Natural England Commissioned Report NECR138

Long term effectiveness of Environmental Stewardship in conserving upland hay meadows in the Pennine Dales

First published 03 June 2014

www.naturalengland.org.uk

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Upland Hay Meadows are listed under Annex 1 of the Habitats Directive, and are a key element of the landscape of the North Pennines. Their conservation importance was already recognised by the introduction of the first agri-environment schemes in 1987, when they were the key habitat targeted by the Pennine Dales ESA.

The Pennine Dales ESA monitoring programme initiated data collection on several hundred meadows throughout the area, and have since been subject to periodic resurvey, most recently in 2003. Many meadows have recently transferred to Higher Level Stewardship (HLS).

This report presents the findings of a survey of 103 meadows now under HLS management, of which a high proportion had previously been part of the ESA monitoring programme. The objectives were to:

- Assess the current condition of a sample of upland hay meadows under HLS management;
- Compare the condition of meadows under maintenance and restoration management; and
- Evaluate and explain any change in communities since previous surveys.

Very few of the meadows monitored contained the highest quality MG3b community, but a high proportion contained semi-improved communities of conservation interest. Of those meadows that had been monitored previously, there was some evidence that sites that were originally towards the better end of the condition spectrum may have experienced slight declines in quality, whereas meadows that had started in poorer condition provided evidence of slight improvement.

It is likely that a combination of factors is driving change in upland hay meadow communities including nutrient addition, grazing and cutting regimes and climate as well as active restoration. Natural England will use the findings of this project alongside evidence from other relevant **research and monitoring** activities to review and, where appropriate, refine HLS management prescriptions and associated guidance.

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Keywords - agri-environment, environmentally sensitive areas (esa), higher level stewardship (hls), management, monitoring, pennine dales, surveys, upland hay meadows

Further information
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ISBN 978-1-78354-108-9

"*I used to git up of a morning, even as a laal lad, and follow the mowing machine, an old Blanford, round the field with a rake. You could see the blades in the grass, there was no fertiliser in them days. You went a long way for a lot of hay, they weren't varra big crops, but it was an interesting time because a lot of hay was turned by hand. We had an old turner that would turn it an'all but the dyke backs were always turned by hand and shook out. A lot of work was done by hand in them days and nearly ivvery farm had a couple of men. There was a mass of flowers in the hay meadows, ivvery wild flower you could think of. When nitrogen cem along it gradually did away with them, which is a pity really because it was summat to see.*"

From: Richardson, K. 2009. Joss – *The life and times of the legendary Lake District fell runner and shepherd Joss Naylor*. River Greta Writer, Keswick, Cumbria, UK.

Penny Anderson Associates Ltd
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CONTENTS

TABLES

FIGURES

APPENDIX

1 Field Survey Proformas

ANNEXES (see standalone documents)

I Pen Portraits (Including Site List)

II DCA Graphs

SUMMARY

This study set out primarily to explore the long term effectiveness of Environmental Stewardship in conserving upland hay meadows in the Pennine Dales and secondly to provide an updated sample to facilitate future resurveys. The project aimed to:

- assess the current condition of a sample of upland hay meadow sites under HLS management;
- compare the current condition of upland hay meadows under HK6 and HK7 options;
- compare the change in condition of upland hay meadows since previous surveys; and
- gather data on management, soil and other relevant information and use this to explore the reasons for any change observed.

The survey assessed a sample of 103 sites in HLS management under options HK6 (n=31) and HK7 (n=72), designed, respectively, to maintain or restore species-rich grassland. The nature and condition of the sites was explored through analysis of the NVC communities (Rodwell 1992, O'Reilly 2011) present at each site and through analysis in conjunction with the keys set out in the Farm Environment Plan (FEP) Manual (Natural England 2010). The sample comprised a mix of existing monitoring sites for which long-term data were available, and new monitoring sites, selected to meet criteria that would enable the performance of the HLS options to be assessed in the future.

Examples of the highest quality upland hay meadow grassland were rare within the sample, but many sites did contain high-diversity semi-improved vegetation of significant conservation value. The most frequently occurring NVC community across both elements of the sample was MG6biii *Lolium perenne-Cynosurus cristatus* grassland, *Anthoxanthum odoratum* sub-community, *Trifolium pratense-Rhinanthus minor* variant (45%). Less than 2% of the sample supported the highest quality upland hay meadow community, MG3b *Anthoxanthum odoratum-Geranium sylvaticum* grassland *Briza media* sub-community, although a further 14% met the criteria for the less species-rich MG3a. Wetter upland hay meadow communities of the MG8 *Cynosurus-cristatus-Caltha palustris* grassland were found on about a quarter of sites with subcommunities that were at least moderately species-rich on about 13%. Less than 2% of sites contained improved grasslands (i.e. MG7 and MG10).

The keys set out in the FEP Manual for identifying species-rich grasslands were effective in identifying upland hay meadow sites that were suitable for management of species-rich grassland in HLS. However, it was less clear whether they had resulted in an appropriate choice of the maintenance (HK6) or restoration (HK7) option. Furthermore, the findings of the survey suggest that the criteria for including upland hay meadows in the maintenance option HK6 may be too lenient; as whilst the NVC analysis indicated the highest quality 'target' upland hay meadow communities were rare within the dataset (<6%), the FEP keys suggested *c*.45% of sites in our sample would qualify for HK6, including many that were considered to be semi-improved grassland, albeit with good species-diversity.

The statistical analyses identified relatively few significant differences between factors tested, although underlying patterns and trends appeared broadly consistent with previous studies (Critchley et al., 2004). There was a high degree of overlap between sites under HK6 and HK7 for various attributes. Although not significant, there was a trend for HK6 sites to have slightly higher species richness and greater composition of stress-tolerant species, and significantly lower available soil P levels than HK7 counterparts. This suggests that overall, HK6 sites were in slightly better condition than HK7, as might be expected. However, many HK6 sites retain soil P levels exceeding published optima for maintenance (and even restoration) of species-rich upland hay meadow vegetation. Taken together with the rarity of

key communities and indicators of upland hay meadows in our sample, this suggests that the levels of nutrient input currently allowed under HK6 could be reviewed.

For those sites where vegetation data could be compared with previous surveys, we found some evidence of change over time at individual sites (as shown in the DCA analysis and reported in pen portraits) but no clear overall trend at sample level. An analysis of general trends in the HK6 and HK7 subsamples suggested that sites now in HK6 (i.e. that might be expected to be higher quality meadows) have declined in mean species richness by 0.6 species since baseline, whereas those now in HK7 showed a slight mean increase of 0.5 species. Although the evidence for change is weak, it is plausible that recent management designed to restore sites has improved the condition of sites now in HK7, albeit from a lower starting point. Any decrease in species richness of the higher quality sites, however, may reflect losses of desirable species, i.e. a decline in quality of the best upland hay meadows.

The new sites chosen for the 2012 survey (i.e. that were not previously within the ESA monitoring sample) appeared to support greater mean species richness than the pre-existing survey sites, although this was not statistically significant. Of the 29 new sites, nine were designated as SