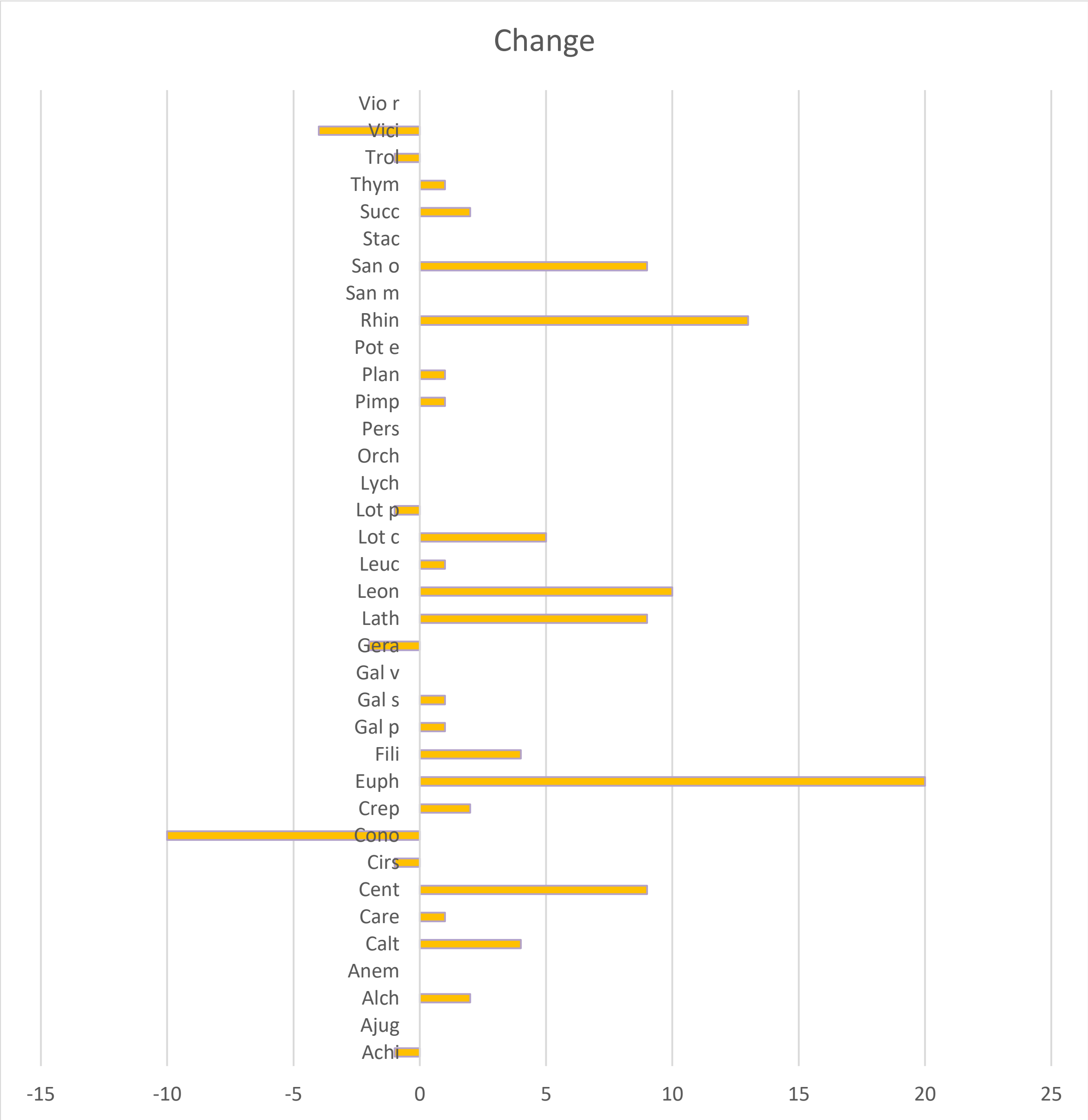
Figure 23. The summed frequency of individual positive indicator species within the entire 'enhancement' sample for the baseline survey prior to sward enhancement and for the 2020 resurvey ≥ 5 years after sward enhancement.



Key to species (those in bold are G09 UHM wildflower indicator species)

Achi	**Achillea ptarmica**	Gal p	Galium palustre	Pimp	**Pimpinella saxifraga**
Ajug	**Ajuga reptans**	Gal s	Galium saxatile	Plan	Plantago media
Alch	**Alchemilla**	Gal v	Galium verum	Pot e	**Potentilla erecta**
Anem	**Anemone nemorosa**	Gera	**Geranium sylvaticum**	Rhin	**Rhinanthus minor**
Calt	**Caltha palustris**	Lath	**Lathyrus pratensis**	San m	Sanguisorba minor
Care	Carex flacca/nigra/panicea	Leon	**Leontodon**	San o	**Sanguisorba officinalis**
Cent	**Centaurea nigra**	Leuc	Leucanthemum vulgare	Stac	Stachys officinalis
Cirs	**Cirsium heterophyllum**	Lot c	**Lotus corniculatus**	Succ	**Succisa pratensis**
Cono	**Conopodium majus**	Lot p	**Lotus pedunculatus**	Thym	Thymus sp.
Crep	Crepis paludosa	Lych	**Lychnis flos-cuculi**	Trol	**Trollius europaeus**
Euph	**Euphrasia**	Orch	**Orchidaceae**	Vici	Vicia cracca
Fili	**Filipendula ulmaria**	Pers	**Persicaria bistorta**	Vio r	Viola riviniana

Figure 24. The change in the total number of sites in the enhancement sample (*n* = 48) occupied by individual positive indicator species for the resurvey compared with the baseline. Any species that occupied the same number of sites has a zero score. Positive change is to the right, negative to the left.



3.7 Change in the non-agreement control sample 1987/92 to 2020

Eighteen of the 20 stands that were selected as a non-agreement control sample were surveyed in 2020. These 18 stands had been part of the original ESA monitoring programme in the 1980s/1990s and had baseline survey data from this time. Three of the 18 stands, it was subsequently discovered, did not enter the ESA scheme but the remaining 15 did: all 18 sites have not been under any form of agri-environment scheme management since the end of the ESA scheme.

The three sites that were never in the ESA scheme were surveyed in 1987, at which point they were recorded as supporting MG7a perennial ley and were meadows managed for silage. One site supported no upland hay meadow positive indicators at that time but the second supported *Alchemilla vulgaris* agg., *Leontodon* spp. and *Sanguisorba officinalis.* The third of this trio of silage fields supported the latter two species in this list too. These three fields are still meadows and shut from mid-May to late June; they receive applications of NPK and are grazed by sheep and dairy heifers. However, as they had recently been cut when surveyed in 2020 these three fields have been removed from the following analysis. No sign of positive indicators was found in the main stand or on the margins, which may show decline or may be a function of the recent hay cut.

Data for the fifteen meadows that did enter the ESA scheme were explored. Table 26 overleaf provides descriptive data for the 15 non-agreement sites during the baseline survey in 1987 (sites 14 to 6004) and 1992 (sites 7115 to 20027), and the status of these sites in the re-survey in 2020. All 15 sites were managed as traditional meadows as they entered the ESA scheme, whereas in 2020 eight (53%) had changed to permanent sheep pasture, three of which were occasionally cut for silage. One site had been planted with trees over half of the area and the remainder appeared unmanaged. Six sites (40%) were still managed as traditional meadow for hay and/or haylage.

The character of the vegetation in the ESA meadows had previously been described using the English Nature grading scheme (Alcock, 1982) or using TWINSPAN analysis (ADAS, 1996). Twinspan is a data analysis technique which uses the same algorithm as Detrended Correspondence Analysis but which provides a dichotomous classification of the data rather than an ordination. The endgroups resulting from TWINSPAN had been identified with NVC types or groups. Whilst statistical analysis of change in NVC community is not possible from the available data, which for 1987/92 lacks quantitative data, there are apparent changes in the NVC community to which stands had the closest affinity during the baseline survey in 1987/92 and the resurvey in 2020 (Table 26). The two English Nature grade 3B meadows in 1987, which represent good quality neutral grasslands (ADAS, 1996) are described as MG6b in 2020. The five TWINSPAN group E meadows, which showed closest affinities to semi-improved MG3a in 1987/92 (rather than improved MG3/MG7 as in group B; Critchley *et al.*, 2004) are also described as MG6b in 2020. Whilst this might represent a difference in community interpretation, it is clear that eleven sites have seen a negative change in the mean number of species per quadrat.

Changes in the mean number of species per quadrat and the change in number and frequency of traditional hay meadow positive indicator species further explored (Table 27).

Table 26. Descriptive data of the character of the non-agreement control sites when first monitored in 1987 or 1992, and for the same sites in the 2020 re-survey. In 1987–92 stands were coded as Meadow or Pasture. Codes 3A and 3B refer to the English Nature grading system (Alcock, 1982) where Grade 4 is highest ecological value and Grade 2 lowest. Grade 3B supports more indicator species of traditional management than 3A. Not all sites were coded. Letters with NVC codes in column 2 refer to groups arising from TWINSPAN analysis of quadrat data (Critchley *et al.,* 2004) based on presence data only.

Site	1987/92		2020		Change in mean number of species per quadrat from 1987/92 to 2020
14	Meadow	MG3a (MG1?)	Hay meadow	MG6b	–3.53
29	Meadow	MG3a	Sheep pasture	MG7	–11.0
2004	Meadow (3A)	E - MG3a	Hay meadow	MG6b	+2.40
2009	Meadow (3B)	C - MG8 (MG6b)	Sheep pasture	MG8	+0.40
4020	Meadow (3B)	B - MG3a (MG7c)	Hay meadow	MG6b	–0.60
4041	Meadow (3A)	B - MG3a (MG7c)	Hay meadow	MG3a	+1.60
6004	Meadow (3A)	B - MG3a (MG7c)	Hay meadow	MG7	–13.20
7115	Meadow (3B)	E - MG3a	Sheep pasture	MG6b	–9.20
12001	Meadow	E - MG3a	Sheep pasture	MG6b	–9.20
12002	Meadow	E - MG3a	Sheep pasture	MG6b	–10.40
15001	Meadow	A - MG6a (MG7b)	Trees planted	MG6b	–3.80
19005	Meadow	E - MG3a	Hay meadow	MG6b	–7.20
20006	Meadow	B - MG3a (MG7c)	Pasture/Silage	MG6b	–2.80
20026	Meadow	C - MG8 (MG6b)	Pasture/Silage	MG6a	–0.60
20027	Meadow	C - MG8 (MG6b)	Pasture/Silage	MG8	–0.20

Table 27. Species richness variables calculated for the non-agreement control group for those sites that were in an ESA agreement but did not enter HLS (n = 15). Analysis of Variance (repeated measures ANOVA; in R with post-hoc Tukey pairwise HSD tests), 95% CI. Means that do not share a letter are significantly different. Significance: ***$P < 0.001$

Variable	1987/92	1995	2020	SE of means	*P*
Mean number of species per m^2 quadrat	19.68 ^{a}	21.92 ^{a}	14.89 ^{b}	0.741	**
Mean number of positive indicators per site	5.13 ^{a}	4.47 ^{a}	2.67 ^{b}	0.492	*
Mean summed frequency of positive indicators per site	10.00	9.87	5.07	-	ns

The mean number of species per $1m^2$ quadrat increased from the baseline survey in 1987/92 to 1995, but had decreased significantly by 2020 ($P < 0.001$)(Table 27, Figure 25a). The mean number of positive indicator species also decreased significantly from the baseline survey in 1987/92 to 2020.

Quadrat data were used to explore presence and frequency of traditional hay meadow positive indicator species as no condition assessment was carried out in 1987, 1992 or 1995 to compare with the 2020 assessment. The mean number of positive indicator species per site decreased from 1987/92 to 1995 and decreased further in 2020, although this decrease was not significant at 95% CI (Figure 25b). The summed frequency of positive indicator species across the five quadrats per site also decreased from 1987/92 to 1995, and 1995 to 2020 but again not significantly at 95% CI (Figure 25c). As losses in hay meadow indicator species had occurred over time since leaving the ESA scheme, losses of individual species were explored (Figure 26).

The current management of the sites was explored with variables: managed as meadow (n = 6), compared with <u>not</u> managed as meadow (n = 9). Meadows suffered lower mean losses in number of species per m^2 from 1987/92 to 2020 compared with non-meadows (difference of –3.42 compared with –5.20, respectively) but the sample size for each group was very small and this result was not significant.

Seven (30%) of the 23 positive indicators of traditionally managed hay meadows recorded within the sample increased in summed frequency from the baseline survey in 1987/92 to the resurvey in 1995 (*Caltha palustris, Carex flacca/nigra/panicea*, *Cirsium heterophyllum, Conopodium majus*, *Euphrasia officinalis* agg., *Filipendula ulmaria, Leontodon* spp. and *Rhinanthus minor*). Two upland calcareous grassland species *Primula farinosa* and *Sanguisorba minor* also appeared in the quadrat data in 1995 where they had not been recorded previously – data not shown). The remaining 16 species remained at the same frequency or declined by 1995.

Following the increases noted in 1995, by 2020 many species declined: 10 species (44%) were at lower summed frequency within the sample in 2020 than in the baseline survey in 19987/92 or had disappeared completely from any quadrat (7 species, 30%).

Of 23 positive indicators, therefore, 17 (74%) were at lower summed frequency in 2020 than in 1987/92. Species that retained or increased their frequency from 1987/92 to 1995 and again to 2020 were *Caltha palustris, Carex flacca/nigra/panicea, Filipendula ulmaria, Lychnis flos-cuculi, Primula veris* and *Sanguisorba officinalis.* All increases were very small – presence in an additional one or two quadrats only out of a possible 75 quadrats – and it should be noted that the summed frequency of all positive indicator species was very low. *Leontodon* spp., *Rhinanthus minor, Conopodium majus* and *Euphrasia officinalis* agg. were the most frequent but these still only occupied 45%, 27%, 19% and 19% of quadrats respectively in 1987/92 and by 2020 these same species occupied 19%, 11%, 1% and 11% of quadrats respectively. Most other species occupied very few quadrats across the sample (Figure 26).

Changes in species variables in the non-agreement control sample in comparison with the core sample of stands that were under HLS management for the long-term data set is investigated in the following section.

Figure 25. Interval plot of the mean number of species (a), the mean number of positive indicator species (b) and the mean summed frequency (c) out of five quadrats at each non-agreement control sample site in 1987/92, 1995 and 2020. 95% CI shown.

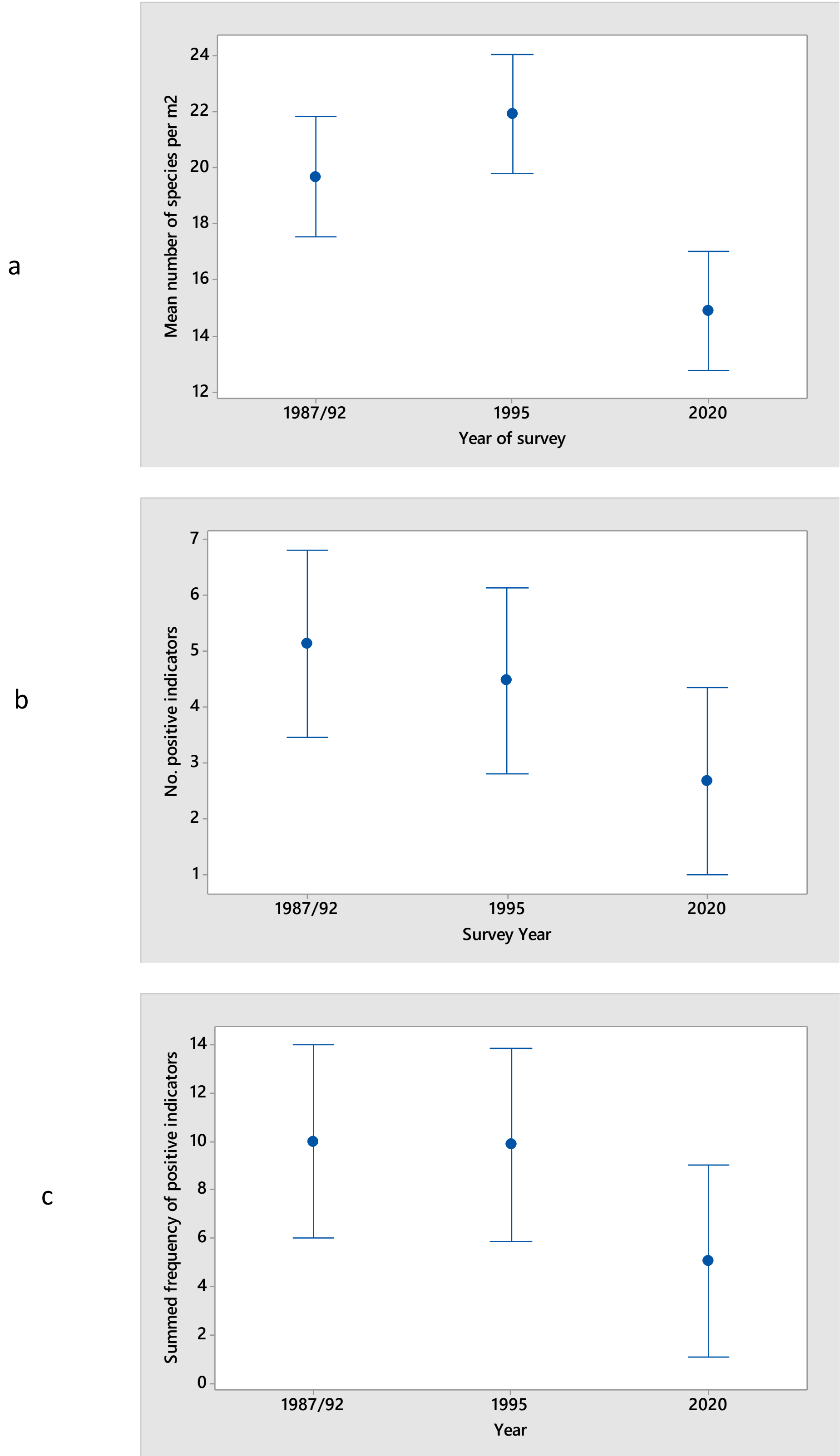
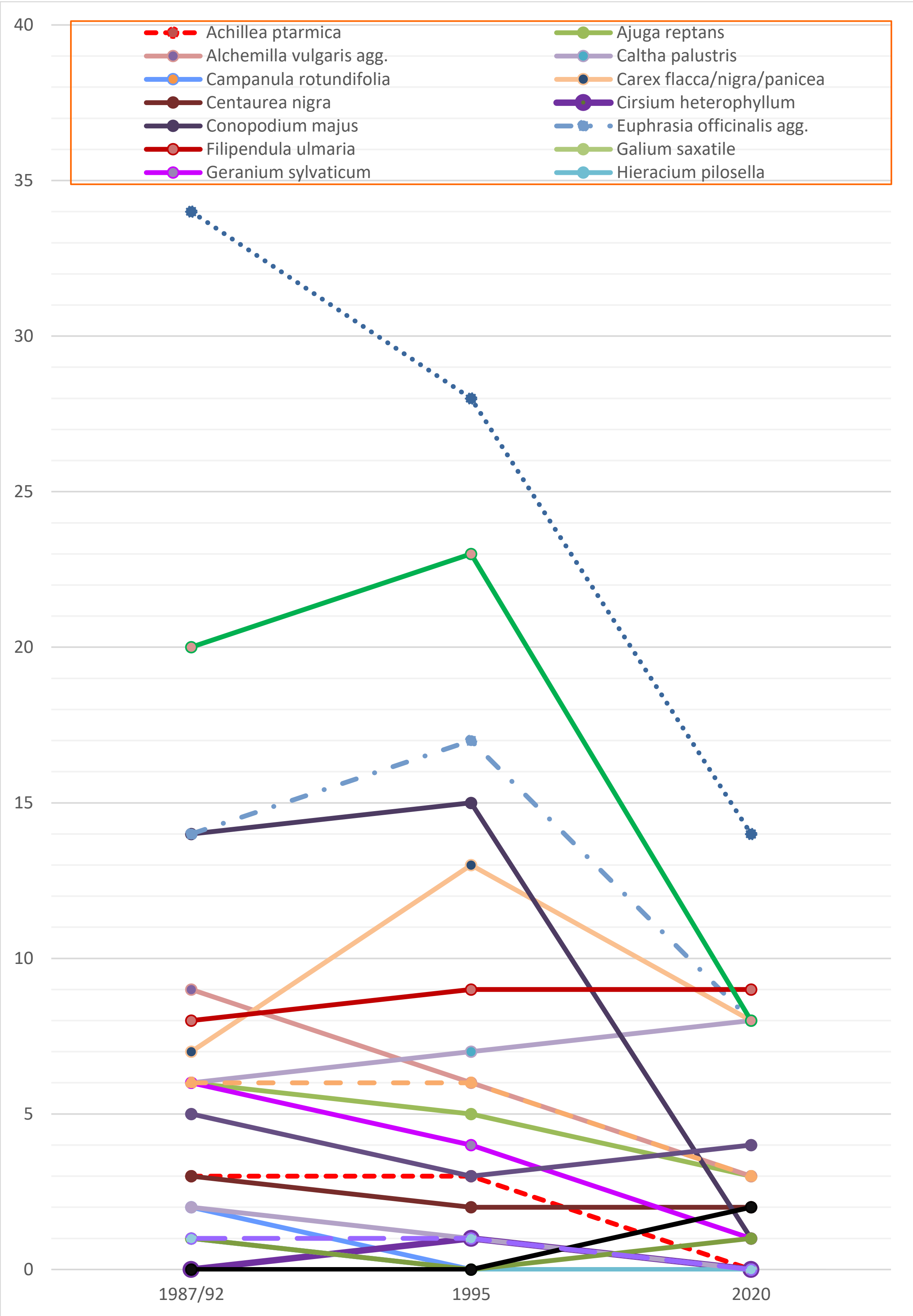


Figure 26. The summed frequency of hay meadow positive indicator species across all five quadrats and all 15 former ESA scheme sites in the non-agreement control group during the baseline survey 1987/92, the resurvey 1995 and the resurvey 2020. Quadrat total *n* = 75.



3.8 Longer-term changes in the condition of UHM stands in response to scheme management

Longer-term changes in relation to time and management (including sward enhancement) were investigated for all sites where runs of data were available. For 2002, 2012 and 2020, quantitative data from quadrats were available (% cover), but in the majority of earlier surveys from 1987–1995 vegetation was recorded on the DAFOR scale only. All data were therefore transformed to presence/absence. Condition assessment data were not available for surveys from 1987–2002.

3.8.1 Core sample data from 2020, 2012 and 2002

Quantitative vegetation data from the 95 core sample sites were examined using the Canonical Correspondence Analysis function in Canoco 5.1 for the years 2002 (partial survey, n = 53), 2012 and 2020 (both n = 95). The explanatory variables Year, HK6 and HK7 options, sward enhancement and no sward enhancement were used. Year, HK6 and HK7 were significant at $P < 0.002$, but the enhancement criteria were not (Table 28).

Table 28. Canonical Correspondence Analysis of vegetation data from the core sample in 2002 (n = 53), 2012 and 2020 (n = 95 for both). Eigenvalues and percentage of variation explained by axes. Significant terms: Year $P < 0.002$, HK6 $P < 0.002$, HK7 $P < 0.002$.

	% of variation explained by the ordination axes (cumulative)	Eigenvalues
Axis 1	1.16	0.0335
Axis 2	1.98	0.0239
Axis 3	9.29	0.2113
Axis 4	14.78	0.1590

Ellenberg Indices and Suited Species Scores were analysed by Repeated Measures ANOVA in relation to Year (2002, 2012, 2020), Option (HK6 and HK7), Restoration (enhancement and no-enhancement), and interactions between year and option and year and restoration (Table 29). Neither interaction term was significant for any EI or SSS, and these are omitted from the table.

The only parameters which showed significant differences between years were Ellenberg Index F (moisture) and SSS Moisture, both of which increased significantly between 2002 and 2012. SSS Grazing Index was significantly higher in HK7+ fields than in HK7- fields, while SSS Nutrient was significantly higher in HK7 fields than in HK6 fields.

Table 29. Analysis of Variance (repeated measures ANOVA; in R with post-hoc Tukey pairwise HSD tests) of Ellenberg Indices and Suited Species Scores: (a) by years 2002, 2012 and 2020, df 2:239; and (b) by option. Significance: *** $P < 0.001$, ** $P < 0.01$, ns Not Significant. Superscript letters: means that do not share a letter are significantly different at $P < 0.05$.

(a)	2002	2012	2020	SEM	*P*
Ellenberg Indices					
L Light	7.05	7.08	7.08		ns
F Moisture	5.36^{a}	5.45^{b}	5.44^{b}	0.019	**
R Reaction	5.80	5.73	5.73		ns
N Nitrogen	4.63	4.53	4.57		ns
Suited species scores					
Grazing Index	0.37	0.42	0.36		ns
Nutrient	–0.08	–0.12	–0.08		ns
Moisture	-0.05^{a}	0.00^{b}	0.02^{b}	0.0073	**

(b)	HK6	HK7-	HK7+	SEM	*P*
Ellenberg Indices					
L Light	7.05	7.07	7.09		ns
F Moisture	5.43	5.48	5.34		ns
R Reaction	5.70	5.76	5.80		ns
N Nitrogen	4.47	4.60	4.65		ns
Suited species scores					ns
Grazing Index	0.38^{ab}	0.36^{a}	0.40^{b}	0.0051	**
Nutrient	-0.14^{a}	-0.08^{b}	-0.06^{b}	0.0061	**
Moisture	–0.01	0.02	–0.04		ns

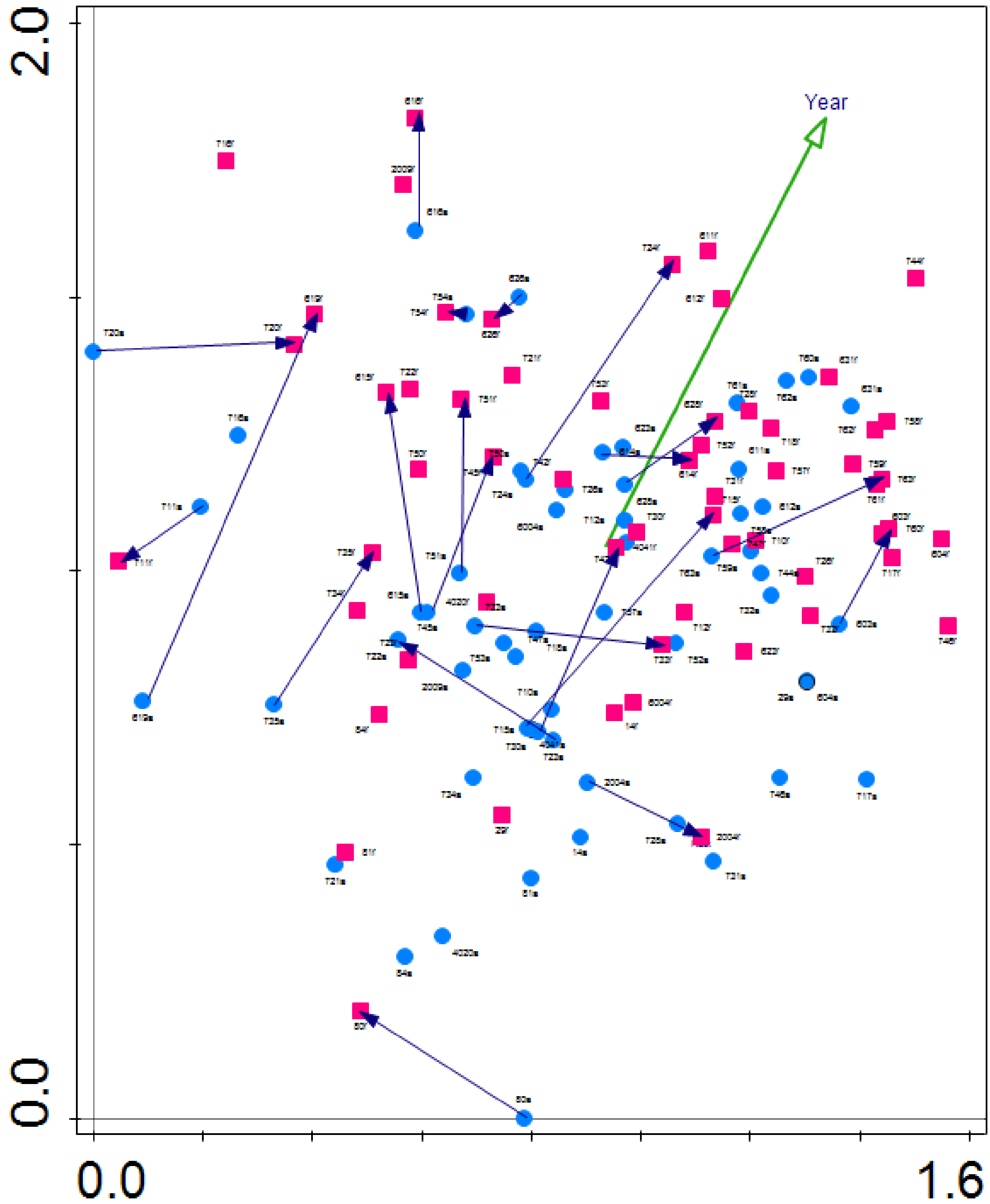
3.8.2 1987–2020 data

Two Canonical Correspondence Analyses were performed on the full dataset. In the first, data from all years were included (Table 30) while in the second, only data from 1987/88 and 2020 were used (Figure 27). In both of these analyses the variables Year, Restoration (sward-enhancement and no sward-enhancement) and scheme option (HK6, HK7 and none) were included in the fitted model, and the effects of all of these were significant at $P < 0.002$.

Table 30. Canonical Correspondence Analysis of vegetation data from the full data set (1987 to 2020). Eigenvalues and percentage of variation explained by axes. Significant explanatory variables: Year $P < 0.002$, HK6 $P < 0.002$, HK7 $P < 0.002$, no option $P < 0.002$, sward enhancement $P < 0.002$.

	% of variation explained by the ordination axes (cumulative)	Eigenvalues
Axis 1	0.87	0.0415
Axis 2	1.61	0.0350
Axis 3	2.08	0.0227
Axis 4	2.43	0.0163

Figure 27. CCA ordination for 1987 (blue circles) and 2020 (red squares) only with variables of scheme option (HK6, HK7 and 'none') and year. Change is shown by arrows for a representative selection of 20 sites.



In Figure 27, arrows join the points representing the same site in the two survey years, illustrating the change in vegetation within the space represented by the first two axes of the ordination. Twenty sites were chosen at random to illustrate these changes. Of these sites, the change trajectory of 13 was closely aligned with the Year vector, at two the vegetation had changed very little and only three sites had a trajectory of change which differed in direction from the Year vector.

A series of Repeated Measures ANOVAs were performed on the vegetation data to determine the effects of time elapsed since the start of agri-environment programmes in 1987 to 2020. These looked at the effects of year and agri-environment option (HK6, HK7 without sward-enhancement, HK7 with sward enhancement and none) and the interaction between these two variables on the vegetation.

Response variables studied were:

- Ellenberg Indices (EI) Light, F (moisture), Reaction (pH) and Nitrogen (Table 31)
- Suited Species Scores (SSS) Grazing Index, Nutrient and Moisture (Table 31)
- Mean number of species per site (Table 32)
- Mean number of species per m^2 quadrat at each site (Table 33)
- Number of positive indicator species (all Priority Habitats) in each m^2 quadrat (Table 34)

Only EI and SSS which showed significant differences are shown in Table 31. There were however significant differences: EI Light was lowest in 1995, while EI Reaction decreased through time, and was lowest in 2012 and 2020. SSS Grazing Index was significantly higher in 2012, and SSS Moisture was highest in 2020.

EI Light and Reaction were lowest under HK6. EI Moisture and SSS Moisture were lowest under HK7+. EI Nitrogen and SSS Nutrient were lowest under HK6, but highest where there was no option. SSS Grazing Index was highest under HK7+.

Mean number of species per stand showed a gradual but non-significant increase from 1987/88 to 1995. Between 1995 and 2002 however, there was a significant decline which continued to 2020 (Table 32). This pattern was repeated under all agri-environment scheme options and none.

When numbers of species per m^2 quadrat were examined however, the data behaved differently in relation to time depending on management option (Table 33). Under HK6 and HK7-, mean numbers increased significantly from 1987/88 to 1995 then decreased to 2002, but more in HK7- than in HK6. Although the pattern of change was similar in HK7+, the decline was less extreme, with the 2020 number being similar to that recorded in 1987, and that recorded in 2020 for HK6 sites. Where no agreement was in place, numbers increased from 1987/88 to 1995, but decreased much more sharply to 2020.

Positive indicator species numbers per m^2 quadrat showed no significant long-term relationship to time, although trends differed between option type (Table 34). Under HK6, numbers increased between 1987/88 and 1995, decreasing between 1995 and 2020. Under

HK7-, numbers remained relatively stable throughout the period from 1987/88 to 2020, while under HK7+, numbers decreased between 1995 and 2002, recovering by 2020. Where there was no agreement, numbers increased slightly but not significantly from 1987/88 to 2002, but then declined significantly between 2002 and 2020.

In four of the six survey years, numbers were significantly higher under HK6 than under HK7- and higher in five years than under HK7+. In all years numbers of positive indicator species were significantly lowest where there was no scheme agreement. In 2020, numbers were similar under all agri-environment scheme options.

Trends through time of numbers of species per quadrat and numbers of positive indicator species per quadrat are shown in Figure 28.

Table 31. Analysis of Variance (repeated measures ANOVA in R with post-hoc Tukey pairwise HSD tests) of Ellenberg Indices and Suited Species Scores from 1987 to 2020: (a) by years (df 5:462); and (b) by option (df 3:462). Significance: *** $P < 0.001$, ** $P < 0.01$, ns Not Significant. Superscript letters: means that do not share a letter are significantly different at $P < 0.05$.

(a)	1987	1990	1995	2002	2012	2020	SEM	*P*
Ellenberg Indices								
L Light	7.043^{ab}	7.041^{ab}	7.019^{a}	7.058^{b}	7.067^{b}	7.074^{b}	0.0034	***
R Reaction	5.884^{a}	5.850^{a}	5.843^{a}	5.852^{a}	5.762^{b}	5.782^{b}	0.0079	***
Suited species scores								
Grazing Index	0.351^{a}	0.349^{a}	0.357^{a}	0.352^{a}	0.411^{b}	0.346^{a}	0.0034	***
Moisture	-0.025^{ab}	-0.029^{b}	-0.031^{b}	-0.040^{b}	-0.002^{ab}	0.027^{a}	0.0055	**

(b)	HK6	HK7-	HK7+	None	SEM	*P*
Ellenberg Indices						
L Light	7.022^{a}	7.055^{b}	7.069^{b}	7.055^{b}	0.0034	***
F Moisture	5.491^{a}	5.468^{a}	5.293^{b}	5.498^{a}	0.0130	***
R Reaction	5.734^{a}	5.855^{b}	5.867^{b}	5.858^{b}	0.0079	***
N Nitrogen	4.475^{a}	4.654^{b}	4.668^{b}	4.853^{c}	0.0136	***
Suited species scores						
Grazing Index	0.352^{a}	0.358^{a}	0.405^{b}	0.337^{a}	0.0034	***
Nutrient	-0.171^{a}	-0.092^{b}	-0.092^{b}	-0.009^{c}	0.0054	***
Moisture	0.0036^{a}	-0.0164^{a}	-0.0942^{b}	0.0141^{a}	0.0055	***

Table 32. Mean number of species per stand for all sites from 1987/88 to 2020 under four different agri-environment regimes (HK6, HK7- without enhancement, HK7+with enhancement, 'none' no agri-environment scheme). Repeated Measures ANOVA in R with post-hoc Tukey pairwise HSD tests. Option: significant at $P < 0.001$ (SEM 0.333; df 3:483). Year of survey: significant at $P < 0.001$ (SEM 0.333; df 5:484). Superscript letters: option means that do not share a letter are significantly different, subscript letters: year of survey means that do not share a letter are significantly different.

Year of survey	HK6	HK7-	HK7+	None
1987/8	37.54^{a}_{a}	35.95^{b}_{a}	35.88^{b}_{a}	29.70^{c}_{a}
1990/2	39.46^{a}_{b}	37.04^{b}_{b}	36.69^{b}_{b}	31.42^{c}_{b}
1995	41.50^{a}_{c}	38.00^{b}_{c}	36.20^{c}_{ab}	24.79^{d}_{c}
2002	32.71^{a}_{d}	31.91^{b}_{d}	29.75^{c}_{c}	28.33^{d}_{d}
2012	32.09^{a}_{d}	31.83^{a}_{d}	29.10^{b}_{c}	
2020	32.95^{a}_{d}	28.87^{b}_{e}	27.30^{c}_{d}	24.06^{d}_{e}

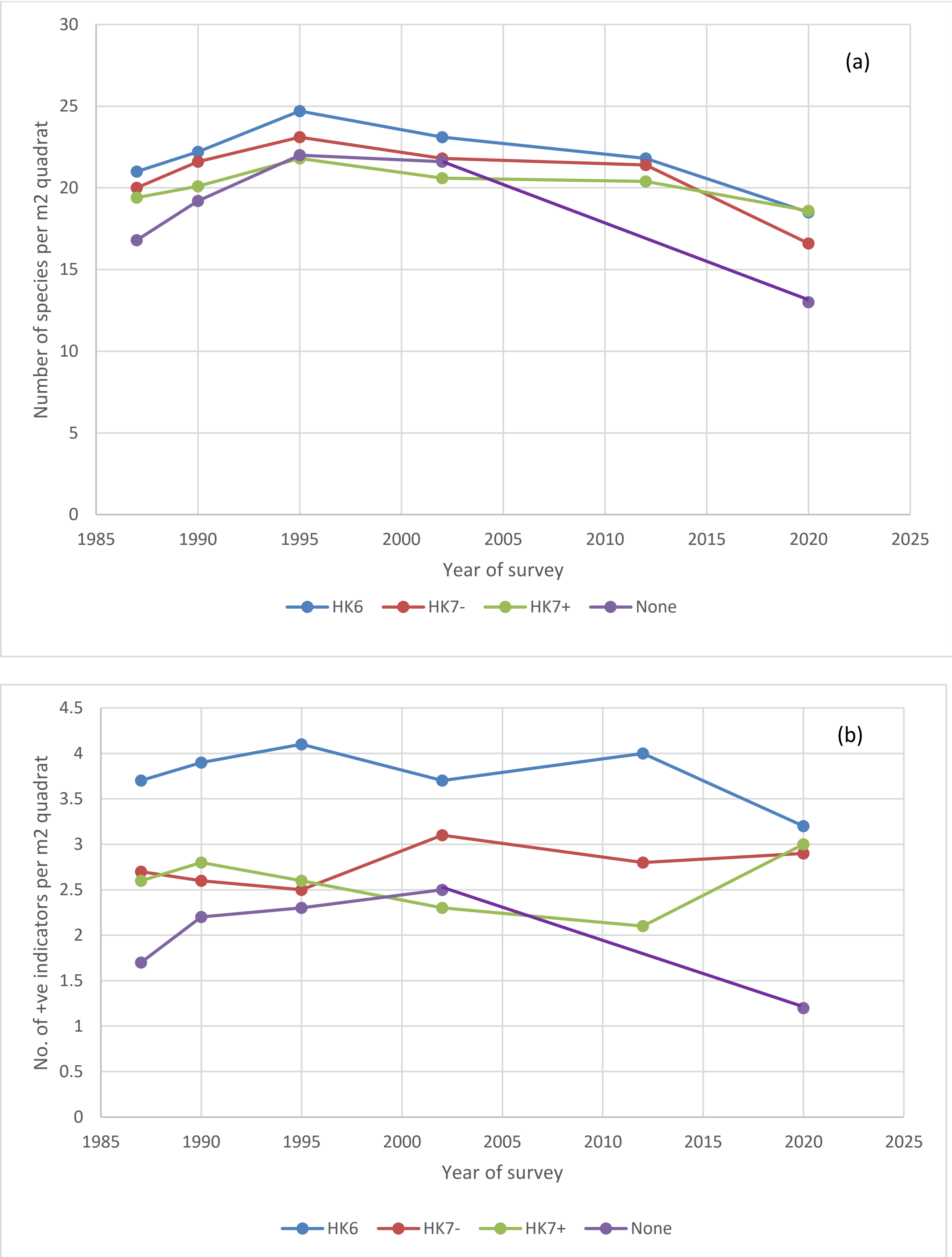
Table 33. Mean numbers of species per m^2 quadrat under four different agri-environment regimes (HK6, HK7- without enhancement, HK7+with enhancement, 'none' no agri-environment scheme) between 1987/88 and 2020. Repeated measures ANOVA in R with Tukey HSD tests. Option significant at $P < 0.001$ (SEM 0.194, df 3:484). Year of survey significant at $P < 0.001$ (SEM 0.194, df 5:484). Tukey pairwise HSD tests significant at $P < 0.05$. Superscript letters: option means that do not share a letter are significantly different. Subscript letters: year of survey means that do not share a letter are significantly different

Year of survey	HK6	HK7-	HK7+	None
1987/8	21.0^{a}_{ac}	20.0^{a}_{a}	19.4^{ab}_{ab}	16.8^{b}_{a}
1990/2	22.2^{a}_{a}	21.6^{a}_{a}	20.1^{ab}_{ab}	19.2^{b}_{a}
1995	24.7^{a}_{a}	23.1^{a}_{b}	21.8^{ab}_{a}	22.0^{b}_{b}
2002	23.1^{a}_{a}	21.8^{a}_{a}	20.6^{ab}_{ab}	21.6^{a}_{b}
2012	21.8^{a}_{a}	21.4^{a}_{a}	20.4^{a}_{ab}	n/a
2020	18.5^{a}_{c}	16.6^{a}_{c}	18.6^{a}_{b}	13.0^{b}_{c}

Table 34. Mean numbers of positive indicator species (all Priority Habitats) per m2 quadrat under four different agri-environment regimes (HK6, HK7- without enhancement, HK7+ with enhancement, 'none' no agri-environment scheme) between 1987/88 and 2020. Repeated measures ANOVA in R with Tukey pairwise HSD tests. Option significant at $P < 0.001$ (SEM 0.156, df 3:484). Year of survey significant at $P < 0.01$ (SEM 0.194, df 5:484). Tukey pairwise HSD tests significant at $P < 0.05$, superscript with respect to agri-environment regime (rows), subscript with respect to year of survey (columns): means that do not share a letter are significantly different.

	HK6	HK7-	HK7+	None
1987/8	3.7^{a}_{a}	2.7^{b}_{a}	2.6^{b}_{a}	1.7^{c}_{a}
1990/2	3.9^{a}_{a}	2.6^{b}_{a}	2.8^{b}_{ab}	2.2^{c}_{a}
1995	4.1^{a}_{a}	2.5^{b}_{a}	2.6^{b}_{b}	2.3^{b}_{a}
2002	3.7^{a}_{a}	3.1^{a}_{a}	2.3^{b}_{a}	2.5^{b}_{a}
2012	4.0^{a}_{a}	2.8^{b}_{a}	2.1^{b}_{b}	n/a
2020	3.2^{a}_{a}	2.9^{a}_{a}	3.0^{a}_{a}	1.2^{b}_{b}

Figure 28. Mean numbers of (a) species and (b) positive indicator species (all Priority Habitats) per m^2 quadrat under four different agri-environment regimes (HK6, HK7- without enhancement, HK7+ with enhancement, 'none' no agri-environment scheme) between 1987/88 and 2020.



4 Discussion

4.1 The current condition of the upland hay meadow sample

NVC communities

The UK Biodiversity Action Plan description for Upland Hay Meadows Priority Habitat (JNCC, 2008) (unchanged since the introduction of Section 41 of the NERC ACT, 2006) includes only the NVC type that is analogous with the Habitats Directive Annex 1 habitat 38.3 Northern Hay Meadows (British types with *Geranium sylvaticum*). Therefore, only the single NVC community MG3 *Anthoxanthum odoratum–Geranium sylvaticum* grassland (Rodwell, 1992) is included within the UK BAP. However, the G09 Upland Hay Meadows priority habitat in the Baseline Evaluation of Higher Tier Agreements (BEHTA) manual (Natural England, 2016) has a broader definition based on geographic area, traditional management practices and vegetation composition (species-richness and cover, and the frequency within the sward of desirable 'positive' wildflower[9] indicator species). It does not have close correspondence to any one NVC community type, but the target communities are MG3 grassland in drier meadows and the northern variant of MG8 *Cynosurus cristatus–Caltha palustris* grassland in wetter meadows, with the intention of placing a threshold between these and semi-improved stands that would largely cover MG6. The success, or otherwise, of the current condition assessment for priority habitat to do that are discussed below.

There was considerable variation in the character and condition of the grasslands encountered in the 2020 survey. The target hay meadow communities of MG3 and MG8-related stands were present but semi-improved MG6 *Lolium perenne-Cynosurus cristatus* grassland, improved MG7 *Lolium perenne* ley and some stands with closer affinities to the lowland meadow community MG5 *Cynosurus cristatus–Centaurea nigra* grassland also featured. MG5 is the principal unimproved mesotrophic grassland type throughout the lowlands of England, but it extends into upland areas to *c.* 300m (Averis *et al.*, 2004). M23 *Juncus effusus/acutiflorus* rush pasture occurred along water courses and in damp depressions, and vegetation analogous to MG10 *Holcus lanatus–Juncus effusus* rush-pasture was occasional but these latter two communities did not feature in the main sampling areas.

The hay-cut area within meadows defined the sampling area for both botanical recording and the condition assessment structured walk. Some hay-cut areas supported homogeneous stands of vegetation but most had at least some variation: for example many sites supported largely dry MG6 of low to moderate species-richness but also had damp areas supporting MG8-related grassland, or fragments of richer MG3 grassland on the margins. MG3/MG8 mosaics were also quite common – indeed homogeneous stands of MG8 with no other community present were rare. Many sites included unimproved, uncut banks such as those formed by glacial features – these were not sampled – but frequently much of the better

[9] Includes some Carices and other non-Graminae.

quality MG3 grassland was noted on these banks and supported species such as *Alchemilla glabra, Geranium sylvaticum, Cirsium heterophyllum, Sanguisorba officinalis* and *Trollius europaeus*; species which were largely absent from the adjacent cut areas. This echoes the findings in the Nectarworks project carried out by the North Pennine AONB Partnership (Starr-Keddle, 2018) where uncut banks were one of the sources of seed used for reintroduction.

In 2020, stands that were assessed as Favourable condition G09 upland hay meadow included MG3, MG5, MG8 and a few species-rich examples of MG6 (O'Reilly, 2011 describes these as the species-rich MG6biii variant) as they met all priority grassland criteria and thresholds. None of the grasslands surveyed appeared entirely unimproved, even the best examples appearing semi-improved, but most had received less intensive management under agri-environment scheme management for many years. However, stands of MG6 within the sample are largely the result of past agricultural improvement and subsequent degradation of former MG3 stands (Averis *et al.*, 2004; Hewins *et al.* 2005) and as such are the primary community targeted for restoration to MG3 upland hay meadow community – hence their high frequency of occurrence in the sample of stands selected for sward enhancement.

The dominant NVC community recorded in the meadows was MG6, predominantly MG6b of varying richness, which was recorded in 52% of all sites. This is a similar proportion to that found in another study of 429 upland hay meadows in the North Pennines (O'Reilly, 2011) where 62% were MG6b. The target community for dry meadows, MG3, was recorded in just over 20% of the combined sample and the wet meadow community MG8 in a further 23%: this is higher than the proportions reported in O'Reilly (2011) but that study was not limited to meadows in agri-environment scheme management. Meadows under Higher Level Stewardship (HLS) or Countryside Stewardship (CS) options – as with 129 of the 2020 sample – would be expected to include a greater proportion of the target community types (MG3 and MG8). Stands with affinities to MG5 were few (two only in the core sample). Improved MG7 meadows were also uncommon with just five stands – all in the non-agreement control sample.

As in the 2012 survey, the highest quality upland hay meadow community MG3b sub-community was extremely rare within the sample (only one meadow in 2020) but recognisable stands of MG3a, albeit much degraded, were recorded in a quarter of the core sample. Many of the MG3a stands represented an MG3a/MG6b continuum and some surveys may have included these within the MG6b sample (or O'Reilly's MG6biii) due to the sparsity or absence in many of these stands of one or more preferential MG3 species *Alchemilla* spp., *Geranium sylvaticum* and *Cirsium heterophyllum*, and to a lesser extent *Sanguisorba officinalis.* This is not a novel finding. Starr-Keddle (2014) reported a significant decline in these species in Upper Teesdale meadows in the previous 20–30 years, and Pacha & Petit (2008) reported a 40% loss of *Geranium sylvaticum* – the preferential associate of MG3 – in 119 meadows in the Yorkshire Dales. *Filipendula ulmaria* was unusually frequent within MG3 stands (and some MG6b) compared with the published tables in Rodwell (1992) and the reason for the MAVIS analysis to return results for the lowland flood meadow community MG4 *Alopecurus pratensis–Sanguisorba officinalis* for several sites, but this has also been noted in floristic analysis of North Pennine upland hay meadows by O'Reilly (2011). The target wet meadow community MG8 was diverse and heterogeneous with drier areas often supporting a damp MG6b with frequent *Filipendula ulmaria.* MATCH analysis often returned a result of MG6d (Wallace & Prosser, 2016) for these stands.

Condition assessment

The most frequent reason for stands failing to meet Favourable condition using the BEHTA criteria was failure to support priority grassland positive indicator species at the required frequency (55%) although 25% failed on low cover of qualifying wildflower (non-Graminae) species. Only 2% of sites failed on negative indicator criteria. No site failed on cover of *Juncus* species or presence of scrub.

The low frequency of *Juncus* spp. within the upland hay meadow stand, in both the condition assessment walk and the quadrats, is of interest. There is a perception by farmers that rushes are increasing in the meadows, which is of concern because it lowers the quality of the yield. Research into this (Hamilton *et al.*, 2018) did not show conclusive evidence for increase in *Juncus* spp. in upland hay meadows over recent years; they observed significant increases at the whole-site level but not at the quadrat level. There was a correlation in that study between *Juncus acutiflorus* and higher numbers of positive indicator species however.

Sites that were assessed as non-priority grassland also failed, variously, on % cover of *Lolium perenne, Trifolium repens* and *Ranunculus repens* and on low number of species per m^2. A greater proportion of MG3 stands were in Favourable condition (77%) compared with the wetter MG8 stands (59%). MG3 grassland was significantly richer in positive indicator species than MG8 stands at the site-level (the reason for more MG3 stands attaining Favourable condition) but the MG8 sample as a whole had a greater diversity of positive indicators. This is likely to be due to the patchy character of MG8 within an upland setting, where it mostly occurs in mosaics with other community types (Averis *et al.,* 2020). Surprisingly, 38% of the stands assigned to MG6b also passed the criteria for G09 priority habitat grasslands but nearly all were in Unfavourable condition – generally they supported sufficient species m^2, and wildflower cover but the positive indicators present were at too few, or at too low frequency within the stand.

Explanatory variables for stand condition included some soil chemistry variables, and aspects of site management. Sites that were assessed as Favourable condition priority habitat grasslands were found to have the lowest levels of available phosphate (Olsen's P), lower than Unfavourable condition stands, and significantly lower than all other non-priority grassland stands: 98% of the 43 Favourable condition grasslands, and 83% of the whole sample had an Index P of 1 or below, meeting the standard HLS indicator of success for species-rich grasslands. The number of species per m^2 was positively related to low Olsen's P. CCA analysis suggested that MG3 stands also appeared to be associated with lower levels of magnesium and potassium, whilst MG8 grasslands were present over a wider range of available phosphate levels, and tolerated higher potassium levels, possibly reflecting the wide range of floristic variation within this community. The relationship between available phosphate content of the soil and species diversity can break down in wetter grasslands – both soil pH and the availability of nutrients is influenced by the intensity and periodicity of waterlogging (Wilson & Wheeler, 2014). In previous studies (Wheeler & Wilson, 2016) stands receiving nutrients from alluvial deposits in floodwater had a both a high available phosphate content and good species diversity. Favourable condition stands were also associated in the CCA with grazing by traditional breeds of sheep and cattle (rather than modern breeds), and there was a positive association between an increase in number and frequency of positive indicators and cutting for hay, relatively late cutting date and cattle grazing. Conversely frequency of positive indicator species were lower where fields were grazed by modern sheep breeds in the absence of any cattle. A “good” hay meadow in our dataset was therefore likely to have low Olsen’s P, be cut for field dried hay late in the season and be grazed before/after with traditional breeds of livestock.

Stand condition and statutory designation

Twenty-two of the meadows surveyed were within Sites of Special Scientific Interest (SSSI), although only six of these represented an entire SSSI unit, the other 16 being a component of larger units. Eight meadows were part of the extensive landscape-scale Upper Teesdale SSSI covering >14,000 ha and comprising habitat of varied character and condition.

The surveyed area within these SSSI units and part-units was delineated by the mown area only, excluding species-rich unmown banks, and therefore did not comprise the whole meadow in all cases. Consequently, assessment against SSSI common standards monitoring (CSM) criteria and thresholds should be considered within this context. It is however of interest to note that when the more stringent CSM thresholds were applied to these 22 meadow stands, the 18 stands that met the BEHTA G09 criteria and thresholds did not meet those of CSM for SSSIs. Only five stands were in SSSI Favourable condition, the remaining stands having failed on frequency of positive indicators despite these stands supporting significantly more positive indicators than non-SSSI stands and greater (but not statistically significant) summed frequency of positive indicator species. Had the species-rich uncut banks been included within the condition assessment structured walk this result would no doubt have been different in at least some of the meadows.

Unlike the BEHTA G09 priority grassland assessment, which includes MG3- and MG8-related positive indicators, the SSSI CSM assessment separates these two communities by providing a different suite of positive indicators and different thresholds for frequency for each. Many of the stands surveyed in this project had elements of both communities, related to differences in topography and associated hydrology. Such variation within stands in relatively small parcels of land are better dealt with by a more extensive list of positive species to indicate ‘good’ quality grassland. However, habitats with statutory designation should aim at the higher end of species richness. A result of only five stands achieving Favourable SSSI status reflects the poor condition of these meadows, not an overly stringent set of condition criteria. Rather, the number of MG6 stands achieving G09 priority grassland status, albeit often in Unfavourable condition, perhaps indicates that the threshold set (two frequent plus two occasional positive indicators for Favourable condition, or three occasional or four rare for Unfavourable condition) is too low.

4.2 Agri-environment scheme management

HLS option and stand condition

The core sample of sites (the 95 sites that had previously been surveyed in 2012 in the predecessor project; Hamilton *et al*., 2014) had at the time of the 2020 survey all been under agri-environment scheme management since at least 2012 and for many, much longer (up to 33 years). Management during and since the 2012 survey has been under HLS options HK6 *maintenance of species-rich, semi-natural grassland* or HK7 *restoration of species-rich grassland, semi-natural grassland*, although some sites have gone on to the corresponding CS Higher Tier GS6 *management of species-rich grassland* or GS7 *restoration towards species-rich grassland* options from 2015 onwards.

Applying the BEHTA manual (Natural England, 2016) condition assessment criteria for priority habitat grassland features, 79% of the core sample of HLS/CS managed stands were assessed as supporting G09 upland hay meadow, although only 45% were in Favourable condition. Meadows that had been put into the HK6 option where the aim of management is to maintain species-rich grassland would be expected to include a much higher proportion of meadows that are in Favourable condition, as their condition should have been relatively good at the outset of HLS, whereas meadows put into option HK7 would be expected to include sub-optimal grasslands that required management to restore them to good condition: this was true to an extent as 93% of HK6/GS6 meadows were assessed as G09 priority habitat compared with 73% of HK7/GS7. However, only 52% of HK6/GS6 meadows were in Favourable condition in 2020 compared with 42% for HK7/GS7. This seems a poor result for the HK6 meadows and, since at the time of the 2020 survey the core sample of meadows had been managed under HLS prescriptions for at least 8 years, it would also be expected that the poorer quality grasslands put into HK7 option would have made gains towards achieving Favourable condition priority grassland.

Impact of HLS over time

For condition assessment of the core sample in 2012, Hamilton *et al*. (2014) used the previous Farm Environment Plan (FEP) method for assessing grassland features coming into the Higher Level Stewardship scheme (Natural England, 2010). The 2012 analysis of condition returned very similar results to the 2020 analysis reported here, for the proportion of HK6 sites and HK7 sites to be in Favourable condition (51% and 43%, respectively), although at the time of the 2012 survey, sites had only recently entered HLS (1–6 years previously) and it would be expected that the HK6 sample would have a much higher proportion of Favourable condition sites than those targeted with HK7 restoration management. This raises questions about option targeting: were Favourable and Unfavourable condition stands of grassland put into the correct option at the outset? If the proportion of Favourable condition sites were the same in 2012 and 2020, this suggests there been no change in condition at the whole sample-level despite HLS management.

The issue of incorrect option targeting due to the quality of semi-natural grasslands having been exaggerated in the original FEP survey has been highlighted by a previous study on the effectiveness of HLS (Staley *et al.*, 2018) and the suitability (or otherwise) of grasslands put into options HK6 or HK7 for restoration to species-rich grasslands has been assessed in another study by Wheeler & Wilson (2016). In that study of 118 grasslands in either option HK6 or HK7 between 2007–2014, 16% of grasslands had low suitability for restoration to a species-rich priority grassland habitat (Group 1) and a further 14% of sites entered into HK6 did not support a favourable condition species-rich priority grassland at the outset and would have been better targeted by option HK7 (Group 2). The impact of these poorly targeted options was that none of the Group 1 sites showed any improvement from non-priority grassland to priority grassland over time, and stands in Group 2 were still in Unfavourable condition at the time of resurvey.

Re-analysis of 2012 data using the same BEHTA criteria as used in 2020 (for consistency) showed a slightly different picture to the Hamilton *et al*. (2014) results, partly due to the loss of 8 sites from the original sample but also due to differences in interpretation of the data. Analysis using a consistent approach for each dataset showed a decline in the proportion of Favourable condition grasslands under the HK7 restoration option over the 8-year period from 2012–2020, and also a decline in the condition of Unfavourable condition priority habitat grasslands with many now classified as good semi-improved (still suitable for restoration but with change in the wrong direction). This was borne out by the significant reduction in mean number of species per m^2 since 2012, but interestingly this was true of sites in both HK6 and HK7 options. The numbers and frequency of positive indicator species had also declined.

The aim of agri-environment management is to maintain and conserve already biodiverse habitat or make biodiversity gains in poorer habitat through restoration (or creation). Further exploration of the dataset at the site-level with regard to performance over time relative to their starting point demonstrated that 69% of sites in HLS management from 2012 to 2020, that were already species-rich priority grassland in Favourable condition in 2012, <u>maintained</u> their Favourable status in 2020 but the rest declined in condition. HK6 management was slightly less effective at maintaining Favourable condition than HK7 management but, conversely, HK6 management demonstrated a greater success in restoring Unfavourable priority grasslands to Favourable condition than the HK7 restoration option. These findings are not what might be expected from the aims of HK6 and HK7 management. Similar proportions in each option group remained in Unfavourable condition during this period.

To disentangle this rather complicated data, the relative change in condition over time was reduced to three 'performance outcomes'. Using this method, it was demonstrated that stands under HK6 management had a higher proportion of 'Good' and 'Neutral' outcomes than HK7, and the lowest proportion of 'Bad' outcomes from 2012 to 2020. However, it also demonstrated that sites under HK7 management were twice as likely to have a Good or Neutral outcome than a Bad outcome. HLS management, maintenance or restoration, has a positive effect, but not as much as might be hoped for. Roughly a third of sites experienced declines in floristic diversity from 2012 to 2020. The gross decline in species richness across the whole sample also suggests that, whilst maintaining Favourable condition, some sites are still seeing losses in species numbers and frequencies that are not picked up by the BEHTA assessment: decline in frequency of positive indicators within sites appears a greater issue than the loss of the indicators altogether. Species typical of unimproved traditionally managed meadows are becoming sparser in the sward rather than disappearing completely.

The non-agreement control sample, those sites that were in ESA management but did not enter the Countryside Stewardship Scheme or HLS, provided some insights into the impact of not being governed by HLS prescriptions. Over 50% of these sites were no longer managed as meadows but were sheep pastures. There was a general trend for increasing species richness under ESA management from 1987/92 to 1995, but by 2020 all but two of fifteen sites saw declines in the mean number of species per quadrat and numbers of positive indicators had fallen.

Sward enhancement

The analysis of the core sample of 16 HK7 restoration sites that had been subject to sward enhancement measures, on first examination, returned some disappointing results when compared with HK7 stands that had not had sward enhancement. A greater proportion of core sample enhanced sites were MG6b and in poorer condition with lower number and frequency of positive indicators, and demonstrated poorer performance over time. This was mirrored in the character and condition in 2020 of the 34 sites outside the core sample, selected from meadow restoration projects undertaken by partner organisations[10] (North Pennine AONB Partnership, Yorkshire Dales Millennium Trust, Cumbria Wildlife Trust and the Forest of Bowland AONB Unit): over half were MG6b. It was thought likely that this may be at least partly the result of the initial selection of the least species-rich fields for enhancement, but may also reflect the length of time needed to achieve sward enrichment, and may reflect the difficulty of establishing some species, especially from seed. Subsequent analysis of data on the condition of sward-enhanced HK7 sites prior to enhancement, revealed that relative to their pre-enhancement status these HK7 meadows had in fact made significant gains in both number and frequency within the sward of positive indicator species, with 60% of meadows seeing increases in number and 90% increases in summed frequency per site. This supports the findings of the North Pennine Hay Time Project (Starr-Keddle & Barrett, 2012; Starr-Keddle, 2018) where ≥80% of sites had made gains in number of indicators, although that study included a wider group of species as positive indicators.

In our analysis of the colonisation/expansion by a restricted list of upland hay meadow priority habitat positive indicators, it was annual species such as *Euphrasia officinalis* agg. (mostly *E. arctica*) and *Rhinanthus minor* that were the most successful colonists, reflecting the findings of Cornish & Hooley (2012) and Starr-Keddle (2018) but '*Leontodon*' spp. (mostly *Scorzoneroides autumnalis*), *Centaurea nigra, Lathyrus pratensis* and *Sanguisorba officinalis* also established in *c.* a quarter of the sites. However, upland hay meadow preferential species *Geranium sylvaticum, Cirsium heterophyllum* and *Trollius europaeus* did not establish in any

[10] North Pennines AONB Partnership's Hay Time and Nectarworks Projects, 2006 onwards; Yorkshire Dales Millennium Trust's Yorkshire Dales Hay Time Project 2006 onwards;
Forest of Bowland AONB Hay Time Project 2012 onwards;
Cumbria Widlife Trust: various funded projects including Wealth of Wildlife Project 2006, Hay-day Project 2009, Cumbria Hay Meadows Restoration Project 2012, Meadow Life Project 2014-15.

of the 50 enhancement meadows, despite being present in some of the donor sites – and in some cases declined where they had been present. *Conopodium majus* also showed a decline, which has been noted in other studies (Sullivan *et al*., 2018). This species flowers early and its decline could be related to late Spring grazing, or possibly due to being overlooked in surveys carried out late in the season. Results from an experiment examining the effects of green-hay collected from a MG3a grassland and applied to an MG6 grassland in Cumbria (Kirkham *et al*., 2012), were similarly equivocal. Species number increased at the receptor site, and some positive indicator species appeared, but others, in particular *Geranium sylvaticum* were absent.

Presence within a donor site does not correlate with presence of seed in the plant material used for enhancement as these species have differing flowering and seed-set times: a single harvest cannot be a 'catch-all' for all upland hay meadow species. Starr-Keddle (2018) observed that issues of germinability and viability may also impact the success of establishing *Geranium sylvaticum* from seed: the difficulties inherent in establishing slow-growing or late-flowering, longer-lived perennial associates of upland hay meadows has been cited as the reason for a move from the use of green-hay towards the use of plug plants in second-phase enhancement of previously restored meadows (Starr-Keddle, 2018). Cornish & Hooley (2012) also reported successes with plug-planting of *Geranium sylvaticum* on some of their restoration meadows. Whilst some of the enhancement sample analysed in our dataset did include plug plants from later projects, there were insufficient replicates in the sample for full statistical analysis. No significant differences were identified between enhancement methods, or between year of enhancement – again probably due to the small number of replicates in each category/year.

4.3 Long-term change 1987–2020

The methods used for assessing grasslands have varied since surveys began in 1987, and the number of sites surveyed has differed between years. Despite this, it has been possible to follow the overall progress of sites included in the early surveys from 1987 up to 2020. Three sets of analyses were investigated. These looked at the periods between 2012 and 2020, between 2002, 2012 and 2020 and the longer run of data from 1987 to 2020 which had a maximum of six sampling points for a site.

The majority of sites surveyed in 2012 and 2020 maintained condition (whether Favourable or Unfavourable) or had improved, although 25% suffered a deterioration, and only 38% had maintained Favourable condition or had improved condition. Particularly concerning was the deterioration of some sites managed under HK7 to a point at which they were no longer recognisable as priority habitat grassland. The principal criterion for failure of condition assessments was a lack of positive indicator species at the required frequencies. In most cases the deterioration in condition involved a decline in frequency of positive indicator species rather than a complete loss of species.

Surveys which started with the first agri-environment schemes in 1987/88 are more informative. It has been shown in previous surveys of wet grasslands managed under agri-environment schemes (Wheeler *et al.*, 2014), that it can take up to 20 years for the species composition of a grassland to stabilise after the changes of management typically involved in enrolment in a scheme. Annual fluctuations and short-term variations can often obscure long-term trends. A run of data that spans more than 30 years is therefore very valuable, and it might be expected that after 30 years under relatively consistent management, a pattern of change common to all sites might emerge. The results of CCA analysis where the trajectories of individual sites from baseline survey to 2020 were plotted show a common trend which may suggest possible stabilisation.

The length of time since the start of agri-environment management was shown to have a significant effect on vegetation composition. Over all sites, the numbers of species per site, numbers of species per quadrat and numbers of positive indicator species all declined from 1987 to 2020. These declines were however different under the different management options studied, and the declines did not follow a consistent trajectory through time.

The number of species per quadrat within the whole sample increased from 1987 to 1995. Between 1995 and 2002 however, numbers began a significant decline which continued to 2020, although this differed between options. This was most marked in fields which were not in an agri-environment scheme option, but was very small in those fields which had received sward enhancement. The number of positive indicator species also declined in fields not managed under an agri-environment scheme, but remained relatively stable where fields were under stewardship management, increasing slightly but not significantly between 2002/2012 and 2020 where sward-enhancement had taken place. These trends are similar to those observed in previous surveys (Critchley *et al*., 2004; Hamilton *et al.,* 2014).

It appears that, although ESA management resulted in early successes, some major changes happened in farming systems in the northern English uplands between 1995 and 2002, which affected the ecology of hay-meadows, whether or not they were managed under agri-environment schemes. The effects of these changes were more marked where no recent scheme agreement was in place, and it is possible that the change of scheme from the early Environmentally Sensitive Areas (ESAs) to the Environmental Stewardship Scheme (ESS) may have played a role. The ESA scheme in the North Pennines began in 1987, with the earliest agreements ending in 1997. The Countryside Stewardship Scheme (CSS) was introduced in 1991 to provide payment to farmers to enhance and conserve land outside designated ESAs. Although some existing agreements under the ESA and CSS schemes continued until 2014, both schemes were closed to new applicants in 2004 and were superseded from 2005 by the Environmental Stewardship scheme. A significant number of ESA agreements however did not transfer to the new scheme, and these included all of those control fields included in the 2020 survey which were managed under ESA agreements in the 1987–1992 baseline surveys. It is possible that some of these control fields then re-entered the mainstream of commercial farming between 1997 and 2002, with consequent intensification of management and loss of species.

Conversely, the relative stability of sites managed under ESA (and from 2005 the Higher Level Stewardship [HLS] strand of the ESS, and from 2016 Countryside Stewardship [CS]), in the restoration option HK7 but with sward enhancement (here referred to as HK7+), may be the result of the addition of plant material designed to improve species-richness under a range of local projects from the mid-2000s onwards. The small increase in number of positive indicator species between 2012 and 2020 may reflect their addition to these fields.

Notwithstanding these factors, other drivers are likely to be responsible for the overall decline in condition after 1995. Critchley *et al*. (2004) suggested that these might include changes in weather patterns, increased soil acidity and a reduction in grazing. An additional factor beyond the control of agri-environment schemes not considered by Critchley et al (2004) is soil compaction associated with the increase in size of farm machinery, and which may interact with climatic changes.

Mean April temperature (Figure 29) and total annual rainfall data (Figure 29 for Newton Rigg weather station (near Penrith, in the Eden Valley between The Lake District and the Western Pennine Fells) were compared with year using GLM for the years 1987 to 2020 https://www.metoffice.gov.uk/pub/data/weather/uk/climate/stationdata/newtonriggdata.txt. While there was no relationship between April temperature and year, there was a significant increase in total annual rainfall over the 33-year period. Longer term temperature records from further south in the Pennines show an increase which is not apparent between 1987 and 2020 (Pinches *et al*., 2013). It is possible therefore that changes in precipitation have contributed to vegetation change, but it seems less likely within the monitoring period that changes in temperature have played a role. The significant increase in Suited Species Score Moisture through time gives some support to this, and Stevens *et al.* (2004) also found a significant effect of increased rainfall on reduced species-diversity in acidic grasslands in Scotland. Changes in rainfall total and the frequency of extreme rainfall events and summer droughts may also have an indirect effect on vegetation condition through their effects on farming operations. Access to fields, especially those with impeded drainage supporting MG8 grasslands, both by machinery and stock can be severely limited by very wet conditions.

Figure 29. Mean April temperature at Newton Rigg weather station

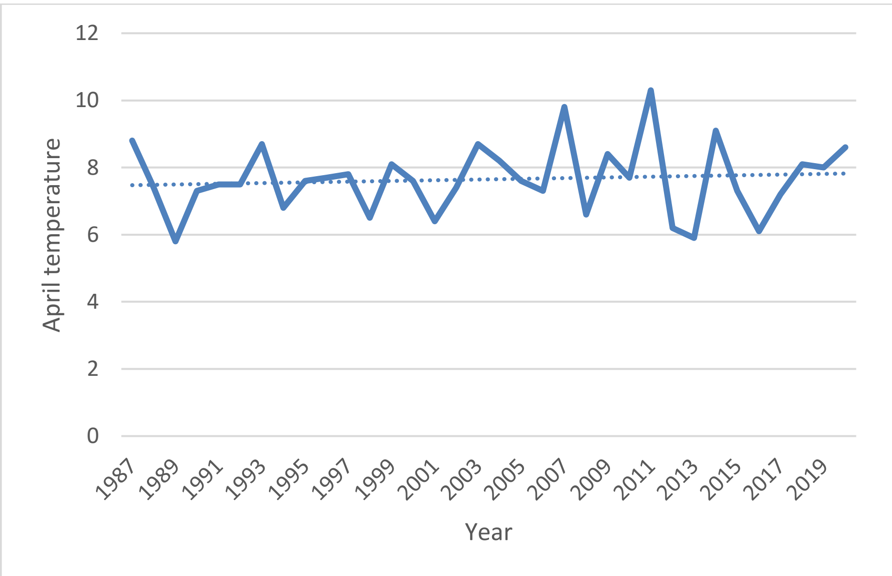
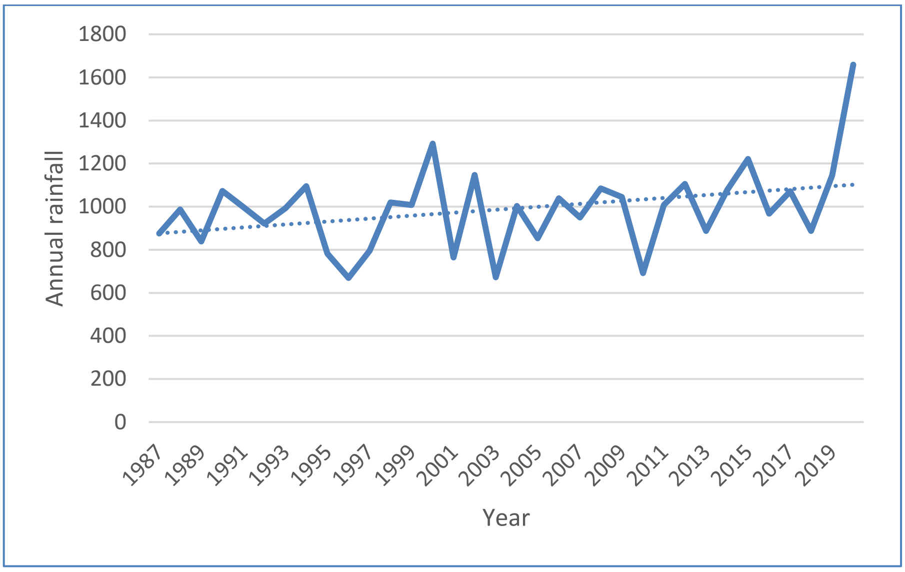


Figure 30. Total annual rainfall at Newton Rigg weather station. GLM (R), Gaussian distribution. $P < 0.05$, coefficient = 6.836, SE 3.178.

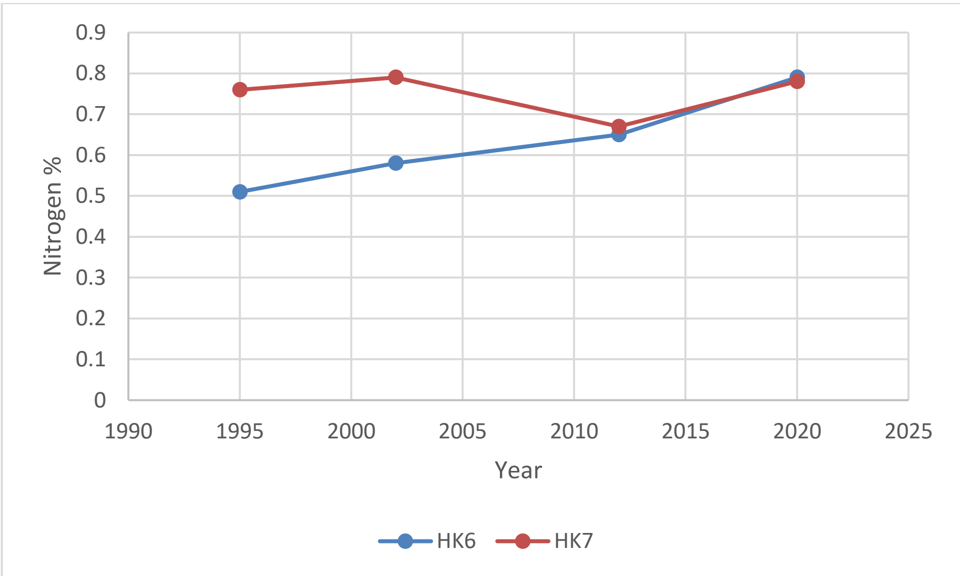


Atmospheric deposition of nitrogen has also been cited as a cause of vegetation change in the uplands of the UK, and is known to have caused species-impoverishment particularly in acidic grasslands throughout the UK (Stevens *et al*., 2004, 2006, 2011a,b; Colston, 2017). Upland areas including the Northern Pennines and the Lake District receive a high rate of nitrogen deposition, locally exceeding 15 kg N ha^{-1} $Year^{-1}$ (Stevens *et al*., 2011a). It has been calculated that a deposition rate of 2.5 kg N ha^{-1} $Year^{-1}$ could cause a loss of one species per 2 × 2 m quadrat in acidic grassland, although this figure is reduced in soils with a greater buffering capacity (Stevens *et al*., 2004). Application of nitrogen to species-rich MG3 grassland as a fertiliser has been shown to reduce species-richness at a rate as low as 9 kg N ha^{-1} (Kirkham, 2012). Potential for restoration of MG5 grassland to more species-rich vegetation is inhibited at rates as low as 4.4 kg N ha^{-1} (Kirkham *et al*., 2012). Other studies have shown reductions in floristic diversity at application rates of 17 kg N ha^{-1} (Smith *et al.*, 1996; Aerts *et al.*, 2003; Honsova *et al.*, 2007). The reduction in species-richness has generally been attributed to the enhanced growth of grasses at the expense of lower growing stress-tolerant herbs (Kirkham *et al.*, 1996, 2012; Honsova, 2007). In most fields studied here, any atmospheric deposition occurs in addition to the annual application of up to 12 t ha^{-1} farmyard manure (≈ 9.6 kg N ha^{-1}), to a potential total of >20 kg N Ha^{-1} $Year^{-1}$, considerably in excess of the rate known to be detrimental to species-richness.

This could represent a serious driver of eutrophication and vegetation change, however there was no significant change through time of total nitrogen in the soil analyses (Figure 31), and neither did the Ellenberg Index N or Suited Species Score Nutrient increase in the fields studied here. The results from the HK6 fields suggest however that with a longer run of data, a significant trend may emerge. It is also important to note that although there are several different parameters of soil nitrogen that can be measured, the only one of these that Stevens *et al.* (2004) found to be significant was deposition of inorganic nitrogen (which is immediately available for uptake by plants), as opposed to total soil nitrogen which includes nitrogen in complex organic molecules as well as that which is available for plant use. Further work on nitrogen deposition may reveal more about its role in the deterioration of upland hay meadow vegetation.

The general intensification of grassland management in the UK is well known, involving an increase in applications of artificial fertilisers and slurry, ploughing and re-seeding, earlier cutting dates and a change from a single annual cut for hay to two or three cuts for silage (Wilkins, 2000; Vickery *et al.*, 2001; Jefferson, 2005). This however has been a long-term process, starting in the 1940s, particularly following the Agriculture Act (1947) and technological advances during the post-war period. The deterioration recorded here however, has occurred not only in non-agreement sites where it might be expected, but also in sites managed for more than 30 years within agri-environment schemes, albeit moderated by management.

Figure 31. Total soil nitrogen (%) in fields surveyed between 1995 and 2020.

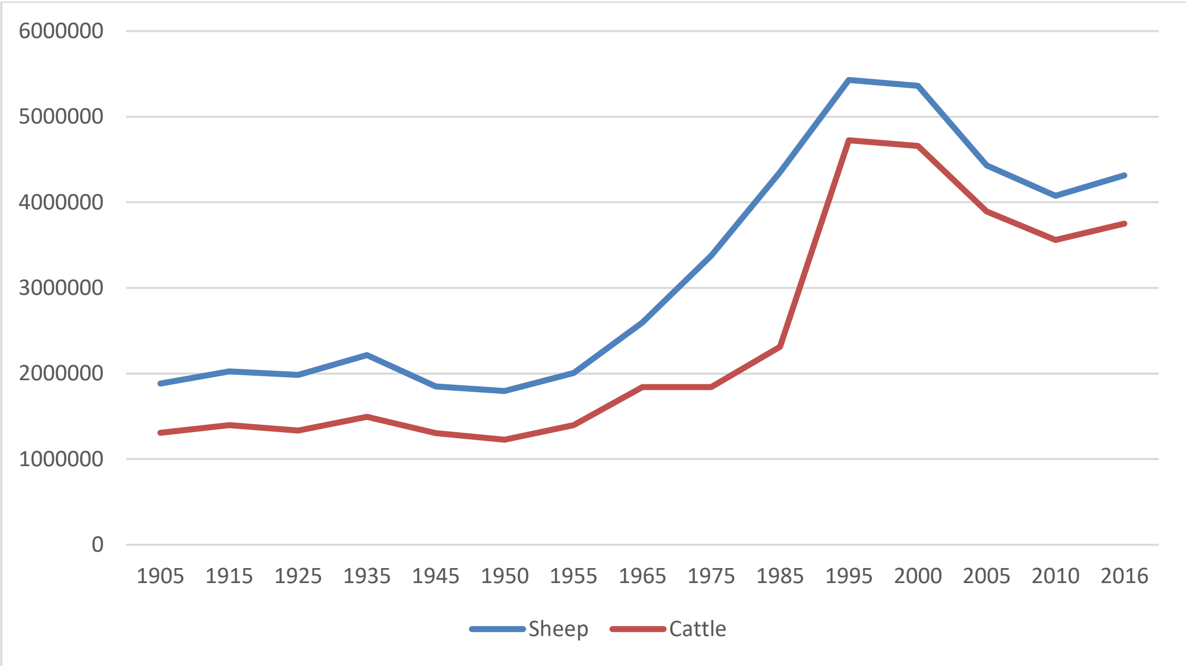


Several possible changes to field management might have occurred even within the constraints of agri-environment schemes. Management prescriptions specified for most upland hay meadows under current scheme agreements require at least an eight-week period of livestock exclusion between, at the latest, 15th May and with the earliest cutting date of 15th July. However, agreements vary and a number within the core sample specified an earlier cutting date of 8th July, whilst others only excluded livestock for 7 weeks after spring grazing. The grazing period is therefore extended, with some fields in this survey being grazed for nearly 10 months of the year. Smith *et al.* (2008) observed delayed flowering and less seed set of hay meadow associates with later shut dates. The majority of farmers in the 2020 survey kept stock on their meadows as late as possible and cut as early as possible, taking advantage of the possibility now of making haylage which requires a field-drying period of only three to four days rather than the longer time (≥ 5 days of dry, sunny weather) required for hay. Several agreements specified only 48 hours of 'wilting' before removal; it is unlikely that this is sufficient to allow seed-shed. It has been shown in a study of five farms within the survey area (Smith & Jones, 1991), that the data at which hay-cutting started was around 1st July in all years from 1946 to 1987, but that the date on which cutting finished could vary by 2 months, depending on the weather. Fields were cut in the same order each year, and on the two farms where NPK fertiliser was not used, there was a significant relationship between vegetation composition and cutting order, although this was not significant on the more intensively managed farms. From the 1960s onwards as farm machinery and forage conservation techniques (wrapped silage etc.) improved, the cutting period became more compressed with the majority of farms within agri-environment schemes in the survey area in 2020 aiming to cut hay on or as soon as possible after 15th July every year. Critchley *et al.* (2004) found that a cutting date before 15th July was detrimental to species-richness, but that a cutting date after 22nd July was associated with greater species-richness, although cutting consistently in late summer could lead to impoverishment and a change in community type from MG3 to MG6.

Over the same period, the numbers of livestock in the uplands of northern England have changed (Figure 32). Until 1955, numbers of sheep and cattle had been stable for at least 50 years at around 2 million and between 1.3 and 1.5 million, respectively, for the whole counties of Cumberland, Westmorland, Durham and the North Riding of Yorkshire (Defra, 2011, 2017)

The introduction of subsidies based on headage in the years following the Agriculture Act and continued under the CAP after accession to the EU in 1973 led to an increase in stock numbers (Silcock *et al.*, 2012) already noticeable by 1953 (Hunt, 1954). Numbers reached a peak around 1995 when headage quotas were introduced, and from 2000 headage payments were phased out under successive CAP reforms, eventually ceasing completely by 2010. At the same time, the UK was affected by a major outbreak of Foot and Mouth Disease (Anderson, 2002), in which the survey area for this project was particularly badly hit. Some farmers took this as an opportunity to leave farming, while the numbers of stock overall and locally were reduced. Additional pressures on cattle farming through the 1990s and 2000s included the threat of Bovine Spongiform Encephalopathy (BSE), and the increasing prevalence of Bovine Tuberculosis (BTb), although incidence of BTb is relatively low in the study areas (https://www.gov.uk/guidance/bovine-tb-testing-intervals-2020). The cumulative effects of these factors are likely to have contributed to the drop in numbers shown. These numbers are consistent with those for Severely Disadvantaged Areas reported by Silcock *et al.* (2012).

Figure 32. Numbers of cattle and sheep in northern England between 1905 and 2016. These data include Cumberland, Westmorland, Durham and the North Riding of Yorkshire up to 1975, and Cumbria, Durham and North Yorkshire after local government re-organisation in 1975.



In addition to this overall reduction in cattle numbers there has been a disproportionate loss of dairy herds from the uplands and a change from traditional breeds to modern "continental" type beef cattle (e.g. Limousin and Belgian Blue), which can offer greater financial return at a time of diminishing margins, but at the same time require more intensive management. Modern cattle breeds require supplementary feeding when housed, and a typical beef cow will receive around 120 kg of concentrate per year, which would be equivalent to 300 g of nitrogen and 1 kg of phosphate, some of which will be passed through into manure and spread on the hay meadows further increasing the nutrient load. Over the lifetime of a cow, this could represent an additional phosphate loading of up to 10mg/l of soil. More traditional breeds would have been fed entirely on hay cut from the meadows in a closed system. A similar trend in the "improvement" of upland sheep breeds has also been noted (Bradshaw, 2018).

5 Conclusions

It is not possible to determine causation from survey data, but the associations shown by analyses of sward condition and vegetation composition in 2020 and through time since baseline surveys in 1987–1992 in relation to management and soil chemistry can allow some conclusions to be made about processes leading to change in condition during the 33 years between 1987 and 2020. These should be considered together with information about changes to farming practice in the English uplands, and more global issues outside the control of the land-manager.

The decline in the condition of upland meadows due to agricultural intensification that started in the 1940s is well documented (e.g. Jefferson, 2005; JNCC, 2008; Pinches *et al*., 2013; Bradshaw, 2018) and it is important to recognise that it is likely that the upland hay meadows in this study were already suffering biodiversity loss at the time of entry into an agri-environment scheme in the 1980s. Scheme management may therefore have had a positive impact in slowing but not halting deterioration. It remains to be seen whether, in the long-term, these meadows can support a vegetation composition that existed under a different set of pressures. What we can hope to achieve is the identification of drivers of change and to aim at maximising biodiversity within the context of modern farming systems.

Favourable condition has been shown here to be positively associated with low levels of available phosphate, and this has been demonstrated to be one of the principal drivers of deterioration of grassland quality in many other surveys (Kirkham *et al.*, 1996; Critchley *et al.*, 2007; Starr-Keddle, 2011; van Dobben *et al*., 2017; Wheeler & Wilson, in prep.). Levels of available phosphate declined only slightly and not significantly between 1995 and 2020 in fields under agri-environment scheme options here, and increased slowly outside agri-environment schemes, differences only becoming significant in 2020. Phosphate is very immobile in soils (van Dobben *et al.*, 2017), and rate of depletion is very slow. Potential restorability of species-rich grassland on soil with an available phosphate level of more than 16 mg/l is considered to be medium to low (Natural England, 2010). The role of other soil nutrients here was more equivocal, although higher pH appeared to be associated with Favourable condition. The importance of management was also demonstrated. Favourable condition in these grasslands was associated with grazing with traditional cattle and sheep breeds but not by modern sheep breeds, and cutting for hay or haylage determined by seasonal conditions rather than by the earliest permissible date. The application of artificial NPK fertiliser was detrimental, but lime application may be favourable. No association between farmyard manure (FYM) application and condition was recorded. Under current scheme agreements FYM may only be applied at a maximum rate of 12 t ha^{-1}: Kirkham *et al.* (2008) found that species-richness was maintained in semi-improved upland hay meadows at or below this rate of application. A positive change in condition was also related to cutting for hay rather than haylage, later cutting and grazing by cattle.

Factors which may have changed through time within an HK6 or HK7 option and which are known to have changed in the survey area since the 1980s include an increase in numbers of sheep relative to cattle, but an overall decrease in stock numbers, a change in breeds of sheep and cattle to more profitable modern breeds, a compression of cutting period, later grazing in the spring and cutting for haylage rather than hay. All of these may have been detrimental to sward condition even where fields are managed within agri-environment options and are compliant with scheme requirements.

To these must be added changes that are outside the control of farmers and agri-environment schemes. These include increases in rainfall and nitrogen deposition, which have effects in their own right and also in conjunction with changes in farming practice.

These changes can be considered within the broader context of upland farming systems and their overall intensification especially since the 1940s, intensification originally stimulated by the Second World War and subsequent national efforts to become more self-sufficient. The remaining upland hay meadows do not exist in isolation, but play a strategic part in whole-farm management. At the simplest level, conserved grass in one form or another is essential on a farm where weather, soil and vegetation conditions require livestock to be kept through the winter months. An appropriate number of fields on an upland farm must therefore be shut up for silage, haylage or hay each year to provide winter fodder for the number of animals kept. On many farms the hay meadows have a further function. They are the fields which are used for lambing in the spring, proximity to the farm buildings enabling easy monitoring and protection of vulnerable stock until they can be let out onto common grazing land. The time of lambing is therefore closely connected to the time at which a meadow can be shut-up for hay.

Any fluctuation in numbers and type of stock will therefore have several effects on the ecology of a farm, three of which: reduction in demand for fodder; change in the number and type of animal available for late-summer to spring grazing; and change in need for secure fields for lambing in the spring will have a direct effect on hay production. The continued existence of the Upland Hay Meadow priority habitat grassland and the farms of which they form part is therefore intimately linked to the economics of meat, dairy and wool production, the market prices of these commodities and the level of payment through agri-environment schemes that is available to support these high nature-value systems (Acs *et al*., 2008).

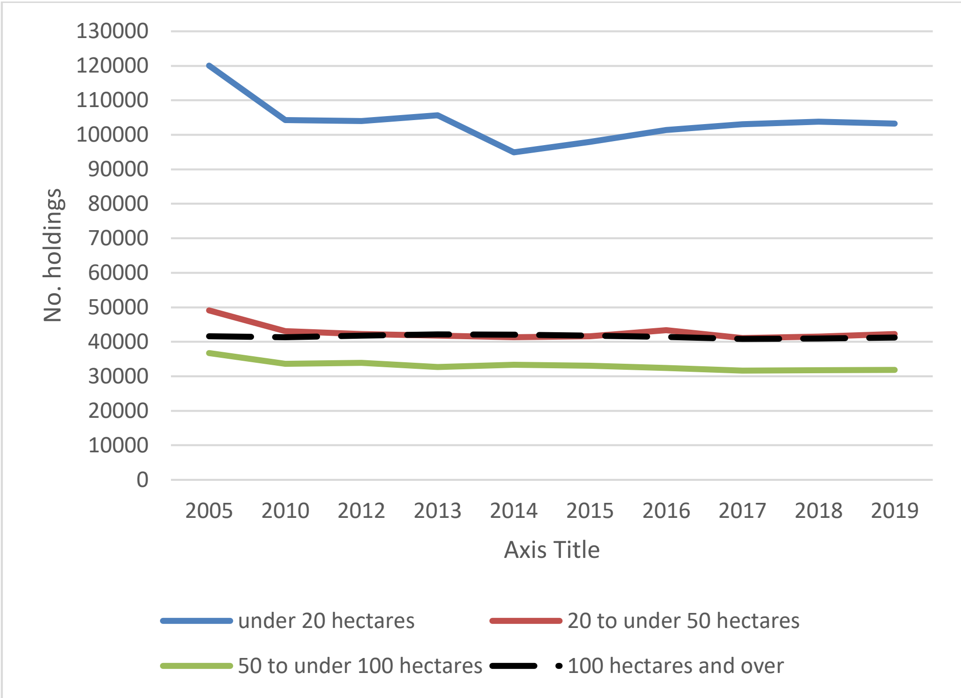
These farms are predominantly small family-run holdings of < 100 ha and recent agricultural data sets (https://www.gov.uk/government/statistical-data-sets/agriculture-in-the-united-kingdom) show that the number of holdings of this size and the concomitant area of land farmed by these holdings is declining throughout the UK (Figure 33). Conversely the area of holdings in the largest size group (>100 ha) is increasing. Agri-environment scheme funding is becoming more essential to the survival of these smaller farms and the habitats and wildlife that they support, and without this, further amalgamation of holdings and agricultural improvement is inevitable. In 2020, agri-environment schemes were generally popular with the farmers interviewed, and integrated well with their farming systems. The hay meadows were a valuable part of the holding, providing winter feed, autumn grazing and spring lambing pasture. Acceptability to farmers is essential for the take-up of agri-environment scheme agreements. Although hay meadows are affected by extraneous pressures outside the farmers' control which may be driving detrimental changes, there are minor changes to management which would probably make management in agri-environment schemes more beneficial to grassland condition. The following changes are suggested:

1. Changing the date for shutting-up meadows from 15th May to 1st May. Derogations possible in cold springs and some flexibility according to geographic locations (meadows at higher elevations are generally slower to grow/flower) .
2. Changing the date for cutting to after 15th July in all agreements and later for those at higher elevations.
3. Requiring cutting to be delayed to 1st August in one year of every five but encourage late cutting to be more frequent.
4. Additional payments for cutting after 1st August
5. Additional payment for hay-cutting (weather permitting). Hay as opposed to haylage should be made in two years of every three.
6. A strict limit of 10 t^{-1} ha^{-1} year for FYM application
7. Additional payments to be available for use of traditional cattle and sheep breeds
8. Supplementary payments for addition of plug plants/green hay

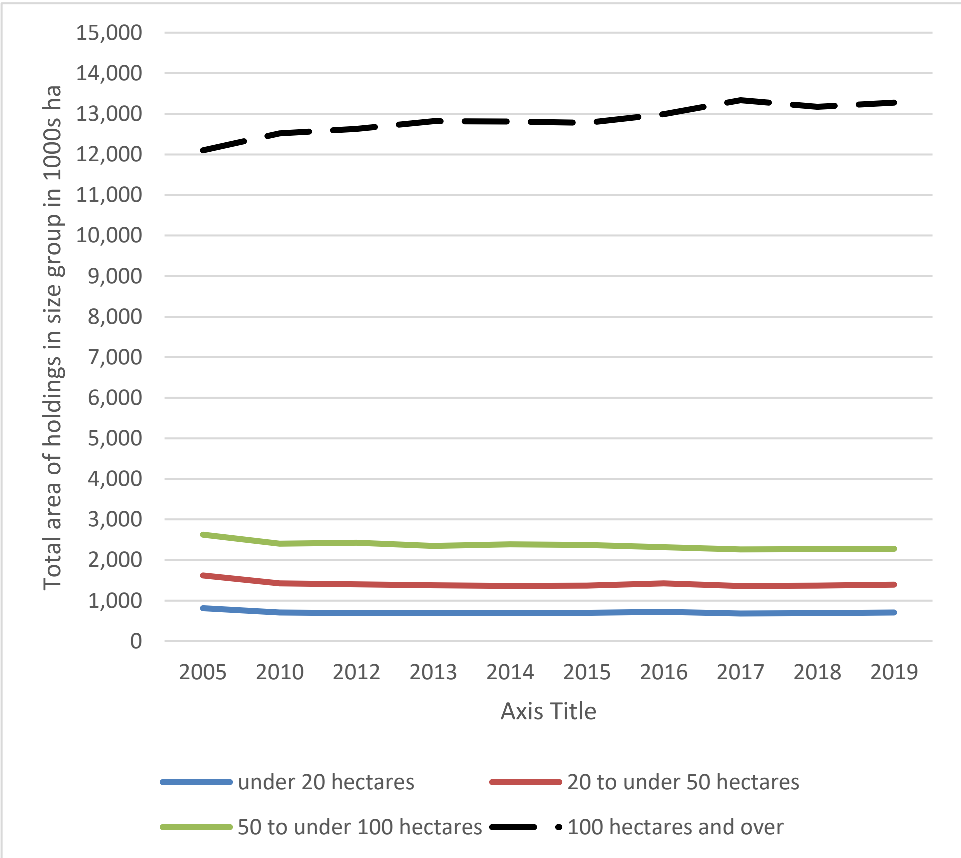
In addition, regular and more frequent contact with a Natural England advisor is strongly advised to provide ongoing support, feedback on progress against indicators of success and to provide more farm-specific guidance.

Figure 33. Changes in farm size in the UK 2005–2019 showing (a) the total number of holdings and (b) the total area in hectares (thousands) of holdings by size group: holdings under 20 ha, holdings 20 to under 50 ha, and holdings 50 to under 100 ha, and holdings of 100 ha and over (source of data: https://www.gov.uk/government/collections/agriculture-in-the-united-kingdom).

(a)



(b)



6 References

Acs, S., Hanley, N., Dallimer, M., Gaston, K.J., Robertson, P., Wilson, P. & Armsworth, P.R. (2008). The effect of decoupling on marginal agricultural systems: implications for farm incomes, land use and upland ecology. *Stirling Economics Discussion Paper* 2008-18

Aerts, R., de Caluwe, H., & Beltman, B. (2003). Is the relation between nutrient supply and biodiversity co-determined by the type of nutrient limitation? *Oikos*, 101, 489-498.

ADAS (1996) *Botanical monitoring of grassland in the Pennine Dales ESA 1987–1995.* ADAS report to MAFF.

Alcock, M.R. (1982) *Yorkshire Grassland: a botanical survey of hay meadows within the Yorkshire Dales National Park.* England Filed Unit, Project Report No. 10. NCC, Banbury.

Anderson, I.A. (2002) *Foot and Mouth Disease 2001:Lessons to be learned inquiry report.* Presented to the Prime Minister and the Secretary of State for Environment, Food and Rural Affairs, and the devolved administrations in Scotland and Wales. Ordered by the House of Commons.

Averis A., Averis B., Birks J., Horsfield D., Thompson D. & Yeo M. (2004) *An illustrated guide to British upland vegetation.* JNCC.

Bradshaw, M.E. (2018) 5 - Flora and vegetation. In: *The Natural History of Upper Teesdale.* Durham Wildlife Trust. Available at: https://livinguplands.com/natural-history-upper-teesdale.

Colston, A. (2017) Atmospheric Nitrogen Pollution and its impact on Dartmoor – the other elephant in the countryside. Available at:

https://adriancolston.wordpress.com/2017/03/31/atmospheric-nitrogen-pollution-and-its-impact-on-dartmoor-the-other-elephant-in-the-countryside/?fbclid=IwAR21s4FJCDiffpuEbMlbZhq4CzUYV1Fo3DCs7Yf6LcH4hm_HZxpasTH5RDI

Cornish, C. & Hooley, J. (2012). “Going for gold (purple and pink) in 2012”. Results from five years of hay meadow restoration in Cumbria. *Aspects of Applied Biology* **115**. *Restoring diverse grassland: What can be achieved where, and what will it do for us?* https://www.cumbriawildlifetrust.org.uk/sites/default/files/2018-05/hay-meadow-restoration-going-for-gold-paper-2012.pdf

Critchley, C.N.R., Fowbert, J.A., Wright, B. & Parkin, A.B. (2004) *Upland Hay Meadows in the Pennine Dales Environmentally Sensitive Area: Vegetation Change between 1987 and 2002 and its Relation with Management Practices and Soil Properties*. Report to DEFRA.

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

Critchley, C.N.R., Maskell, L.C., Mitchley, J., Adamson, H.F., Burch, F.M., Carey, P.D., Firbank, L.G., Fowbert, J.A., Parkin, A.B., Smart, S.M. & Sparks, T.M. (2002). *Review and Recommendations of Methodologies to be used for Botanical Monitoring of Agri-Environment Schemes in England.* Report to DEFRA.

Defra (2011) *Agriculture in the UK* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/82818/defra-stats-foodfarm-crosscutting-auk-auk2011-120709.pdf

Defra (2017) *Agriculture in the UK* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/741062/AUK-2017-18sep18.pdf

Defra (2018) *A Green Future: Our 25 Year Plan to improve the Environment.* HM Government. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf

van Dobben, H.F., Wamelink, G.W.W., Slim, P.A., Kamiński, J. & Piórkowski, H. (2017) Species-rich grassland can persist under nitrogen-rich but phosphorus-limited conditions. *Plant Soil* 411:451–466

Ellenberg, H. (1988). *Vegetation ecology of central Europe*. (Fourth edition English translation). Cambridge: Cambridge University Press.

Gamble, D., Perry, C. & St Pierre, T. (2012) Haytime Final Report 2012. Yorkshire Dales Millennium Trust. https://www.ydmt.org/resources/files/hay-time-final-report.pdf

Hamilton, H., Jackson, S. & Blackshaw, A. (2014) *Long term effectiveness of environmental stewardship in conserving upland hay meadows in the Pennine Dales*. Natural England Commissioned Report NECR138. www.naturalengland.org.uk

Hamilton H, Ross S, Silcock P & Steer S (2018). *Towards an Understanding of the Perceived Increase in* Juncus *(Rush) Species in Species-Rich Upland Hay Meadows*. Natural England.

Hewins, E.J., Pinches, C., Arnold, J., Lush, M., Robertson, H., Escott, S. (2005). *The condition of lowland BAP priority grasslands: results from a sample survey of non-statutory stands in England*. English Nature Research Report No. 636. English Nature, Peterborough

Hill, M.O., Mountford, J.O., Roy, D.B. & Bunce, R.G.H. (1999). *Ellenberg's Indicator Values for British Plants*. Centre for Ecology and Hydrology.

Honsova, D., Hejcman, M., Klaudisova, M., Pavlu, V., Kocourkova, D. & Hakl, J. (2007). Species composition of an alluvial meadow after 40 years of applying nitrogen, phosphorus and potassium fertiliser. *Preslia*, 79: 245-258.

Hunt, K.E. (1954). *The State of British Agriculture 1953-1954.* University of Oxford, Institute for Research into Agricultural Economics

Jefferson, R.G. (2005). The conservation management of upland hay meadows in Britain: a review. *Grass and Forage Science*, 60, 322-331.

JNCC (2004) Common Standards Monitoring Guidance for Lowland Grassland Habitats. JNCC, Peterborough.

JNCC (2008) UK Biodiversity Action Plan Priority Habitat Descriptions. Upland Hay Meadows. JNCC. Available at: http://jncc.defra.gov.uk/page-5706

Kirkham, F.W., Mountford, J.O., & Wilkins, R.J. (1996). The effects of nitrogen, potassium and phosphorus addition on the vegetation of a Somerset peat moor under cutting management. *Journal of Applied Ecology,* 33, 1013-1029.

Kirkham, F.W., Tallowin, J.R.B., Sanderson, R.A., Bhogal, A., Chambers, B.J. & Stevens, D.P. (2008) The impact of organic and inorganic fertilizers and lime on the species-richness and plant functional characteristics of hay meadow communities. *Biological Conservation*, **141**, 1411-1427.

Kirkham, F.W., Dunn, R.M., Tallowin, J.R.B., Bhogal, A., Chambers, B.J., & Bardgett, R.D. (2012). *Ecologically-sustainable fertility management for the maintenance of species-rich hay meadows: a 12 year fertiliser and lime experiment. Appendix 1 of Defra Final report BD1468 Sustainable nutrient management of semi-natural neutral grasslands* Rothamsted Research, North Wyke & ADAS Ltd 22nd February 2012.

Natural England (2010) Higher Level Stewardship Farm Environment Plan (FEP) Manual. Third Edition March 2010. www.naturalengland.org.uk

Natural England (2016) Countryside Stewardship. Baseline Evaluation of Higher Tier Agreement (BEHTA) Manual: Part 2. Technical user guidance on BEHTA feature identification, condition assessment and data collection in the field. Second edition – May 2016. Natural England www.gov.uk/natural-england

North Pennines AONB (2013) Hay Time Highlights 2006-2012. Available at:

http://www.northpennines.org.uk/wp-content/uploads/sites/37/2016/11/HayTimeHighlights2006-2012.pdf

O’Reilly, J. (2011) An analysis of survey data from upland hay meadows in the North Pennines AONB. Natural England Commissioned Report NECR069.

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

Pinches, C.E., Gowing, D.J.G., Stevens, C.J., Fagan, K. & Brotherton, P.N.M. (2013) Natural England review of upland evidence – Upland hay meadows: what management regimes maintain the diversity of meadow flora and populations of breeding birds? *Natural England Evidence Review*, Number 005.

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Robertson, H.J. & Jefferson, R.G. (2000) *Monitoring the condition of lowland grassland SSSIs: English Nature's rapid assessment method.* English Nature Research Reports Number 315, English Nature, Peterborough.

Robinson, S. & Gamble, D. (2014) *Bowland Hay Time. Final report of the Bowland Hay Time project, April 2102 to March 2014*. https://www.forestofbowland.com/files/uploads/pdfs/haytime_final_project_report.pdf

Rodwell, J.S. (ed) (1991–2000) *British Plant Communities, volumes 1–5*. Cambridge University Press, Cambridge.

Rodwell, J.S. (ed.) (1992) *British Plant Communities, volume 3. Grasslands and montane communities*. Cambridge University Press, Cambridge.

Silcock, P., Brunyee, J. & Pring. J. (2012). *Changing livestock numbers in the UK LFA - an analysis of likely biodiversity implications*. Final Report prepared for the Royal Society for the Protection of Birds by Cumulus Consultants Ltd

Smart. S., Goodwin, A., Wallace, H. & Jones, M. (2016) MAVIS (Ver 1.03) User Manual. Centre for Ecology and Hydrology. Available at: https://www.ceh.ac.uk/

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

Smith, R.S., Pullan, S., & Shiel, R.S. (1996). Seed shed in the making of hay from mesotrophic grassland in a field in Northern England: effects of hay cut date, grazing and fertiliser in a split-split-plot experiment. *Journal of Applied Ecology*, 33, 833-841.

Smith, R.S., Shiel, R.S., Millward, D., Simkin, J. & Pratt, S. (2012). *Spring grazing in northern hay meadows: influence of the timing and intensity of sheep grazing on the floristic diversity and restorative potential.* Unpublished 2011-12 Annual report to DEFRA. Newcastle University School of Agriculture, Food and Rural Development, Newcastle upon Tyne.

Smith, R.S., Shiel, R.S., Millward, D. & Simkin, J.M. (2016). Effects of sheep stocking on the plant community and agricultural characteristics of upland *Anthoxanthum odoratum–Geranium sylvaticum* meadow in northern England. *Grass and Forage Science,* 72, 502–515.

Stace, C. A. (2019) *New Flora of the British Isles*, 4th Edn. Cambridge University Press, Cambridge.

Starr-Keddle, R.E. & Barrett, R.M. (2012) Hay Time: A landscape-scale approach to upland hay meadow restoration using green hay – preliminary results. *Aspects of Applied Biology*, 115, *Restoring diverse grassland: What can be achieved where, and what will it do for us?*, 187–193.

Starr-Keddle, R.E., (2014). *Upper Teesdale: changes in upland hay meadow vegetation over the past twenty to thirty years – results presented from botanical surveys*. Natural England Commissioned report NECR139. Natural England.

Starr-Keddle R.E. (2018). From Hay Time to Nectarworks: novel approaches to landscape-scale upland hay meadow restoration in the North Pennines. *Aspects of Applied Biology*, 139, 157−166. *Ecosystem and Habitat Management: Research, Policy, Practice*

Stevens, C.J., Dise, N.B., Mountford, J.O. & Gowing, D.J. (2004) Impact of nitrogen deposition on the species richness of grasslands. *Science* 303: 1876-1879.

Stevens, C.J., Dise, N.B., Gowing, J.G. & Mountford, J.O. (2006) Loss of forb diversity in relation to nitrogen deposition in the UK: regional trends and potential controls. *Global Change Biology*, 12, 1460–1465.

Stevens, C.J., Dupre, C., Dorland, E., Gaudnik, C., Gowing, D.J.G., Bleeker, A., Diekmann, M., Alard, D., Bobbink, R., Fowler, D., Corcket, E., Mountford, J.O., Vandvik, V., Aarrestad, P.A., Muller, S. & Dise, N.B. (2011a) The impact of nitrogen deposition on acid grasslands in the Atlantic region of Europe. *Environmental Pollution* 159: 2243-2250.

Stevens, C.J., Smart, S.M., Henrys, P.A., Maskell, L.C., Walker, K.J., Preston, C.D., Crowe, A., Rowe, E.C., Gowing, D.J. & Emmett, B.A. (2011b). *Collation of evidence of nitrogen impacts on vegetation in relation to UK biodiversity objectives*. JNCC Report 447. http://jncc.defra.gov.uk/page-5894

Stewart, K.E.J, Bourn, N.A.D. & Thomas, J.A. (2001) *An evaluation of three quick methods commonly used to assess sward height in ecology.* Journal of Ecology **38**, 1148–1154.

ter Braak, C.J.F. & Smilauer, P. (2018) *Canoco reference manual and user's guide: software for ordination (version 5.10)*. Biometris, Wageningen University & Research.

Tytherleigh A (2008). Soil sampling for habitat recreation and restoration. Natural England Technical Information Note TIN035.

UK Government (2006). *The Natural Environment and Rural Communities Act 2006*. https://www.legislation.gov.uk/ukpga/2006/16/contents

Vickery, J.A., Tallowin, J.R., Feber, R.E., Asteraki, E.J., Atkinson, P.W., Fuller, R.J. & Brown, V.K. (2001). The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food sources. *Journal of Applied Ecology,* 38: 647-664.

Wallace, H. & Prosser, M. (2016) Plant communities of floodplain meadows. In Chapter 8, Rothero, E., Lake, S. & Gowing, D. (eds) (2016). *Floodplain Meadows – Beauty and Utility. A Technical Handbook*. Milton Keynes, Floodplain Meadows Partnership.

Wheeler, B.R., Wilson, P.J. & Bealey, C.E.B. (2014) Long-term effectiveness of Environmental Stewardship in conserving the botanical interest of lowland wet grassland. *Natural England Commissioned Report* (*ref LM0421*)*,* http://randd.defra.gov.uk/

Wheeler, B.R. & Wilson, P.J. (2016) *The effectiveness of Higher Level Stewardship for maintaining and restoring species-rich grasslands: a re-survey of a sample of grasslands under HLS options HK6 and HK7.* Natural England Commissioned Report (14093_LM0443)

Wheeler, B.R. & Wilson P.J. (in prep). The effectiveness of agri-environment schemes in delivering outcomes in non-statutory priority grasslands. Report to Defra, Project RP04171

Wilkins, R.J. (2000) *Grassland in the Twentieth Century*. Institute of Grassland and Environmental Research, IGER, Aberystwyth

Wilson, P.J. (2013) A detailed examination of the results from a survey and assessment of soil pH and nutrient status on sites of high botanical value. Natural England Commissioned Report (12461_LM0423)

Wilson, P.J. & Wheeler, B.R. (2014) Survey of soil nutrient status on sites of high botanical value. Natural England Commissioned Report (14092_LM0444)

Appendices

Appendix 1 – Survey forms

Quadrat survey form

Management questionnaire

Rapid Condition Assessment: MG3

Rapid Condition Assessment: MG8-related (north), MG3-related

Lowland grassland SSSI condition assessment: MG3

Lowland grassland SSSI condition assessment: M26, MG8-related, MG3-related (wet northern hay meadow)

IMPACTS OF A-E MANAGEMENT ON UHMs 2019-2021: QUADRAT SURVEY FORM											
Site Name:				**Site No:**				**Quadrat No:**			
Surveyor:				**Date:**				**Grid Ref:**			
Species	**Inner 1×1**		**Outer 2× 2**	**Species**	**Inner 1×1**		**Outer 2× 2**	**Species**	**Inner 1×1**		**Outer 2× 2**
	% Cover	**Domin**	**DAFOR**		**% Cover**	**Domin**	**DAFOR**		**% Cover**	**Domin**	**DAFOR**
Agros cani				Achi mill				Planta lanc			
capi				ptar				majo			
stol				Ajug rept				Poten anse			
Alope geni				Alche fili				erec			
prat				glab				rept			
Antho odor				Anen nemo				Primu fari			
Arrhe elat				Ange sylv				veri			
Briza medi				Anthr sylv				vulg			
Brom comm				Belli pere				Prune vulg			
hord				Calth palu				Pteri aqui			
Cyno cris				rotu				Ranun acri			
Dact glom				Card prat				bulb			
Danth decu				flex				repe			
Desch cesp				Centa nigr				Rhina mino			
flex				Ceras arve				Rubus frut			
Elym repe				font				Rumex acet			
Festu arun				glom				cong			
prat				Chame angu				crisp			
rubr				Cirsi arve				obtu			
Glyce decl				diss				Sagin nodo			
Helic prat				erio				proc			
pube				hetero				Sangi offi			
Holc lana				palu				Saxi gran			
Horde seca				vulg				Senec aqua			
Loliu pere				Conop maju				jaco			
Molin caer				Dacty purp				Sonch arve			
Nard stric				Digit purp				aspe			
Phleu bert				Eleoc palu				oler			
prat				Equi palu				Stella alsi			
Poa ann				Euphr sp.				gram			
humi				Filip ulma				Succi prat			
prat				Galiu apar				Tarax sp.			
triv				moll				Trifo medi			
Trise flav				palu				prat			
				saxa				repe			
				uligin				Troll euro			
Carex cary				veru				Urtic dioc			
demi				Geran prat				Valer dioc			
dista				sylv				Veron cham			
disti				Geum riva				serp			
flac				Herac spho				Vicia cracc			
hirt				Hypo radi				sat nig			
nigr				Lathy lini				sepi			
oval				prat				Viola cani			
pani				Leont autu				lute			
				hisp				rivi			
				Leuca vulg							
Juncu acut				Linum cath							
arti				Lotus corn					cm	cm	cm
bufo				pedu				Veg. height			
bulb				Lychn f-cuc					% cover		
cong				Menth aqua				Bare Ground			
effu				Myoso arve				Litter			
infl				disco				Bryophytes			
squa				scor				Grasses			
subn				Orchi masc				Forbs			
Luzu camp								Sedges			
mult								Rushes			

IMPACTS OF A-E MANAGEMENT ON UHMs 2019-2021: MANAGEMENT QUESTIONNAIRE		
Site Name:	**Site No:**	**Respondent name:**
Interviewer (or postal?): postal	**Date:**	

It is important to be clear exactly which parcels) is/are being discussed. Interviewer will need to be confident that they can identify the field to be surveyed to the farmer. WHERE THERE ARE MULTIPLE SITES IN ONE OWNERSHIP COMPLETE ONE QUESTIONNAIRE PER SITE.

1. CURRENT & PREVIOUS SCHEME DETAILS

HLS OPTIONS	HK6 Maintenance of species-rich semi-natural grassland	-
	HK7 Restoration of species-rich semi-natural grassland	-
	HK18 Haymaking Supplement	-
CS OPTIONS	GS6 Management of species-rich grassland (Higher tier)	-
	GS7 Restoration towards species-rich grassland (Higher tier)	-
	GS15 Haymaking supplement (Higher tier)	-
	Other	
Additional information:		

2. CUTTING MANAGEMENT

HAY-CUTTING	Has field been consistently managed for field dried hay since entering HLS?	Yes/No
	If **YES** for how long?	years
	If **NO** what has been done instead? (grazed/haylage/silage/other)	
RECENT CUTTING DATES	2019	
	2018	
	2017	
	2016	
	2015	
Has this changed significantly in last 10 years? How?		
OTHER CUTTING	Have you cut rushes?	Yes/No
	If **YES** last year rushes were cut?	
	Have you cut other species, such as weedy species?	Yes/No
	If **YES** last year other species were cut?	
Additional information:		

3. GRAZING MANAGEMENT INCLUDING SUPPLEMENTARY FEEDING

TIMING OF CURRENT GRAZING	Autumn	Dates:	Cattle / sheep / cattle & sheep / horses
	Winter	Dates:	Cattle / sheep / cattle & sheep / horses
	Spring	Dates:	Cattle / sheep / cattle & sheep / horses
	Summer		Cattle / sheep / cattle & sheep / horses
Livestock breeds / rarity?			
Has the grazing pattern changed recently? Yes / No			
If **YES** In what way and how long ago? e.g. numbers per ha, timing during year or livestock type.			
Additional information:			

CURRENT SUPPLEMENTARY FEEDING OF LIVESTOCK WITHIN FIELD	None / hay / haylage / silage (big bale) / silage clamp / straw / other
	Salt lick
	When
	Where
PAST SUPPLEMENTARY FEEDING	Has it changed? No change / in last year / last 5 years / last 10 years?
	How?

Additional information:	
4. FERTILISER & LIME APPLICATION	
LIME APPLICATION	Yes / No
	How often?
	Approx. date / year of last application?
	How much? None / < 1t per ha / 1-2 t per ha / >2 t per ha?
CURRENT FERTILISER USE	NPK - Yes / No (specify ratios if known, usually ____: ____:____ , and application rate.
	FYM – Yes /No
	How often? Every year / every other year / other (detail)
	How much? < 10 t per ha / 10-15 t per ha / 16-20 t per ha / 21 - 25 t per ha?
Has this changed in past years? If Has this changed in past years? If YES see below.	
PREVIOUS FERTLISER USE	Yes / No
	What?
	How often?
	How much?
Additional information:	
5. OTHER MANAGEMENT	
DRAINAGE	What & when?
WEED CONTROL	What & when?
OTHER	What & when?
Additional information:	
6. RESTORATION MANAGEMENT	
SWARD ENHANCEMENT THROUGH SEED ADDITION	Yes / No
	How funded? Hay Time / self-funded / other
	When?
	What method? Commercial seed / brush harvested seed / green hay / dried hay / plugs
	Sources of seed? e.g. local meadow
	Yellow rattle added?
	Site preparation before seed? (scarify / harrow / none / other
	Site preparation after seed addition?
	Contractor used?
	Site preparation before seed? (scarify / harrow / none / other
Additional information:	
7. OBSERVATIONS / IMPRESSIONS OF CHANGE	
Have you noted any differences to sward and yields relating to management measures undertaken in recent years?	Sward:
	Yield:
	Other:
Would you like to receive a copy of the field survey data? Yes/ No	
Would you like to receive a copy of the soil analysis data? Yes/ No **THANK YOU**	

Rapid Condition Assessment
(Lowland Grassland) Fieldform

NVC Stand Type: Mountain hay meadows: MG3

Survey: PSU Code: Survey Year: Visit: FSU Code: Stand Code (Optional):

NVC Communities / Sub-communities

Codes:	Communities:

Personnel

Initials:	Name:	Fieldwork:	Data Entry:

Stand Details

Date of Visit to Stand:

Number of Stops during Structured Walk:

Notes:

Sward Structure

Extent of bare ground (not rock) distributed through the sward, visible without disturbing the vegetation. %

Extent of litter (in a more or less continuous layer, distributed either in patches or in one larger area) in the Sward % cover

Average height of sward (recorded in summer visit period only) cm.

Extent of Community

Non-recoverable reduction	
Recoverable reduction	
No change	
Increase	

Sward Composition

Negative Indicator Species aggregate cover [Cirsium arvense, Cirsium vulgare, Rumex crispus, Rumex obtusifolius, Senecio jacobaea, Urtica dioica] % cover

Grass/herb (ie non-Graminae) ratio %

Cover of all scrub and tree species, considered together. % cover

Frequency Counts

Latin Name:	Locally Abundant:	Frequency Count:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Alchemilla																						
Anemone nemorosa																						
Anthriscus sylvestris																						
Centaurea nigra																						
Cirsium arvense																						
Cirsium heterophyllum																						
Cirsium vulgare																						
Conopodium majus																						
Euphrasia																						
Filipendula ulmaria																						
Geranium sylvaticum																						
Geum rivale																						
Lathyrus pratensis																						
Leontodon																						
Lotus corniculatus																						
Persicaria bistorta																						
Rhinanthus minor																						
Rumex crispus																						
Rumex obtusifolius																						
Sanguisorba officinalis																						
Senecio jacobaea																						
Succisa pratensis																						
Trees & scrub																						
Trollius europaeus																						
Urtica dioica																						

Percentage Cover

% Cover of Anthriscus sylvestris

Rapid Condition Assessment
(Lowland Grassland) Fieldform

NVC Stand Type: Upland wet northern hay meadow:
MG8-related (north) , MG3-related

Survey: PSU Code: Survey Year: Visit: FSU Code: Stand Code (Optional):

NVC Communities / Sub-communities

Codes:	Communities:

Personnel

Initials:	Name:	Fieldwork:	Data Entry:

Stand Details

Date of Visit to Stand:

Number of Stops during Structured Walk:

Notes:

Sward Structure

Extent of bare ground (not rock) distributed through the sward, visible without disturbing the vegetation. %

Extent of litter (in a more or less continuous layer, distributed either in patches or in one larger area) in the Sward % cover

Average height of sward (Excl. Juncus spp.) [if pasture record null] cm.

Average height of pasture sward (Excl. Juncus spp.) [if not pasture record null] cm.

Extent of Community

Non-recoverable reduction	
Recoverable reduction	
No change	
Increase	

Sward Composition

Negative Indicator Species aggregate cover [Anthriscus sylvestris, Cirsium arvense, Cirsium vulgare, Rumex crispus, Rumex obtusifolius, Urtica dioica] % cover

Grass/herb (ie non-Graminae) ratio %

Cover of all scrub and tree species, considered together. % cover

Frequency Counts

Latin Name:	Locally Abundant:	Frequency Count:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Achillea ptarmica																						
Ajuga reptans																						
Anthriscus sylvestris																						
Caltha palustris																						
Carex flacca/nigra/panicea																						
Cirsium arvense																						
Cirsium vulgare																						
Crepis paludosa																						
Euphrasia																						
Filipendula ulmaria																						
Geum rivale																						
Leontodon																						
Lychnis flos-cuculi																						
Orchidaceae																						
Potentilla erecta																						
Rhinanthus minor																						
Rumex crispus																						
Rumex obtusifolius																						
Sanguisorba officinalis																						
Serratula tinctoria																						
Succisa pratensis																						
Trollius europaeus																						
Urtica dioica																						
Valeriana dioica																						

Percentage Cover

% cover of Deschampsia cespitosa.	
% cover of Juncus species (Juncus conglomeratus, J. effusus and J. inflexus)	
% cover of Juncus species (Juncus conglomeratus, J. effusus, J. inflexus, Juncus acutiflorus, J. articulatus and J. subnodulosus)	

ENGLISH NATURE

Lowland grassland SSSI condition assessment (version date 10/10/00)

Site Name: . . . .

NVC type: **MG3**

Unit/subdivision reference . . . . Date. . . . .

Condition: Favourable maintained/Favourable recovered /Unfavourable improving/
Unfavourable no change/Unfavourable declining/Partially destroyed/Destroyed

Recommended visiting period: Late May - mid July (until hay cut time) with periodic visit in autumn-spring visit to check condition at end of aftermath grazing period.
Recommended frequency of visits: Site-specific decision

Key management activities affecting condition to discuss with manager:

Hay+aftermath grazing
FYM input
Other inputs
Drainage
Scrub and weed control
Grazing intensity/stocking rate
Grazing period
Supplementary feeding
Rolling and chain harrowing

Attribute (*= mandatory attribute. One failure among mandatory attributes = unfavourable condition)	***Target***	***Estimate for attribute***
*Extent of community (recoverable reduction = unfavourable; non-recoverable reduction = partially destroyed).	No loss without prior consent	(Describe and refer to map)
*Sward composition: grass/herb (ie non-Graminae) ratio	**50-90%** herbs	
*Sward composition: frequency of positive indicator species. *Alchemilla* spp ( ), *Anenome nemorosa* ( ), *Centaurea nigra* ( ), *Cirsium heterophyllum* ( ), *Conopodium majus* ( ), *Euphrasia* spp. ( ), *Filipendula ulmaria* ( ), *Geranium sylvaticum* ( ), *Geum rivale* ( ), *Lathyrus pratensis* ( ), *Leontodon* spp ( ), *Lotus corniculatus* ( ), *Persicaria bistorta* ( ), *Rhinanthus minor* ( ), *Sanguisorba officinalis* ( ), *Succisa pratensis* ( ), *Trollius europaeus* ( ).	At least three species/taxa **frequent** and three **occasional** throughout the sward, **or locally abundant** over more than 10% of the sward	
*Sward composition: frequency and % cover of negative indicator species. *Cirsium arvense* ( ), *Cirsium vulgare* ( ), *Rumex crispus* ( ), *Rumex obtusifolius* ( ), *Senecio jacobaea* ( ), *Urtica dioica* ( ).	No species more than **occasional** throughout the sward or singly or together more than **5%** cover	
*Sward composition: frequency and % cover of all tree and scrub species, considered together.	No more than occasional throughout the sward or more than **1%** cover.	

Attribute (= mandatory attribute. One failure among mandatory attributes = unfavourable condition)*	*Target*	*Estimate for attribute*
*Sward composition: frequency of negative indicator species (More than frequent = more than **60%** frequency). *Anthriscus sylvestris* ( ).	*Anthriscus sylvestris* no more than **frequent** throughout the sward or more than **5%** cover	
Sward structure: average height of sward, recorded in summer visit period only. NB If site is permanent pasture in summer period discuss with site manager.	5 cm or above	
Sward structure: litter in a more or less continuous layer, distributed either in patches or in one larger area.	Total extent no more than **25%** of the sward	
Sward structure: extent of bare ground (not rock) distributed through the sward, visible without disturbing the vegetation.	No more than **5%**	

Structured walk recording form
Frequencies: totals out of 20 stops. 1-4 = rare, 5-8 = occasional, 9+ = frequent or more

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total

Lowland grassland SSSI condition assessment (version date 10/10/00)

ENGLISH NATURE

Site Name: . . . .

NVC type: **M26, MG8-related (north) , MG3-related (wet northern hay meadow)**

Unit/subdivision reference . . . . Date. . . . .

Condition: Favourable maintained / Favourable recovered / Unfavourable improving / Unfavourable no change / Unfavourable declining / Partially destroyed / Destroyed

---

Recommended visiting period: Hay meadows: June-July (before hay cut), with periodic visit in autumn-spring visit to check condition at end of aftermath grazing period. Pastures: June-August.
Recommended frequency of visits: Site-specific decision

Key management activities affecting condition to discuss with manager:

Hay +aftermath grazing	Grazing intensity/stocking rate
FYM input	Grazing period
Other inputs	Supplementary feeding
Drainage	Rolling and chain harrowing
Scrub and weed control	Burning

Attribute (*= mandatory attribute. One failure among mandatory attributes = unfavourable condition)	***Target***	***Estimate for attribute***
*Extent of community (recoverable reduction = unfavourable; non-recoverable reduction = partially destroyed).	No loss without prior consent	(Describe and refer to map)
*Sward composition, **MG8-related** and **MG3-related only**: grass/herb (ie non-Graminae) ratio	**50-90%** herbs	
*Sward composition: frequency of positive indicator species/taxa. *Achillea ptarmica* ( ), *Ajuga reptans* ( ), *Caltha palustris* ( ), *Crepis paludosa* ( ), *Euphrasia* spp. ( ), *Filipendula ulmaria* ( ), *Geum rivale* ( ), *Leontodon* spp ( ), *Lychnis flos-cuculi* ( ), Orchidaceae spp. ( ), *Potentilla erecta* ( ), *Rhinanthus minor* ( ), *Sanguisorba officinalis* ( ), *Serratula tinctoria* ( ), *Succisa pratensis* ( ), *Trollius europaeus* ( ) *Valeriana dioica* ( ), small blue-green *Carex* spp. (leaves less than 5mm wide) (=*C. flacca*, *C. nigra*, *C. panicea*) ( ).	At least two species/taxa **frequent** throughout the sward, and four **occasional** throughout the sward, or **locally abundant** over more than 10% of the sward	
*Sward composition, **M26 only**: frequency and % cover of *Molinia caerulea*	At least **frequent** throughout the sward but no more than **80%** cover	
*Sward composition: frequency and % cover of negative indicator species/taxa. *Anthriscus sylvestris* ( ), *Cirsium arvense* ( ), *Cirsium vulgare* ( ), *Rumex crispus* ( ), *Rumex obtusifolius* ( ), *Urtica dioica* ( ).	No species/taxa more than **occasional** throughout the sward or singly or together more than **5%** cover	

Attribute (*= mandatory attribute. One failure among mandatory attributes = unfavourable condition)	***Target***	***Estimate for attribute***
*Sward composition: frequency and % cover of all scrub and tree species, considered together. NB If scrub/tree species are more than occasional throughout the sward but less than 5% cover, they are soon likely to become a problem if grazing levels are not sufficient or if scrub control is not being carried out.	No more than **5%** cover	
*Sward composition: % cover of *Juncus* species in Group A and B. **Group A**: jointed rushes (=*Juncus acutiflorus, J. articulatus, J. subnodulosus*) **Group B**: *Juncus conglomeratus, J. effusus and J. inflexus*	**MG8-related, MG3-related** All species combined no more than **50%** cover, of which no more than **25%** made up of species from Group B	
	M26 All species combined no more than **80%** cover, of which no more than **50%** made up of species from Group B	
*Sward composition: % cover of *Deschampsia cespitosa*.	No more than **10%** cover	
*Sward composition, **M26** only: cover of *Phragmites australis*.	No more than **5%** cover	
Sward structure: average height. Upper target applies to pastures only.	**MG8-related, MG3-related** **5** cm (excluding *Juncus* species) to **15** cm (including *Juncus* species)	
	M26 **5 cm** or greater (excluding *Juncus* species) but no more than **25%** of sward over **40** cm (including *Juncus* species)	
Sward structure: cover of litter in a more or less continuous layer, distributed either in patches or in one larger area.	Total extent no more than **25%** of the sward	
Sward structure: extent of bare ground (not rock) distributed through the sward, visible without disturbing the vegetation.	No more than **5%**	

Structured walk recording form
Frequencies: totals out of 20 stops. 1-4 = rare, 5-8 = occasional, 9+ = frequent or more

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total

Appendix 2 – Indicator species

Positive indicator species, composite list for all priority grassland habitats (Natural England, 2016)

Positive indicator species for priority grasslands: indicators of upland hay meadows in **bold**		
Achillea ptarmica	***Euphrasia* spp**	*Pilosella officinarum*
Agrimonia eupatoria	***Filipendula ulmaria***	***Pimpinella saxifraga***
Ajuga reptans	*Filipendula vulgaris*	*Plantago coronopus*
***Alchemilla* spp**	*Fragaria vesca*	*Plantago media*
Anagallis tenella	*Galium palustre/uliginosum*	*Polygala spp*
Anemone nemorosa	*Galium saxatile*	***Potentilla erecta***
Angelica sylvestris	*Galium verum*	*Potentilla palustris*
Anthyllis vulneraria	*Genista tinctoria*	*Primula veris*
Aphanes spp	*Gentianella* spp	*Ranunculus flammula*
Arenaria serpyllifolia	*Geranium sanguineum*	***Rhinanthus minor***
Asperula cynanchica	***Geranium sylvaticum***	*Rumex acetosella*
Astragalus danicus	***Geum rivale***	*Sanguisorba minor*
Berula erecta	*Helianthemum canum*	***Sanguisorba officinalis***
Blackstonia perfoliata	*Helianthemum nummularium*	*Scabiosa columbaria*
Calluna vulgaris	*Hippocrepis comosa*	*Sedum acre*
Caltha palustris	*Hydrocotyle vulgaris*	***Serratula tinctoria***
Campanula glomerata	*Jasione montana*	*Silaum silaus*
Campanula rotundifolia	*Juncus articulatus/acutiflorus/subnodulosus*	*Sphagnum spp*
Carex flacca/nigra/panicea	*Knautia arvensis*	*Stachys officinalis*
Carlina vulgaris	*Lathyrus linifolius*	***Succisa pratensis***
Carum verticillatum	***Lathyrus pratensis***	*Teesdalia nudicaulis*
Centaurea nigra	***Leontodon* spp**	*Teucrium scorodonia*
Centaurea scabiosa	*Leucanthemum vulgare*	*Thalictrum flavum*
Centaurium erythraea	*Lichen spp*	*Thymus* spp
Cirsium acaule	*Linum catharticum*	*Tragopogon pratensis*
Cirsium dissectum	***Lotus corniculatus***	***Trollius europaeus***
Cirsium heterophyllum	***Lotus pedunculatus***	*Vaccinium myrtillus*
Clinopodium vulgare	***Lychnis flos-cuculi***	***Valeriana dioica***
Conopodium majus	*Mentha aquatica*	*Valeriana officinalis*
Crepis paludosa	*Narthecium ossifragum*	*Veronica officinalis*
Dianthus deltoides	*Oenanthe silaifolia*	*Viola hirta*
Erica cinerea	*Ononis repens/spinosa*	*Viola palustris*
Erica tetralix	**Orchidaceae**	*Viola riviniana/canina*
Erigeron acer	*Origanum vulgare*	

Erodium cicutarium	*Pedicularis sylvatica*	
Eupatorium cannabinum	***Persicaria bistorta***	

Negative indicator species, composite list for all priority grassland habitats

Negative indicator species
Anthriscus sylvestris
Carduus nutans
Chamerion angustifolium
Cirsium arvense
Cirsium palustre
Cirsium vulgare
Plantago major
Rumex obtusifolius
Rumex crispus
Senecio aquatica
Senecio jacobaea
Urtica dioica

Appendix 3 – Results of NVC analysis

MATCH analysis of all survey data 1987–2020 where quantitative quadrat data was available (MAVIS v1.03, Smart *et al.*, 2016).

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
14	**Validation site 14**	**NON-AGREEMENT CONTROL**	MG6b	**None**	**1**	**MG6b**	**72.69**					**MG6b**	**75.73**	**MG6a**	**67.85**	**MG6b**	**65.42**
14		NON-AGREEMENT CONTROL			2	MG6a	72.32					MG6	72.26	MG6	67.77	MG6	64.68
14		NON-AGREEMENT CONTROL			3	MG6	71.34					MG6a	68.35	MG7E	66.56	MG3a	64.17
14		NON-AGREEMENT CONTROL			4	MG3a	63.90					MG3a	65.44	MG6b	65.70	MG6a	63.39
14		NON-AGREEMENT CONTROL			5	MG7d	62.41					MG6c	63.39	MG7D	64.36	MG7D	63.17
29	**Validation site 29**	**NON-AGREEMENT CONTROL**	MG7	**None**	**1**	**MG7d**	**65.13**			**MG6b**	**61.56**	**MG3a**	**71.46**	**MG3a**	**71.68**	**MG8d**	**74.27**
29		NON-AGREEMENT CONTROL			2	MG7	63.12			MG3a	61.24	MG3	69.84	MG8d	69.92	MG3a	71.18
29		NON-AGREEMENT CONTROL			3	MG6	62.60			MG6	59.10	MG6b	68.28	MG6b	67.37	MG6b	69.78
29		NON-AGREEMENT CONTROL			4	MG6a	62.55			MG8d	59.06	MG8d	67.04	MG3	67.17	MG6	68.02
29		NON-AGREEMENT CONTROL			5	MG6b	60.83			MG4b	58.85	MG6	63.25	MG6	64.41	MG3	67.46
80	**Validation site 80**	**NON-AGREEMENT CONTROL**	MG7	**None**	**1**	**MG7a**	**66.95**							**MG7B**	**63.72**	**MG7A**	**54.42**
80		NON-AGREEMENT CONTROL			2	MG7	58.14							MG7D	60.42	MG7B	53.44
80		NON-AGREEMENT CONTROL			3	MG7b	56.58							MG7	59.83	MG7	52.41
80		NON-AGREEMENT CONTROL			4	MG11a	50.42							MG11a	56.66	MG10a	52.04
80		NON-AGREEMENT CONTROL			5	MG7d	49.80							MG7E	55.92	MG11a	51.49
81	**Validation site 81**	**NON-AGREEMENT CONTROL**	MG7	**None**	**1**	**MG7a**	**57.91**							**MG7**	**71.61**	**MG6**	**65.55**
81		NON-AGREEMENT CONTROL			2	MG11a	53.97							MG7B	71.07	MG6b	63.60
81		NON-AGREEMENT CONTROL			3	MG10a	51.95							MG7D	68.80	MG6a	63.24
81		NON-AGREEMENT CONTROL			4	MG7	47.90							MG6a	67.40	MG3a	62.41
81		NON-AGREEMENT CONTROL			5	MG7b	45.98							MG6	67.34	MG7D	60.27
84	**Validation site 84**	**NON-AGREEMENT CONTROL**	MG7	**None**	**1**	**MG10a**	**59.75**							**MG7B**	**64.29**	**MG7**	**62.50**
84		NON-AGREEMENT CONTROL			2	MG7a	57.49							MG11a	63.66	MG7D	60.45
84		NON-AGREEMENT CONTROL			3	MG7	55.23							MG7D	61.96	MG11a	60.34

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
84		NON-AGREEMENT CONTROL			4	MG11a	51.06							MG7	61.54	MG15b	57.64
84		NON-AGREEMENT CONTROL			5	MG7b	49.05							MG6a	60.56	MG6a	56.93
103	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**70.38**										
103		ENHANCEMENT			2	MG6d	70.04										
103		ENHANCEMENT			3	MG8d	68.56										
103		ENHANCEMENT			4	MG6	67.23										
103		ENHANCEMENT			5	MG6a	65.86										
105	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6d**	**73.75**										
105		ENHANCEMENT			2	MG6b	73.41										
105		ENHANCEMENT			3	MG6a	70.30										
105		ENHANCEMENT			4	MG6	70.20										
105		ENHANCEMENT			5	MG8d	69.81										
106	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6d**	**69.14**										
106		ENHANCEMENT			2	MG4b	68.23										
106		ENHANCEMENT			3	MG6b	67.44										
106		ENHANCEMENT			4	MG15b	66.28										
106		ENHANCEMENT			5	MG6	64.35										
108	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**68.97**										
108		ENHANCEMENT			2	MG3a	65.80										
108		ENHANCEMENT			3	MG6	64.80										
108		ENHANCEMENT			4	MG3	64.16										
108		ENHANCEMENT			5	MG8d	63.05										
109	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**GS7**	**1**	**MG6b**	**69.72**										
109		ENHANCEMENT			2	MG6	64.00										
109		ENHANCEMENT			3	MG8d	62.78										

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
109		ENHANCEMENT			4	MG6a	57.14										
109		ENHANCEMENT			5	MG6c	56.06										
110	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**GS7**	**1**	**MG6b**	**66.96**										
110		ENHANCEMENT			2	MG8d	63.15										
110		ENHANCEMENT			3	MG6	62.76										
110		ENHANCEMENT			4	MG6a	62.33										
110		ENHANCEMENT			5	MG6d	60.18										
112	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG8d**	**62.96**										
112		ENHANCEMENT			2	MG6d	62.95										
112		ENHANCEMENT			3	MG6b	61.95										
112		ENHANCEMENT			4	MG6	60.91										
112		ENHANCEMENT			5	MG3a	58.16										
113	**NP AONB Hay Time site**	**ENHANCEMENT**	MG3a	**HK7**	**1**	**MG3a**	**72.37**										
113		ENHANCEMENT			2	MG4b	70.16										
113		ENHANCEMENT			3	MG4v2	67.93										
113		ENHANCEMENT			4	MG6d	67.75										
113		ENHANCEMENT			5	MG6b	67.74										
114	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG8d**	**73.57**										
114		ENHANCEMENT			2	MG6b	70.44										
114		ENHANCEMENT			3	MG6d	68.66										
114		ENHANCEMENT			4	MG5a	68.48										
114		ENHANCEMENT			5	MG5	67.64										
115	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**63.83**										
115		ENHANCEMENT			2	MG7b	63.03										
115		ENHANCEMENT			3	MG6	62.41										

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
115		ENHANCEMENT			4	MG6d	60.30										
115		ENHANCEMENT			5	MG6a	60.07										
116	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG3a**	**68.32**										
116		ENHANCEMENT			2	MG6b	65.85										
116		ENHANCEMENT			3	MG3	64.72										
116		ENHANCEMENT			4	MG8d	62.85										
116		ENHANCEMENT			5	MG6	62.76										
118	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**73.29**										
118		ENHANCEMENT			2	MG8d	72.14										
118		ENHANCEMENT			3	MG6	69.36										
118		ENHANCEMENT			4	MG6a	66.06										
118		ENHANCEMENT			5	MG3a	62.84										
119	**NP AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**73.76**										
119		ENHANCEMENT			2	MG6	68.87										
119		ENHANCEMENT			3	MG6d	68.13										
119		ENHANCEMENT			4	MG8d	66.20										
119		ENHANCEMENT			5	MG6a	63.75										
205	**YDMT Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**70.84**										
205		ENHANCEMENT			2	MG6	68.24										
205		ENHANCEMENT			3	MG6a	67.11										
205		ENHANCEMENT			4	MG6d	66.14										
205		ENHANCEMENT			5	MG8d	64.79										
206	**YDMT Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG8d**	**70.77**										
206		ENHANCEMENT			2	MG6b	67.78										
206		ENHANCEMENT			3	MG6d	66.06										

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
206		ENHANCEMENT			4	MG6	64.40										
206		ENHANCEMENT			5	MG4b	63.05										
275	**YDMT Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**73.22**										
275		ENHANCEMENT			2	MG6	69.15										
275		ENHANCEMENT			3	MG6a	64.39										
275		ENHANCEMENT			4	MG3a	64.09										
275		ENHANCEMENT			5	MG6d	62.17										
298	**YDMT Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG8d**	**69.83**										
298		ENHANCEMENT			2	MG6b	66.25										
298		ENHANCEMENT			3	MG6d	64.58										
298		ENHANCEMENT			4	MG3a	63.17										
298		ENHANCEMENT			5	MG3	63.09										
301	**FoB AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**61.52**										
301		ENHANCEMENT			2	MG8d	57.43										
301		ENHANCEMENT			3	MG6	57.23										
301		ENHANCEMENT			4	MG6a	55.51										
301		ENHANCEMENT			5	MG4b	55.36										
302	**FoB AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**61.22**										
302		ENHANCEMENT			2	MG6	59.82										
302		ENHANCEMENT			3	MG6d	55.97										
302		ENHANCEMENT			4	MG6a	55.97										
302		ENHANCEMENT			5	MG8d	55.49										
303	**FoB AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**66.62**										
303		ENHANCEMENT			2	MG8d	63.10										
303		ENHANCEMENT			3	MG6	62.87										

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
303		ENHANCEMENT			4	MG6a	62.84										
303		ENHANCEMENT			5	MG6d	60.39										
304	**FoB AONB Hay Time site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**59.13**										
304		ENHANCEMENT			2	MG6	55.83										
304		ENHANCEMENT			3	MG6a	53.92										
304		ENHANCEMENT			4	MG8d	53.44										
304		ENHANCEMENT			5	MG6d	52.57										
401	**CWT Meadow Life site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**68.50**										
401		ENHANCEMENT			2	MG8d	65.34										
401		ENHANCEMENT			3	MG6d	65.15										
401		ENHANCEMENT			4	MG6	62.84										
401		ENHANCEMENT			5	MG4b	62.53										
406	**CWT Hay Day, Meadow Life**	**ENHANCEMENT**	MG3a	**HK7**	**1**	**MG8d**	**65.50**										
406		ENHANCEMENT			2	MG6d	64.27										
406		ENHANCEMENT			3	MG4b	62.30										
406		ENHANCEMENT			4	MG3	62.23										
406		ENHANCEMENT			5	MG3a	61.87										
407	**CWT Meadow Life site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG8d**	**64.15**										
407		ENHANCEMENT			2	MG6b	63.34										
407		ENHANCEMENT			3	MG8	60.87										
407		ENHANCEMENT			4	MG6d	59.93										
407		ENHANCEMENT			5	MG6	57.41										
409	**CWT Hay Day site**	**ENHANCEMENT**	MG3a	**HK7**	**1**	**MG6b**	**64.80**										
409		ENHANCEMENT			2	MG4b	64.45										
409		ENHANCEMENT			3	MG8d	63.99										

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
409		ENHANCEMENT			4	MG3	61.83										
409		ENHANCEMENT			5	MG6	61.68										
410	**CWT Hay Day site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**69.24**										
410		ENHANCEMENT			2	U4b	63.84										
410		ENHANCEMENT			3	MG5c	63.33										
410		ENHANCEMENT			4	MG5a	62.81										
410		ENHANCEMENT			5	MG5	62.73										
419	**CWT CHMRP site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**75.93**										
419		ENHANCEMENT			2	MG6	71.88										
419		ENHANCEMENT			3	MG8d	67.85										
419		ENHANCEMENT			4	MG6a	67.77										
419		ENHANCEMENT			5	MG6d	66.74										
421	**CWT CHMRP site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**73.64**										
421		ENHANCEMENT			2	MG6	68.14										
421		ENHANCEMENT			3	MG8d	67.49										
421		ENHANCEMENT			4	MG6d	66.05										
421		ENHANCEMENT			5	MG6a	65.26										
432	**CWT CHMRP, Meadow Life**	**ENHANCEMENT**	MG3a	**HK7**	**1**	**MG8d**	**66.13**										
432		ENHANCEMENT			2	MG6b	65.61										
432		ENHANCEMENT			3	MG4b	63.76										
432		ENHANCEMENT			4	MG3	63.46										
432		ENHANCEMENT			5	MG6d	63.16										
433	**CWT Meadow Life site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG8d**	**67.32**										
433		ENHANCEMENT			2	MG6d	64.02										
433		ENHANCEMENT			3	MG8	64.00										

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
433		ENHANCEMENT			4	MG4b	62.88										
433		ENHANCEMENT			5	MG8v2	60.76										
435	**CWT Meadow Life site**	**ENHANCEMENT**	MG6b	**GS7**	**1**	**MG6b**	**71.25**										
435		ENHANCEMENT			2	MG6	67.77										
435		ENHANCEMENT			3	MG6d	67.48										
435		ENHANCEMENT			4	MG6a	66.01										
435		ENHANCEMENT			5	MG8d	65.59										
453	**CWT Meadow Life site**	**ENHANCEMENT**	MG8	**HK7**	**1**	**MG8d**	**69.16**										
453		ENHANCEMENT			2	MG6b	61.36										
453		ENHANCEMENT			3	MG6d	61.12										
453		ENHANCEMENT			4	MG8v2	59.96										
453		ENHANCEMENT			5	MG4b	59.80										
454	**CWT Meadow Life site**	**ENHANCEMENT**	MG3a	**HK7**	**1**	**MG8d**	**69.90**										
454		ENHANCEMENT			2	MG6b	66.99										
454		ENHANCEMENT			3	MG3a	64.03										
454		ENHANCEMENT			4	MG6	62.46										
454		ENHANCEMENT			5	MG6d	60.80										
463	**CWT Meadow Life site**	**ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**67.80**										
463		ENHANCEMENT			2	MG6	66.12										
463		ENHANCEMENT			3	MG8d	63.49										
463		ENHANCEMENT			4	MG5	62.50										
463		ENHANCEMENT			5	MG5a	61.69										
602	**New Site 2012**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**64.88**	**MG8d**	**76.83**								
602		CORE			2	MG6b	58.47	MG6d	66.53								
602		CORE			3	MG8	56.17	MG8	63.49								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
602		CORE			4	MG6d	54.85	MG15b	60.53								
602		CORE			5	MG6	54.09	MG6b	60.12								
603	**Validation Site 19**	**CORE**	MG3a	**HK6**	**1**	**MG4b**	**68.90**	**MG3a**	**73.61**	**MG3a**	**71.51**	**MG3a**	**71.98**	**MG3a**	**69.99**	**MG3a**	**73.30**
603		CORE			2	MG6b	68.85	MG3	70.99	MG3	69.79	MG8d	68.07	MG3	67.16	MG8d	69.71
603		CORE			3	MG3a	68.62	MG3b	65.26	MG8d	67.01	MG3	67.69	MG4a	65.07	MG3	69.29
603		CORE			4	MG6	66.94	MG8d	64.99	MG3b	65.08	MG4a	66.88	MG8d	64.92	MG6b	65.48
603		CORE			5	MG4v2	65.79	MG4a	64.61	MG4a	65.03	MG4b	65.20	MG5a	64.32	MG4a	65.36
604	**Validation Site 46**	**CORE**	MG3a	**HK6**	**1**	**MG3a**	**70.72**	**MG3**	**72.23**	**MG3a**	**67.54**	**MG3**	**72.57**	**MG3a**	**70.56**	**MG3a**	**68.99**
604		CORE			2	MG3	69.08	MG3a	71.53	MG3	66.82	MG3a	72.11	MG3	69.76	MG3	68.77
604		CORE			3	MG6b	67.91	MG8d	67.01	MG8d	64.14	MG8d	67.75	MG8d	66.16	MG6b	65.40
604		CORE			4	MG4a	66.59	MG4a	64.74	MG4a	60.63	MG3b	66.62	MG6b	66.01	MG8d	65.40
604		CORE			5	MG8d	65.37	MG3b	63.60	MG3b	60.59	MG4a	64.77	MG3b	63.07	MG4a	62.59
605	**Indicative Site 403**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**68.01**	**MG8d**	**77.53**	**MG8d**	**70.32**						
605		CORE			2	MG6b	65.55	MG6d	68.58	MG6d	63.26						
605		CORE			3	MG6d	64.22	MG8	65.28	MG3a	60.84						
605		CORE			4	MG7c	63.89	MG4b	63.88	MG3	60.84						
605		CORE			5	MG4b	63.26	MG15b	62.86	MG4b	59.63						
606	**Indicative site 395**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**69.00**	**MG8d**	**77.08**								
606		CORE			2	MG15b	65.63	MG8	70.64								
606		CORE			3	MG3a	65.06	MG6d	68.23								
606		CORE			4	MG8	65.03	MG8v2	65.14								
606		CORE			5	MG6	64.59	MG4b	62.18								
607	**New Site 2012**	**CORE**	MG3a	**HK6**	**1**	**MG3a**	**68.38**	**MG3a**	**69.33**								
607		CORE			2	MG5a	66.75	MG3	68.61								
607		CORE			3	MG3	66.59	MG4a	64.70								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
607		CORE			4	MG4a	65.56	MG8d	62.50								
607		CORE			5	MG5	65.36	MG5a	61.67								
609	**Indicative Site 379**	**CORE**	MG8	**HK6**	**1**	**MG6d**	**60.17**	**MG8d**	**59.12**								
609		CORE			2	MG4c	59.32	MG8	58.13								
609		CORE			3	MG8v2	58.32	MG8v2	56.36								
609		CORE			4	MG8d	55.82	MG8a	53.44								
609		CORE			5	MG8	55.40	MG6d	51.51								
611	**Validation site 64**	**CORE**	MG6b	**HK6**	**1**	**MG6b**	**66.25**	**MG8d**	**63.57**	**MG8d**	**65.29**	**MG3**	**71.15**	**MG3**	**73.44**	**MG3**	**68.85**
611		CORE			2	MG8d	65.83	MG3	60.03	MG3	64.00	MG8d	70.78	MG3a	72.73	MG8d	67.32
611		CORE			3	MG3	63.99	MG5a	59.27	MG3a	63.86	MG3a	69.84	MG3b	69.40	MG3a	66.84
611		CORE			4	MG3a	62.64	MG5	59.15	MG3b	61.34	MG3b	67.13	MG8d	68.12	MG6b	63.35
611		CORE			5	MG6	61.63	MG5c	58.78	MG6b	59.62	MG6b	63.31	MG5a	65.79	MG3b	63.29
612	**Validation site 63**	**CORE**	MG6b	**HK6**	**1**	**MG5**	**64.88**	**MG8d**	**64.66**	**MG3**	**64.80**	**MG3**	**68.85**	**MG3a**	**68.00**	**MG6b**	**67.37**
612		CORE			2	MG6b	64.74	MG3	62.95	MG3a	64.10	MG8d	67.32	MG3	67.46	MG3a	65.59
612		CORE			3	MG5a	63.08	MG6b	62.14	MG8d	62.83	MG3a	66.84	MG8d	64.15	MG5c	65.03
612		CORE			4	MG6	62.70	MG3a	61.27	MG6b	62.80	MG6b	63.35	MG6b	62.14	MG3	64.81
612		CORE			5	MG3a	62.65	MG4b	60.12	MG3b	60.86	MG3b	63.29	MG5a	61.47	MG5a	64.75
613	**Indicative site 164**	**CORE**	MG6b	**HK6**	**1**	**MG8d**	**75.69**	**MG8d**	**76.37**	**MG8d**	**68.82**						
613		CORE			2	MG6b	68.09	MG6d	71.88	MG3	63.80						
613		CORE			3	MG8	65.09	MG4b	66.72	MG6b	63.78						
613		CORE			4	MG6d	65.07	MG8	65.46	MG4a	62.59						
613		CORE			5	MG6	64.83	MG3	64.87	MG3a	62.05						
614	**Indicative site 165**	**CORE**	MG6b	**HK6**	**1**	**MG8d**	**74.34**	**MG8d**	**77.13**	**MG8d**	**72.65**						
614		CORE			2	MG6b	72.24	MG6d	70.27	MG3a	68.43						
614		CORE			3	MG6	68.43	MG3a	66.08	MG3	65.05						

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
614		CORE			4	MG6d	66.51	MG4b	65.74	MG6b	64.05						
614		CORE			5	MG3a	65.08	MG3	65.21	MG8	61.45						
615	**Indicative Site 114**	**CORE**	MG6b	**HK6**	**1**	**MG8v2**	**64.77**	**MG8d**	**72.31**	**MG6b**	**70.85**						
615		CORE			2	MG8d	63.87	MG6d	68.53	MG6d	70.48						
615		CORE			3	MG6b	63.69	MG6b	65.50	MG3a	69.00						
615		CORE			4	MG6d	63.12	MG8	64.19	MG8d	66.24						
615		CORE			5	MG6	61.71	MG3a	64.00	MG3	65.64						
616	**Indicative Site 117**	**CORE**	MG8	**HK6**	**1**	**MC9e**	**58.79**	**MG8a**	**55.53**	**MG5c**	**51.63**						
616		CORE			2	MG8d	58.55	MG8d	54.99	MG3	51.28						
616		CORE			3	MG8v2	58.47	U4b	53.46	U4b	50.15						
616		CORE			4	MG6d	56.68	MG8v2	52.72	MG8d	49.45						
616		CORE			5	MG8b	54.97	MG5c	52.31	MG3b	48.89						
617	**NEW SITE 2012**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**71.09**	**MG8d**	**74.48**								
617		CORE			2	MG6d	70.82	MG6d	66.49								
617		CORE			3	MG6b	69.74	MG8	65.65								
617		CORE			4	MG8	68.33	MG3a	64.54								
617		CORE			5	MG6	66.59	MG6b	62.70								
618	**NEW SITE 2012**	**CORE**	MG3a	**HK6**	**1**	**MG3a**	**70.68**	**MG8d**	**73.90**								
618		CORE			2	MG4b	69.22	MG3a	68.09								
618		CORE			3	MG8d	69.09	MG6d	66.24								
618		CORE			4	MG6d	66.82	MG3	65.64								
618		CORE			5	MG4v2	66.45	MG4b	62.25								
619	**Indicative Site 197**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**65.45**	**MG8d**	**76.21**								
619		CORE			2	MG6d	61.09	MG6d	65.98								
619		CORE			3	MG6b	58.31	MG6b	62.13								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
619		CORE			4	MG8v2	58.30	MG8	62.02								
619		CORE			5	MG8	58.23	MG3a	59.03								
620	**NEW SITE 2012**	**CORE**	MG6a	**HK6**	**1**	**MG7d**	**67.07**	**MG8d**	**68.66**								
620		CORE			2	MG6a	64.91	MG6b	64.55								
620		CORE			3	MG6b	63.43	MG6d	64.37								
620		CORE			4	MG7	63.29	MG3a	62.17								
620		CORE			5	MG7c	62.21	MG6	60.17								
621	**Indicative Site 334**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**72.20**	**MG8d**	**76.06**	**MG8d**	**74.60**						
621		CORE			2	MG6d	67.20	MG6d	69.05	MG6b	63.96						
621		CORE			3	MG6b	66.33	MG6b	65.42	MG6d	63.62						
621		CORE			4	MG6	62.94	MG8	62.92	MG8	61.55						
621		CORE			5	MG8	62.93	MG3a	62.18	MG4b	59.88						
622	**Indicative Site 337**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**74.07**	**MG8d**	**65.56**	**MG8d**	**70.62**						
622		CORE			2	MG6d	66.92	MG6d	59.45	MG6d	63.44						
622		CORE			3	MG8	65.61	MG4b	59.01	MG4b	61.92						
622		CORE			4	MG4b	64.61	MG3a	56.42	MG15b	61.48						
622		CORE			5	MG15b	64.34	MG4v2	55.94	MG4v2	61.41						
623	**Indicative Site 240**	**CORE**	MG6b	**HK6**	**1**	**MG3a**	**66.80**	**MG3a**	**69.70**								
623		CORE			2	MG6b	63.87	MG8d	69.05								
623		CORE			3	MG6	61.70	MG3	67.93								
623		CORE			4	MG3	60.63	MG6b	65.95								
623		CORE			5	MG4a	60.50	MG6d	62.09								
624	**NEW SITE 2012**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**69.54**	**MG8d**	**71.70**								
624		CORE			2	MG8	67.99	MG6d	67.69								
624		CORE			3	MG6d	65.86	MG8	63.26								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
624		CORE			4	MG6b	65.46	MG6b	62.35								
624		CORE			5	MG8v2	61.78	MG3a	58.11								
625	**Indicative Site 322**	**CORE**	MG6b	**HK6**	**1**	**MG6b**	**63.21**	**MG8d**	**65.42**	**MG6b**	**63.68**						
625		CORE			2	MG8d	60.64	MG6b	63.71	MG3a	63.20						
625		CORE			3	MG3	59.75	MG3a	63.33	MG8d	61.89						
625		CORE			4	MG3a	59.44	MG6d	62.26	MG3	61.45						
625		CORE			5	MG6	59.43	MG3	61.47	MG4a	59.41						
626	**Indicative Site 316**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**75.28**	**MG8d**	**76.52**								
626		CORE			2	MG8	66.39	MG8	67.81								
626		CORE			3	MG6d	65.35	MG6d	67.72								
626		CORE			4	MG8v2	64.75	MG6b	61.48								
626		CORE			5	MG3	63.69	MG4b	61.33								
627	**NEW SITE 2012**	**CORE**	MG8	**HK6**	**1**	**MG8d**	**71.08**	**MG8d**	**71.78**								
627		CORE			2	MG8	66.84	MG3	64.56								
627		CORE			3	MG6d	66.06	MG6b	63.19								
627		CORE			4	MG6	64.76	MG3a	62.83								
627		CORE			5	MG6b	62.86	MG6d	60.87								
628	**Indicative Site 306**	**CORE**	MG5c	**HK6**	**1**	**MG5a**	**69.43**	**MG3**	**68.79**								
628		CORE			2	MG6b	68.50	MG3b	67.09								
628		CORE			3	MG8d	68.27	MG5a	66.64								
628		CORE			4	MG3	67.91	MG3a	66.49								
628		CORE			5	MG5	67.72	MG5	65.65								
629	**Indicative Site 291**	**CORE**	MG6b	**GS6**	**1**	**MG6b**	**73.26**	**MG6b**	**67.97**								
629		CORE			2	MG8d	72.55	MG8d	63.98								
629		CORE			3	MG3a	67.11	MG3a	63.59								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
629		CORE			4	MG6	66.89	MG6	62.78								
629		CORE			5	MG8	66.86	MG6d	61.02								
630	**Indicative Site 297**	**CORE**	MG3a	**HK6**	**1**	**MG8d**	**73.91**	**MG3a**	**73.74**	**MG3a**	**71.18**						
630		CORE			2	MG3a	69.14	MG3	71.19	MG3	67.86						
630		CORE			3	MG6	69.11	MG8d	70.59	MG8d	65.60						
630		CORE			4	MG4b	68.27	MG4b	69.66	MG6b	63.94						
630		CORE			5	MG6b	66.73	MG5a	68.07	MG3b	61.61						
631	**Validation Site 2**	**CORE**	MG3a	**HK6**	**1**	**MG8d**	**67.93**	**MG3a**	**68.02**	**MG3a**	**68.48**	**MG8d**	**69.81**	**MG8d**	**70.64**	**MG8d**	**66.19**
631		CORE			2	MG3a	66.92	MG3	67.81	MG3	67.71	MG3	66.39	MG6b	65.08	MG3	65.92
631		CORE			3	MG3	66.41	MG4b	66.43	MG8d	66.14	MG3a	65.46	MG3	64.54	MG3a	64.80
631		CORE			4	MG4b	66.20	MG6d	65.57	MG4b	66.13	MG6b	63.65	MG3a	63.93	MG3b	63.62
631		CORE			5	MG6b	66.06	MG8d	64.96	MG6d	65.30	MG6d	61.57	MG5	63.75	MG5	59.47
632	**NEW SITE 2012**	**CORE**	MG3a	**GS6**	**1**	**MG8d**	**71.80**	**MG8d**	**75.86**								
632		CORE			2	MG6b	69.32	MG6b	73.40								
632		CORE			3	MG6	67.67	MG3a	70.54								
632		CORE			4	MG8	66.67	MG3	69.69								
632		CORE			5	MG4b	65.75	MG6	67.63								
701	**Indicative Site 459**	**CORE**	MG3a	**HK7**	**1**	**MG6d**	**66.74**	**MG3a**	**64.68**	**MG4c**	**61.67**						
701		CORE			2	MG4b	65.19	MG6b	64.16	MG4v2	60.35						
701		CORE			3	MG3a	64.06	MG7c	62.54	MG15b	60.17						
701		CORE			4	MG7c	63.11	MG7d	61.87	MG7d	58.87						
701		CORE			5	MG4c	62.85	MG8d	61.01	MG4b	57.41						
702	**NEW SITE 2012**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**60.08**	**MG8d**	**73.16**								
702		CORE			2	MG6	54.43	MG8	64.52								
702		CORE			3	MG7	52.40	MG6d	61.86								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
702		CORE			4	MG7d	52.36	MG4b	59.85								
702		CORE			5	MG6a	51.10	MG6b	58.33								
703	**NEW SITE 2012**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**63.44**	**MG8d**	**66.57**								
703		CORE			2	MG6d	56.34	MG6d	63.41								
703		CORE			3	MG6b	55.90	MG15b	62.18								
703		CORE			4	MG15b	55.59	MG15	62.16								
703		CORE			5	MG7c	54.79	MG4c	61.64								
704	**Indicative Site 419**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**69.67**	**MG8d**	**72.05**								
704		CORE			2	MG6a	66.26	MG6d	69.29								
704		CORE			3	MG6	66.22	MG15b	65.96								
704		CORE			4	MG6d	60.00	MG6b	63.07								
704		CORE			5	MG8d	59.35	MG15	62.46								
707	**Indicative Site 432**	**CORE**	MG6b	**GS7**	**1**	**MG6a**	**69.42**	**MG8d**	**72.21**								
707		CORE			2	MG6b	68.83	MG6d	70.14								
707		CORE			3	MG6	68.76	MG6b	66.70								
707		CORE			4	MG8d	64.06	MG3a	63.77								
707		CORE			5	MG7c	63.66	MG6	62.84								
708	**NEW SITE 2012**	**CORE**	MG6b	**GS7**	**1**	**MG6b**	**60.78**	**MG6b**	**65.20**								
708		CORE			2	MG6d	59.33	MG8d	63.71								
708		CORE			3	MG4c	59.00	MG3a	63.54								
708		CORE			4	MG6a	58.78	MG6a	62.41								
708		CORE			5	MG15b	57.89	MG6d	61.78								
709	**NEW SITE 2012 &**	**CORE & ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6**	**66.43**	**MG8d**	**73.82**								
709	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG6a	64.61	MG6d	69.18								
709		CORE & ENHANCEMENT			3	MG6d	64.48	MG6b	67.73								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
709		CORE & ENHANCEMENT			4	MG6b	64.14	MG3a	67.59								
709		CORE & ENHANCEMENT			5	MG8d	63.65	MG6	65.89								
710	**Indicative Site 42**	**CORE**	MG6a	**HK7**	**1**	**MG7d**	**65.90**	**MG8d**	**69.76**	**MG8d**	**72.28**						
710		CORE			2	MG6a	65.57	MG6b	66.67	MG6d	62.92						
710		CORE			3	MG7c	62.83	MG6d	65.40	MG6b	61.79						
710		CORE			4	MG6	62.76	MG3a	64.94	MG8	59.89						
710		CORE			5	MG7	62.03	MG6	64.08	MG4b	59.74						
711	**Indicative Site 23**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**62.91**	**MG8d**	**71.70**								
711		CORE			2	MG15b	62.39	MG6d	63.55								
711		CORE			3	MG15	60.72	MG8	63.13								
711		CORE			4	MG10a	59.73	MG15b	60.81								
711		CORE			5	MG4c	58.82	MG4b	58.87								
712	**Indicative Site 14**	**CORE**	MG8	**HK7**	**1**	**MG6b**	**73.53**	**MG8d**	**71.79**								
712		CORE			2	MG8d	73.36	MG15b	69.69								
712		CORE			3	MG6a	69.91	MG6d	67.98								
712		CORE			4	MG6	69.81	MG4b	64.29								
712		CORE			5	MG3a	69.33	MG15	63.49								
713	**NEW SITE 2012**	**CORE**	MG3a	**HK7**	**1**	**MG6**	**63.70**	**MG3a**	**70.73**								
713		CORE			2	MG6b	62.99	MG8d	70.34								
713		CORE			3	MG7d	62.40	MG3	67.14								
713		CORE			4	MG3a	61.96	MG6d	67.02								
713		CORE			5	MG6a	61.95	MG4b	62.85								
714	**NEW SITE 2012 &**	**CORE & ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**69.67**	**MG8d**	**68.03**								
714	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG6	68.07	MG6d	62.50								
714		CORE & ENHANCEMENT			3	MG6a	67.75	MG6b	60.95								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
714		CORE & ENHANCEMENT			4	MG8d	65.71	MG3a	60.38								
714		CORE & ENHANCEMENT			5	MG3a	63.93	MG4b	59.66								
715	**Indicative Site 9**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**66.48**	**MG6b**	**71.51**	**MG7d**	**64.74**						
715		CORE			2	MG6a	65.88	MG8d	69.73	MG6a	63.90						
715		CORE			3	MG6	64.76	MG6d	67.40	MG6b	63.88						
715		CORE			4	MG8d	57.01	MG3a	67.05	MG6	62.66						
715		CORE			5	MG7	55.87	MG6	64.68	MG7	62.64						
716	**Indicative Site 82**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**70.40**	**MG8d**	**69.31**	**MG8d**	**74.04**						
716		CORE			2	MG8	65.06	MG8v2	59.66	MG6d	66.28						
716		CORE			3	MG8v2	64.71	MG8	59.62	MG15b	63.15						
716		CORE			4	MG6d	60.00	MG6d	58.52	MG8v2	61.26						
716		CORE			5	MG8b	58.33	MG8a	57.44	MG4b	60.65						
717	**Validation Site 42**	**CORE**	MG3a	**HK7**	**1**	**MG3a**	**73.89**	**MG3**	**70.86**	**MG3**	**71.11**	**MG3**	**74.05**	**MG3**	**72.44**	**MG3a**	**76.51**
717		CORE			2	MG3	72.16	MG3a	70.32	MG3a	70.64	MG3a	72.18	MG3a	72.24	MG3	76.08
717		CORE			3	MG6b	65.97	MG3b	64.22	MG4a	67.78	MG3b	68.15	MG3b	65.33	MG3b	67.09
717		CORE			4	MG4a	64.26	MG4a	61.71	MG3b	65.27	MG5a	65.57	MG8d	64.56	MG5a	63.44
717		CORE			5	MG8d	62.87	MG8d	61.59	MG4b	63.42	MG4a	64.34	MG5a	63.91	MG6b	62.56
718	**Indicative Site 65 &**	**CORE & ENHANCEMENT**	MG8	**HK7**	**1**	**MG6b**	**71.07**	**MG8d**	**70.88**	**MG8d**	**66.93**						
718	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG8d	68.79	MG3	68.65	MG3a	65.44						
718		CORE & ENHANCEMENT			3	MG6	67.25	MG3a	68.38	MG6b	64.13						
718		CORE & ENHANCEMENT			4	MG5a	66.53	MG6b	66.67	MG3	63.99						
718		CORE & ENHANCEMENT			5	MG3a	66.27	MG5a	63.49	MG5a	61.07						
720	**Validation Site 27**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**67.08**	**MG8d**	**68.56**			**MG8d**	**66.56**	**MG8d**	**64.93**	**MG8d**	**69.31**
720		CORE			2	MG8v2	65.78	MG6d	63.75			MG8v2	61.27	MG14b	57.17	MG8	60.61
720		CORE			3	MG6d	63.97	MG8v2	61.71			MG8	60.68	MG8	56.70	MG8b	59.50

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
720		CORE			4	MG8b	61.34	MG8	61.08			MG8b	59.85	MG8b	56.33	MG8v2	59.45
720		CORE			5	MG8	60.10	MG8b	59.75			MG6d	59.66	MG6d	56.32	SD17c	57.87
721	**Indicative Site 70**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**67.92**	**MG8d**	**67.15**	**MG8d**	**70.99**						
721		CORE			2	MG6d	64.38	MG6d	61.38	MG6d	66.15						
721		CORE			3	MG6a	64.11	MG3a	59.93	MG3a	65.65						
721		CORE			4	MG4b	62.60	MG6b	58.73	MG4b	61.79						
721		CORE			5	MG15b	62.31	MG8	57.14	MG6b	61.61						
722	**Indicative Site 79**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**74.44**	**MG8d**	**80.19**	**MG8d**	**75.24**						
722		CORE			2	MG8	65.04	MG6d	68.48	MG8	64.65						
722		CORE			3	MG6d	65.03	MG3a	67.35	MG6d	63.26						
722		CORE			4	MG8v2	62.65	MG3	66.95	MG6b	60.09						
722		CORE			5	MG3a	59.30	MG8	64.71	MG4b	58.75						
723	**Indicative Site 68**	**CORE**	MG6b	**HK7**	**1**	**MG9**	**64.19**	**MG8b**	**54.70**	**MG6d**	**58.52**						
723		CORE			2	MG7c	62.96	MG15	53.99	MG8d	58.48						
723		CORE			3	MG6a	62.46	MG4c	53.71	MG6b	55.20						
723		CORE			4	MG10a	60.46	MG14	53.53	MG3a	53.48						
723		CORE			5	MG15	60.12	MG10	53.32	MG7b	52.86						
724	**Indicative Site 60**	**CORE**	MG3b	**HK7**	**1**	**MG8v2**	**65.52**	**MG3**	**71.37**	**MG8d**	**67.78**						
724		CORE			2	MG8a	63.51	MG3a	69.52	MG5a	65.64						
724		CORE			3	MG8d	62.01	MG3b	66.10	MG3	65.16						
724		CORE			4	MG4b	61.88	MG5a	63.96	MG5	63.96						
724		CORE			5	MG4v2	59.85	MG8d	63.87	MG5c	63.49						
725	**Indicative Site 101 &**	**CORE & ENHANCEMENT**	MG6b	**HK7**	**1**	**MG8d**	**68.78**			**MG8d**	**72.40**						
725	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG6b	67.06			MG3a	65.64						
725		CORE & ENHANCEMENT			3	MG6	65.37			MG6d	62.70						

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
725		CORE & ENHANCEMENT			4	MG3a	64.90			MG6b	61.91						
725		CORE & ENHANCEMENT			5	MG6a	61.56			MG3	61.44						
726	**Indicative Site 54**	**CORE**	MG3a	**HK7**	**1**	**MG3a**	**71.43**	**MG3a**	**72.30**	**MG8d**	**66.03**						
726		CORE			2	MG6b	71.12	MG8d	71.40	MG3a	63.75						
726		CORE			3	MG6	70.88	MG3	67.94	MG6b	63.75						
726		CORE			4	MG6a	68.59	MG6b	64.92	MG3	62.17						
726		CORE			5	MG8d	66.05	MG4b	64.05	MG5a	61.29						
728	**Indicative Site 52 &**	**CORE & ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**68.89**	**MG8d**	**68.39**	**MG6b**	**67.68**						
728	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG8d	66.18	MG6b	67.32	MG8d	65.87						
728		CORE & ENHANCEMENT			3	MG6d	62.98	MG3a	65.20	MG6d	65.70						
728		CORE & ENHANCEMENT			4	MG6	61.88	MG6a	64.44	MG3a	65.43						
728		CORE & ENHANCEMENT			5	MG6a	58.90	MG6d	64.21	MG4b	63.60						
730	**Indicative Site 49 &**	**CORE & ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**69.01**	**MG8d**	**70.69**	**MG8d**	**67.22**						
730	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG8d	68.90	MG6b	70.35	MG15b	66.59						
730		CORE & ENHANCEMENT			3	MG6d	65.99	MG6d	67.39	MG6d	66.05						
730		CORE & ENHANCEMENT			4	MG6	65.53	MG6	65.22	MG4c	63.60						
730		CORE & ENHANCEMENT			5	MG6a	64.21	MG3a	64.76	MG6b	63.47						
731	**Validation Site 17 &**	**CORE & ENHANCEMENT**	MG6b	**HK7**	**1**	**MG8d**	**67.86**			**MG3a**	**60.18**	**MG3a**	**62.36**	**MG3a**	**64.04**	**MG3a**	**69.80**
731	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG6b	67.69			MG6b	59.48	MG6b	59.23	MG3	62.17	MG3	66.06
731		CORE & ENHANCEMENT			3	MG6	67.18			MG7d	59.42	MG3	58.21	MG6b	59.24	MG4a	61.77
731		CORE & ENHANCEMENT			4	MG6d	65.76			MG6a	59.41	MG6	56.95	MG6	58.37	MG6	60.40
731		CORE & ENHANCEMENT			5	MG4b	64.52			MG7	59.27	MG7E	55.09	MG6a	56.42	MG6b	60.03
732	**Validation Site 20**	**CORE**	MG3a	**HK7**	**1**	**MG3a**	**69.29**	**MG3a**	**75.81**	**MG3a**	**68.27**	**MG3a**	**70.26**	**MG3a**	**71.28**	**MG3a**	**72.25**
732		CORE			2	MG6b	68.46	MG3	70.34	MG8d	65.78	MG3	67.14	MG3	68.22	MG3	70.89
732		CORE			3	MG3	66.94	MG8d	67.53	MG3	63.79	MG8d	66.24	MG6b	65.06	MG8d	70.27

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
732		CORE			4	MG8d	66.92	MG6b	65.43	MG6b	62.66	MG6b	65.56	MG8d	64.76	MG6b	66.38
732		CORE			5	MG4b	66.06	MG5a	64.47	MG5a	60.37	MG5a	62.28	MG6	63.36	MG5a	65.57
733	**Indicative Site 53**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**65.43**	**MG8d**	**73.36**	**MG8d**	**72.83**						
733		CORE			2	MG6	63.30	MG3a	72.31	MG3a	68.22						
733		CORE			3	MG3a	63.25	MG3	68.29	MG6d	66.08						
733		CORE			4	MG8d	61.22	MG6b	65.95	MG3	64.94						
733		CORE			5	MG6a	60.52	MG6d	65.60	MG6b	63.65						
734	**Indicative Site 75**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**68.06**	**MG8d**	**69.03**	**MG8d**	**63.90**						
734		CORE			2	MG6d	61.60	MG6b	62.95	MG3a	61.32						
734		CORE			3	MG4c	60.98	MG6	59.60	MG6d	59.68						
734		CORE			4	MG3a	60.47	MG6a	59.22	MG3	59.29						
734		CORE			5	MG4v2	59.67	MG4v2	57.70	MG4c	56.13						
735	**Indicative Site 59**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**71.18**	**MG8d**	**74.30**	**MG8d**	**73.47**						
735		CORE			2	MG15b	67.20	MG6d	62.69	MG6b	65.85						
735		CORE			3	MG6a	66.02	MG6b	61.39	MG15b	65.19						
735		CORE			4	MG6b	65.46	MG8	61.33	MG6d	65.09						
735		CORE			5	MG4c	64.74	MG4b	60.87	MG8	64.38						
736	**NEW SITE 2012 &**	**CORE & ENHANCEMENT**	MG8	**HK7**	**1**	**MG8d**	**73.34**	**MG8d**	**68.56**								
736	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG6b	64.96	MG6d	61.79								
736		CORE & ENHANCEMENT			3	MG8	62.80	MG8	60.01								
736		CORE & ENHANCEMENT			4	MG6d	62.18	MG3a	59.23								
736		CORE & ENHANCEMENT			5	MG6	61.96	MG3	59.03								
738	**NEW SITE 2012**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**75.76**	**MG8d**	**74.78**								
738		CORE			2	MG8	68.78	MG6d	64.33								
738		CORE			3	MG6d	67.78	MG8	61.99								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
738		CORE			4	MG8v2	65.32	MG8v2	59.73								
738		CORE			5	MG4b	62.80	MG4b	58.34								
739	**NEW SITE 2012**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**75.41**	**MG8d**	**73.85**								
739		CORE			2	MG6d	71.52	MG6d	70.26								
739		CORE			3	MG4b	68.49	MG4b	66.46								
739		CORE			4	MG8	67.54	MG6b	66.20								
739		CORE			5	MG8v2	66.52	MG3a	65.80								
740	**NEW SITE 2012**	**CORE**	MG3a	**GS7**	**1**	**MG3a**	**62.89**	**MG8d**	**72.53**								
740		CORE			2	MG6	60.15	MG3a	68.57								
740		CORE			3	MG6a	59.72	MG3	65.19								
740		CORE			4	MG4b	59.67	MG6d	64.39								
740		CORE			5	MG4v2	59.27	MG6b	59.82								
741	**NEW SITE 2012 &**	**CORE & ENHANCEMENT**	MG6b	**GS7**	**1**	**MG8d**	**72.84**	**MG8d**	**72.58**								
741	**CWT Hay Day, Meadow Life**	CORE & ENHANCEMENT			2	MG6b	70.38	MG6d	64.57								
741		CORE & ENHANCEMENT			3	MG6d	68.09	MG6b	62.09								
741		CORE & ENHANCEMENT			4	MG6	67.76	MG6a	60.97								
741		CORE & ENHANCEMENT			5	MG6a	65.92	MG15b	60.75								
742	**Indicative Site 162**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**76.14**	**MG8d**	**74.14**	**MG3a**	**67.57**						
742		CORE			2	MG6	72.62	MG6d	67.65	MG6b	66.34						
742		CORE			3	MG8d	69.46	MG6b	67.63	MG8d	66.11						
742		CORE			4	MG8	66.91	MG3a	66.75	MG3	63.62						
742		CORE			5	MG6a	66.63	MG4b	65.03	MG6d	61.73						
743	**NEW SITE 2012**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**65.06**	**MG3a**	**70.10**								
743		CORE			2	MG3a	64.71	MG3	66.02								
743		CORE			3	MG6	62.01	MG6b	64.48								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
743		CORE			4	MG3	61.37	MG8d	60.22								
743		CORE			5	MG6d	61.00	MG6	58.79								
744	**Indicative Site 194**	**CORE**	MG3a	**HK7**	**1**	**MG3**	**68.41**	**MG3**	**68.02**								
744		CORE			2	MG8d	67.06	MG3a	65.93								
744		CORE			3	MG6d	64.67	MG6b	65.16								
744		CORE			4	MG3a	64.07	MG8d	62.80								
744		CORE			5	MG6b	63.35	MG5a	60.50								
745	**Validation Site 60 &**	**CORE & ENHANCEMENT**	MG8	**HK7**	**1**	**MG8d**	**74.29**	**MG8d**	**68.46**			**MG8d**	**68.81**	**MG8d**	**75.69**	**MG8d**	**76.50**
745	**YDMT Hay Time site**	CORE & ENHANCEMENT			2	MG6d	67.44	MG6d	60.58			MG6d	62.65	MG3a	68.31	MG6d	76.14
745		CORE & ENHANCEMENT			3	MG6b	65.11	MG8	57.24			MG6b	61.70	MG6d	65.60	MG6b	72.16
745		CORE & ENHANCEMENT			4	MG8	64.72	MG8v2	54.91			MG3a	61.28	MG3	65.08	MG8v2	69.37
745		CORE & ENHANCEMENT			5	MG15b	62.99	MG6b	54.88			MG6	58.99	MG6b	64.32	MG4b	68.97
746	**Indicative Site 131**	**CORE**	MG3a	**HK7**	**1**	**MG6b**	**65.52**	**MG3a**	**71.75**	**MG3a**	**65.10**						
746		CORE			2	MG3a	65.24	MG3	68.55	MG3	62.24						
746		CORE			3	MG3	62.13	MG8d	63.40	MG6d	59.78						
746		CORE			4	MG6	60.02	MG4b	62.24	MG4b	59.68						
746		CORE			5	MG8d	58.85	MG4a	62.21	MG8d	58.60						
747	**Indicative Site 157**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**74.80**	**MG8d**	**60.05**	**MG3a**	**67.97**						
747		CORE			2	MG6	69.11	MG6b	59.97	MG8d	65.13						
747		CORE			3	MG6a	64.56	MG3a	57.75	MG6b	64.14						
747		CORE			4	MG6d	62.67	MG4b	57.58	MG6d	62.23						
747		CORE			5	MG8d	60.86	MG6	57.18	MG3	62.23						
749	**Indicative Site 382**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**70.30**	**MG8d**	**68.16**								
749		CORE			2	MG6	67.73	MG6b	67.81								
749		CORE			3	MG6d	67.13	MG3a	66.76								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
749		CORE			4	MG4b	65.28	MG6d	66.13								
749		CORE			5	MG8d	65.03	MG6	63.97								
750	**Indicative Site 212**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**71.97**	**MG8d**	**73.75**	**MG8d**	**70.20**						
750		CORE			2	MG6b	66.27	MG6d	62.75	MG6b	68.90						
750		CORE			3	MG8	64.03	MG6b	60.66	MG6d	64.79						
750		CORE			4	MG15b	64.02	MG8	59.59	MG6	63.22						
750		CORE			5	MG6	63.51	MG8v2	57.92	MG3a	62.14						
751	**Indicative Site 210**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**61.52**	**MG8d**	**70.92**	**MG8d**	**70.91**						
751		CORE			2	MG8v2	60.50	MG6d	68.71	MG6d	70.38						
751		CORE			3	MG6d	60.25	MG4b	62.60	MG4b	66.64						
751		CORE			4	MG4b	57.92	MG6b	60.96	MG6b	63.89						
751		CORE			5	MG8d	57.68	MG8	58.40	MG3a	63.07						
752	**Indicative Site 215**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**67.06**	**MG8d**	**74.19**	**MG6b**	**71.76**						
752		CORE			2	MG6d	63.25	MG6d	63.84	MG8d	69.84						
752		CORE			3	MG6	63.08	MG6b	63.17	MG6d	67.95						
752		CORE			4	MG6a	61.18	MG4b	61.14	MG3a	66.46						
752		CORE			5	MG4b	60.88	MG8	59.90	MG6	65.75						
753	**Indicative Site 211**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**69.55**	**MG8d**	**71.49**	**MG8d**	**67.74**						
753		CORE			2	MG6	65.81	MG6b	62.62	MG6d	63.13						
753		CORE			3	MG6d	63.96	MG6d	61.92	MG6b	60.24						
753		CORE			4	MG6a	62.09	MG3a	58.97	MG4b	59.12						
753		CORE			5	MG8	61.77	MG4b	57.02	MG3a	57.74						
754	**Indicative Site 216**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**69.01**	**MG8d**	**73.55**	**MG8d**	**73.59**						
754		CORE			2	MG6d	65.38	MG8v2	63.73	MG6d	65.23						
754		CORE			3	MG8	64.30	MG6d	62.48	MG8	63.62						

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
754		CORE			4	MG6	64.03	MG8	61.04	MG6b	61.95						
754		CORE			5	MG8d	63.82	MG8a	60.52	MG8v2	60.19						
755	**Indicative Site 352 &**	**CORE & ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**62.08**	**MG8d**	**70.47**								
755	**YDMT Hay Time site**	CORE & ENHANCEMENT			2	MG8d	61.78	MG8	65.25								
755		CORE & ENHANCEMENT			3	MG6	59.00	MG6d	63.52								
755		CORE & ENHANCEMENT			4	MG7c	58.78	MG6b	63.15								
755		CORE & ENHANCEMENT			5	MG6d	58.21	MG6	58.99								
756	**Indicative Site 324 &**	**CORE & ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6b**	**69.94**	**MG8d**	**60.26**	**MG6a**	**64.32**						
756	**YDMT Hay Time site**	CORE & ENHANCEMENT			2	MG6	65.16	MG6b	59.22	MG6b	62.17						
756		CORE & ENHANCEMENT			3	MG8d	64.85	MG3a	58.79	MG7b	61.38						
756		CORE & ENHANCEMENT			4	MG6a	63.82	MG8	55.99	MG6	59.16						
756		CORE & ENHANCEMENT			5	MG6d	61.69	MG4c	55.49	MG7d	57.80						
757	**Indicative Site 304**	**CORE**	MG6b	**HK7**	**1**	**MG6b**	**67.78**	**MG3**	**67.48**	**MG8d**	**74.17**						
757		CORE			2	MG8d	67.28	MG8d	66.42	MG6b	66.99						
757		CORE			3	MG6	64.40	MG3a	66.05	MG3a	66.03						
757		CORE			4	MG3	60.41	MG6b	65.37	MG6d	64.46						
757		CORE			5	MG8	60.29	MG5a	65.29	MG8	63.56						
758	**Indicative Site 259**	**CORE**	MG3a	**HK7**	**1**	**MG6b**	**72.42**	**MG8d**	**67.69**	**MG8d**	**70.53**						
758		CORE			2	MG3a	71.97	MG3	67.40	MG3a	68.09						
758		CORE			3	MG3	70.45	MG4a	63.61	MG3	65.67						
758		CORE			4	MG5a	69.44	MG5a	63.49	MG6d	65.47						
758		CORE			5	MG6	69.28	MG3a	63.39	MG4a	65.46						
759	**Indicative Site 258**	**CORE**	MG3a	**HK7**	**1**	**MG3a**	**73.07**	**MG5**	**67.52**	**MG6d**	**64.00**						
759		CORE			2	MG6b	70.68	MG3	66.69	MG6b	63.74						
759		CORE			3	MG3	70.51	MG5a	66.62	MG8d	63.03						

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
759		CORE			4	MG8d	68.70	MG3a	64.75	MG3	62.14						
759		CORE			5	MG5a	66.78	MG8d	64.56	MG5a	62.12						
760	**Indicative Site 253**	**CORE**	MG3a	**HK7**	**1**	**MG3a**	**70.31**	**MG5a**	**69.47**	**MG8d**	**68.42**						
760		CORE			2	MG6b	69.80	MG3a	68.40	MG3a	67.09						
760		CORE			3	MG4b	69.12	MG3	67.93	MG3	66.95						
760		CORE			4	MG5a	69.02	MG5	66.74	MG5a	65.98						
760		CORE			5	MG3	68.61	MG6b	65.57	MG4a	64.88						
761	**Indicative Site 254**	**CORE**	MG5c	**HK7**	**1**	**MG5a**	**70.37**	**MG8d**	**67.24**								
761		CORE			2	MG3a	69.72	MG3a	65.40								
761		CORE			3	MG8d	69.37	MG5a	64.74								
761		CORE			4	MG5	69.10	MG5	64.20								
761		CORE			5	MG4a	68.81	MG3	62.48								
762	**Indicative Site 274 &**	**CORE & ENHANCEMENT**	MG3a	**HK7**	**1**	**MG8d**	**68.47**	**MG8d**	**70.49**	**MG8d**	**69.22**						
762	**YDMT Hay Time site**	CORE & ENHANCEMENT			2	MG6b	64.45	MG3	69.80	MG3a	68.86						
762		CORE & ENHANCEMENT			3	MG6	63.36	MG3a	69.79	MG3	67.42						
762		CORE & ENHANCEMENT			4	MG3a	62.53	MG6b	68.87	MG6b	63.85						
762		CORE & ENHANCEMENT			5	MG5a	61.82	MG5a	68.64	MG6d	62.87						
763	**Indicative Site 273 &**	**CORE & ENHANCEMENT**	MG3a	**HK7**	**1**	**MG6b**	**68.71**	**MG8d**	**65.71**	**MG3**	**67.34**						
763	**YDMT Hay Time site**	CORE & ENHANCEMENT			2	MG6	66.48	MG3a	63.82	MG3a	66.36						
763		CORE & ENHANCEMENT			3	MG8d	66.31	MG4b	63.43	MG5a	65.07						
763		CORE & ENHANCEMENT			4	MG3a	64.49	MG3	63.42	MG8d	63.72						
763		CORE & ENHANCEMENT			5	MG3	62.28	MG5a	63.06	MG5	62.95						
764	**Indicative Site 281**	**CORE**	MG3a	**HK7**	**1**	**MG8d**	**67.29**	**MG8d**	**70.29**	**MG8d**	**65.17**						
764		CORE			2	MG3a	63.00	MG3a	65.97	MG3a	62.87						
764		CORE			3	MG3	62.67	MG6b	65.65	MG6d	59.96						

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
764		CORE			4	MG6d	62.59	MG3	63.97	MG6b	58.79						
764		CORE			5	MG8	62.37	MG6d	62.99	MG3	58.51						
765	**Indicative Site 289**	**CORE**	MG6b	**HK7**	**1**	**MG8d**	**71.30**	**MG8d**	**69.02**								
765		CORE			2	MG6b	67.03	MG3a	68.07								
765		CORE			3	MG6d	66.83	MG3	66.91								
765		CORE			4	MG6	65.63	MG6d	63.96								
765		CORE			5	MG8	64.78	MG5a	62.85								
766	**Indicative Site 299**	**CORE**	MG3a	**HK7**	**1**	**MG8d**	**66.05**	**MG6b**	**67.31**	**MG3a**	**69.32**						
766		CORE			2	MG3a	64.85	MG5a	67.01	MG3	67.99						
766		CORE			3	MG3	64.72	MG5	64.60	MG6b	65.97						
766		CORE			4	MG8	64.09	MG8d	63.94	MG8d	64.68						
766		CORE			5	MG6b	62.50	MG6	63.00	MG4a	63.37						
767	**Indicative Site 298**	**CORE**	MG6b	**HK7**	**1**	**MG6**	**68.44**	**MG8d**	**71.55**	**MG8d**	**66.64**						
767		CORE			2	MG6b	66.67	MG6d	68.93	MG6d	62.89						
767		CORE			3	MG6a	65.40	MG6b	68.69	MG6b	62.73						
767		CORE			4	MG3a	65.29	MG3a	67.18	MG3a	60.69						
767		CORE			5	MG8d	65.06	MG4b	66.11	MG8	58.39						
768	**NEW SITE 2012**	**CORE**	MG3a	**HK7**	**1**	**MG6d**	**67.80**	**MG8d**	**74.76**								
768		CORE			2	MG8d	67.28	MG6d	65.72								
768		CORE			3	MG6b	66.63	MG4b	65.59								
768		CORE			4	MG4b	66.60	MG3	65.11								
768		CORE			5	MG6	62.18	MG3a	63.35								
769	**NEW SITE 2012**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**68.51**	**MG8d**	**69.72**								
769		CORE			2	MG6b	63.49	MG6d	63.72								
769		CORE			3	MG8	62.59	MG3a	61.80								

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
769		CORE			4	MG6d	62.24	MG4b	61.49								
769		CORE			5	MG4b	60.50	MG6b	61.21								
770	**NEW SITE 2012 &**	**CORE & ENHANCEMENT**	MG6b	**HK7**	**1**	**MG6d**	**68.12**	**MG6b**	**69.78**								
770	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG6b	67.36	MG3a	69.75								
770		CORE & ENHANCEMENT			3	MG8d	66.24	MG8d	68.09								
770		CORE & ENHANCEMENT			4	MG4b	64.64	MG6d	67.36								
770		CORE & ENHANCEMENT			5	MG6	64.27	MG6	67.13								
771	**NEW SITE 2012**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**69.67**	**MG8d**	**69.71**								
771		CORE			2	MG8v2	65.49	MG8v2	62.95								
771		CORE			3	MG8	60.67	MG8	60.11								
771		CORE			4	MG8a	59.66	MG6d	59.73								
771		CORE			5	MG8b	58.99	MG14b	59.06								
772	**NEW SITE 2012**	**CORE**	MG8	**HK7**	**1**	**MG8d**	**64.18**	**MG8d**	**68.54**								
772		CORE			2	MG8v2	61.46	MG8	58.41								
772		CORE			3	Sd17c	58.36	MG8v2	58.24								
772		CORE			4	MG14b	57.05	MG8b	56.67								
772		CORE			5	MG8b	56.95	MG6d	56.23								
774	**NEW SITE 2012 &**	**CORE & ENHANCEMENT**	MG8	**HK7**	**1**	**MG8d**	**78.15**	**MG8d**	**75.04**								
774	**NP AONB Hay Time site**	CORE & ENHANCEMENT			2	MG6d	66.87	MG6d	63.99								
774		CORE & ENHANCEMENT			3	MG8	66.67	MG8	63.72								
774		CORE & ENHANCEMENT			4	MG8v2	63.55	MG6b	61.02								
774		CORE & ENHANCEMENT			5	MG4b	62.58	MG8v2	59.58								
2004	**Indicative Site 5**	**NON-AGREEMENT CONTROL**	MG6b	**None**	**1**	**MG6a**	**73.27**			**MG6b**	**71.20**						
2004		NON-AGREEMENT CONTROL			2	MG6	72.19			MG6	66.32						
2004		NON-AGREEMENT CONTROL			3	MG6b	71.12			MG3a	66.12						

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
2004		NON-AGREEMENT CONTROL			4	MG7d	69.17			MG8d	63.55						
2004		NON-AGREEMENT CONTROL			5	MG7c	66.90			MG6a	63.31						
2009	**Indicative Site 10**	**NON-AGREEMENT CONTROL**	MG8	**None**	**1**	**MG8d**	**64.64**			**MG8d**	**76.18**						
2009		NON-AGREEMENT CONTROL			2	MG6d	62.63			MG6d	69.25						
2009		NON-AGREEMENT CONTROL			3	MG8	61.49			MG4b	62.93						
2009		NON-AGREEMENT CONTROL			4	MG8v2	60.96			MG6b	61.85						
2009		NON-AGREEMENT CONTROL			5	MG8b	59.93			MG8	61.15						
4020	**Indicative Site 121**	**NON-AGREEMENT CONTROL**	MG6b	**None**	**1**	**MG8d**	**70.96**			**MG6d**	**62.24**						
4020		NON-AGREEMENT CONTROL			2	MG6	69.99			MG8d	61.85						
4020		NON-AGREEMENT CONTROL			3	MG6b	69.95			MG15b	60.28						
4020		NON-AGREEMENT CONTROL			4	MG6a	69.69			MG7c	60.16						
4020		NON-AGREEMENT CONTROL			5	MG6d	69.62			MG15	58.82						
4041	**Indicative Site 138**	**NON-AGREEMENT CONTROL**	MG3a	**None**	**1**	**MG8d**	**75.71**			**MG8d**	**69.72**						
4041		NON-AGREEMENT CONTROL			2	MG6d	73.45			MG6d	68.53						
4041		NON-AGREEMENT CONTROL			3	MG6b	71.66			MG6b	66.30						
4041		NON-AGREEMENT CONTROL			4	MG3a	67.17			MG4b	65.69						
4041		NON-AGREEMENT CONTROL			5	MG6	66.17			MG15b	65.29						
6004	**Indicative Site 227**	**NON-AGREEMENT CONTROL**	MG7	**None**	**1**	**MG6b**	**58.73**			**MG7d**	**64.34**						
6004		NON-AGREEMENT CONTROL			2	MG7c	56.47			MG7c	61.92						
6004		NON-AGREEMENT CONTROL			3	MG6a	55.85			MG7b	61.74						
6004		NON-AGREEMENT CONTROL			4	MG7d	55.38			MG6b	60.44						
6004		NON-AGREEMENT CONTROL			5	MG7	55.03			MG3a	60.30						
7115	**Indicative Site 293**	**NON-AGREEMENT CONTROL**	MG6b	**None**	**1**	**MG6**	**65.07**			**MG8d**	**67.22**						
7115		NON-AGREEMENT CONTROL			2	MG6d	62.43			MG3a	66.12						
7115		NON-AGREEMENT CONTROL			3	MG6a	61.62			MG3	64.73						

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
7115		NON-AGREEMENT CONTROL			4	MG4b	59.21			MG4b	61.19						
7115		NON-AGREEMENT CONTROL			5	MG9	58.94			MG4a	60.86						
12001	**Indicative Site 346**	**NON-AGREEMENT CONTROL**	MG6b	**None**	**1**	**MG6b**	**65.86**			**MG8d**	**74.87**						
12001		NON-AGREEMENT CONTROL			2	MG6d	64.90			MG6d	63.64						
12001		NON-AGREEMENT CONTROL			3	MG8d	64.15			MG6b	62.83						
12001		NON-AGREEMENT CONTROL			4	MG8	61.08			MG3	62.15						
12001		NON-AGREEMENT CONTROL			5	U4b	60.98			MG3a	61.97						
12002	**Indicative Site 347**	**NON-AGREEMENT CONTROL**	MG6b	**None**	**1**	**MG8d**	**65.62**			**MG8d**	**72.30**						
12002		NON-AGREEMENT CONTROL			2	MG6b	63.93			MG6d	62.48						
12002		NON-AGREEMENT CONTROL			3	MG6d	63.11			MG6b	60.50						
12002		NON-AGREEMENT CONTROL			4	MG8v2	60.85			MG4b	57.86						
12002		NON-AGREEMENT CONTROL			5	MG8	59.60			MG3a	57.60						
15001	**Indicative Site 368**	**NON-AGREEMENT CONTROL**	MG6b	**None**	**1**	**MG6b**	**60.88**										
15001		NON-AGREEMENT CONTROL			2	MG6a	58.77										
15001		NON-AGREEMENT CONTROL			3	MG10a	57.52										
15001		NON-AGREEMENT CONTROL			4	MG6	57.24										
15001		NON-AGREEMENT CONTROL			5	MG7c	52.82										
19005	**Indicative Site 426**	**NON-AGREEMENT CONTROL**	MG6b	**None**	**1**	**MG6b**	**63.10**			**MG8d**	**74.01**						
19005		NON-AGREEMENT CONTROL			2	MG8d	61.87			MG6d	66.84						
19005		NON-AGREEMENT CONTROL			3	MG15b	59.24			MG6b	66.34						
19005		NON-AGREEMENT CONTROL			4	MG4b	58.92			MG8	65.10						
19005		NON-AGREEMENT CONTROL			5	MG4c	58.59			MG6	63.66						
20006	**Indicative Site 441**	**NON-AGREEMENT CONTROL**	MG6d	**None**	**1**	**MG6d**	**72.78**			**MG15b**	**60.00**						
20006		NON-AGREEMENT CONTROL			2	MG6b	69.70			MG15	58.99						
20006		NON-AGREEMENT CONTROL			3	MG15b	67.80			MG8d	58.98						

2020 PSU Code	Derivation	2020 Sample Category	NVC assigned	Option	Rank of MAVIS result	2020 NVC	2020 % match	2012 NVC	2012 % match	2002 NVC	2002 % match	1995 NVC	1995 % match	1990 NVC	1990 % match	1987 NVC	1987 % match
20006		NON-AGREEMENT CONTROL			4	MG8d	65.68			MG6d	57.60						
20006		NON-AGREEMENT CONTROL			5	MG6	65.34			MG4c	57.11						
20026	**Indicative Site 460**	**NON-AGREEMENT CONTROL**	MG6a	**None**	**1**	**MG6**	**67.37**			**MG8d**	**65.00**						
20026		NON-AGREEMENT CONTROL			2	MG6a	67.02			MG6d	59.89						
20026		NON-AGREEMENT CONTROL			3	MG6b	65.85			MG6b	59.15						
20026		NON-AGREEMENT CONTROL			4	MG8d	63.79			MG8	58.25						
20026		NON-AGREEMENT CONTROL			5	MG8	61.25			MG15b	56.35						
20027	**Indicative Site 461**	**NON-AGREEMENT CONTROL**	MG8	**None**	**1**	**MG6b**	**64.60**										
20027		NON-AGREEMENT CONTROL			2	MG8d	63.74										
20027		NON-AGREEMENT CONTROL			3	MG6a	63.71										
20027		NON-AGREEMENT CONTROL			4	MG6d	63.61										
20027		NON-AGREEMENT CONTROL			5	MG6	63.34										

Appendix 4 – Ellenberg indicator values and Suited Species Scores (SSS) and stand condition in 2020

Significant associations (GLMs in R) were detected between all Ellenberg indices and Suited Species Scores (SSS) calculated for the hay meadow sites and soil/management variables (Table 35).

The survey regions Weardale, Wensleydale and the Western Fells had meadows which scored relatively highly for both Ellenberg Nitrogen and SSS Nutrient, while Wharfedale and Weardale meadows were positively associated with Ellenberg Reaction.

SSS Moisture was negatively associated with sites normally cut for hay (as opposed to haylage or silage). Wetter sites (Ellenberg F and SSS Moisture) were also negatively associated with grazing by sheep. SSS Grazing index was associated with sites grazed by traditional cattle breeds but modern sheep breeds. Sites which were not enrolled in an agri-environment scheme were positively associated with Ellenberg Light – several of these were managed as pasture.

In relation to the stand condition (Table 36), values for Ellenberg Nitrogen and SSS Nutrient were significantly higher (indicating a higher proportion of species associated with higher levels of nitrogen/nutrients) for poor condition stands (G01, G02) than for priority habitat G09 (Favourable and Unfavourable) (Figure 34). Ellenberg Light showed a weak relationship with stand condition, with poor semi-improved grasslands (G02) having a significantly lower Light value.

G01 improved stands had a significantly higher score for Ellenberg Reaction, indicating a higher number of preferential species for higher pH values, than for all other condition classes. There were no significant relationships between stand condition and Moisture or the related SSS Moisture, or SSS Grazing Index.

Table 35. Significant associations between Ellenberg Indicator Values (EIV), Suited Species Scores (SSS), soil variables and management factors. Generalised Linear Model, Gaussian distributions. Coefficients ± standard errors. Significance levels: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$. Stock: A traditional cattle only; B traditional cattle, traditional sheep; C traditional cattle, modern sheep; E Modern cattle, any sheep; F Traditional sheep only; G modern sheep.

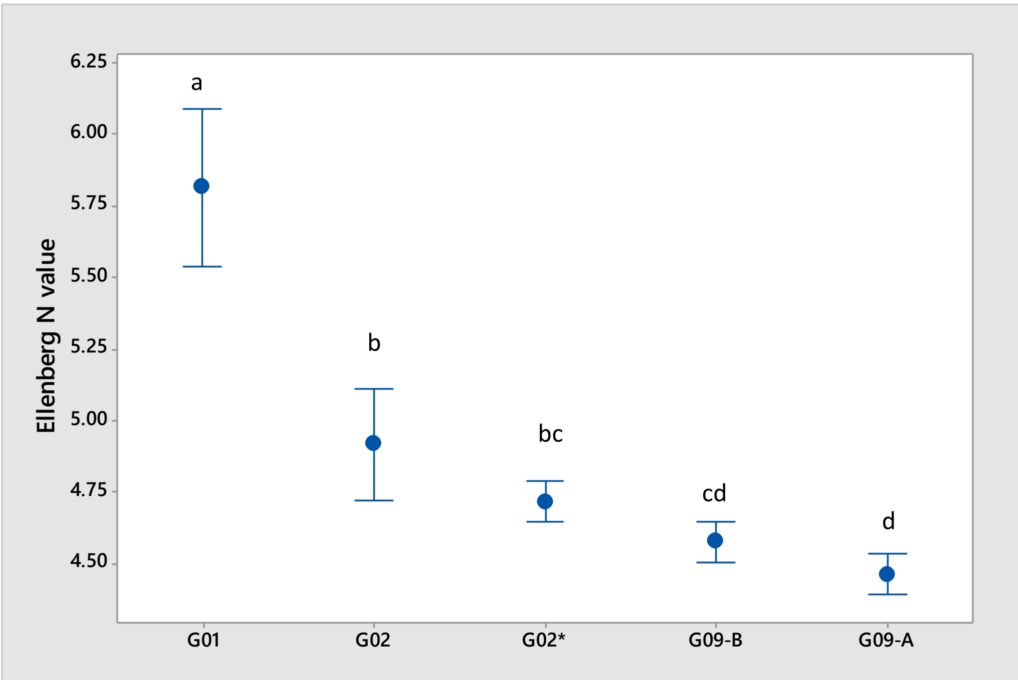
EIV	**Intercept**					
Light	*** 7.010 ± 0.520	No option* 0.132 ± 0.050				
Moisture	*** 5.822 ± 0.585	Stock B* –0.366 ± 0.158	Stock E* –0.034 ± 0.152	Stock F* –0.316 ± 0.156	Stock G* –0.415 ± 0.169	
Reaction	*** 5.095 ± 0.298	Weardale* 0.220 ± 0.029	Wharfedale* +0.176 ± 0.0739	Total P** $+1.63\times10^{-4} \pm 5.98\times10^{-5}$		
Nitrogen	*** 3.420 ± 0.527	Olsen's P** 0.0185 ± 0.007	(Soil) Nitrogen* +0.445 ± 0.193	Weardale* +0.329± 0.158	Wensleydale** +0.0382 ± 0.135	W Fells* +0.232 ± 0.116
SSS						
Grazing index	** 0.503 ± 0.179	Olsen's P* –0.0052 ± 0.0024	Stock C* +0.151 ± 0.0075			
Nutrient	* –0.369 ± 0.182	Weardale* 0.152 ± 0.055	Wensleydale* +0.119 ± 0.046	Olsen's P* +0.0057 ± 0.0024		
Moisture		Haycrop* –0.0445 ± 0.0198	Stock G* –0.146 ± 0.064			

Table 36. ANOVA with post-hoc Tukey pairwise comparisons for Ellenberg values and Suited Species Scores (SSS) and stand condition – mean values shown. Significance: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$. Means that do not share a letter are significantly different.

Condition	L	F	R	N	GI	Nu	Mo
G09-A	7.09[a]	5.52	5.77[a]	4.465[a]	0.355	–0.141[a]	0.023
G09-B	7.07[ab]	5.49	5.76[a]	4.578[ab]	0.344	–0.104[a]	0.028
G02*	7.08[ab]	5.42	5.79[a]	4.718[bc]	0.339	–0.042[b]	0.008
G02	6.99[b]	5.45	5.76[a]	4.919[c]	0.288	0.028[b]	0.017
G01	7.07[ab]	5.54	6.18[b]	5.817[d]	0.358	0.250[c]	0.075
P	*	ns	**	***	ns	***	ns

Ellenberg values 0–10: L Light, F Moisture, R Reaction & N Nitrogen
Suited Species Scores –1 to +1: GI Grazing Index, Nu Nutrient & Mo Moisture.

Figure 34. Mean Ellenberg Nitrogen values for 2020 upland hay meadow stands stratified by the results of the BEHTA condition assessment: G01 improved grassland, G02 poor semi-improved grassland, G02* good semi-improved grassland, G09-B Unfavourable condition upland hay meadow priority habitat and G09-A Favourable condition upland hay meadow priority habitat. Tukey Pairwise comparisons: means that do not share a letter are significantly different



Differences in Ellenberg values and Suited Species Scores in relation to agri-environment scheme enrolment and option. Sites that have not been under agri-environment scheme management ('none' – the control sample) had significantly higher mean Ellenberg values for Nitrogen, Suited Species Score Grazing Index and SSS Nutrient than sites currently managed under scheme options HK6 and HK7. However, there was no significant differences in any Ellenberg value or SSS between sites managed under HK6 maintenance option compared with HK7 restoration option (Table 37**Error! Reference source not found.**).

When the HK7 sample was divided into those that had received sward enhancement (HK7+) and those that had not (HK7-), enhanced sites had significantly more species suited to grazing than sites not selected for enhancement (Table 38). Enhanced sites also had significantly lower Ellenberg moisture and SSS Moisture but this is simply an artefact of the lower number of the wetter MG8 stands selected for sward enhancement.

Table 37. ANOVA of mean Ellenberg Indices and Suited Species Scores for all meadow sites stratified by HLS option HK6/GS6 'maintenance' or HK7/GS7 'restoration'. CI 95%, df 3,146. Significance levels: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$.

	HK6	HK7	None	*P*
Ellenberg Index				
Light	7.070	7.082	7.052	ns
Moisture	5.459	5.416	5.534	ns
Reaction	5.712	5.730	5.755	ns
Nitrogen	4.523 [a]	4.576 [a]	4.884 [b]	***
SSS				
Grazing index	0.357 [a]	0.347 [a]	0.284 [b]	**
Nutrient	–0.098 [a]	–0.076 [a]	0.004 [b]	***
Moisture	0.023	0.012	0.066	ns

Table 38. ANOVA of mean Ellenberg Indices and Suited Species Scores for all HK7 meadow sites stratified by sward enhancement: HK7- no enhancement, HK7+ with enhancement. CI 95%, df 2,100. Significance levels: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$.

	HK7-	HK7+	*P*
Ellenberg Index			
Light	7.065	7.099	ns
Moisture	5.513	5.318	***
Reaction	5.719	5.740	ns
Nitrogen	4.591	4.560	ns
SSS			
Grazing index	0.327	0.368	***
Nutrient	–0.074	–0.077	ns
Moisture	0.049	–0.027	***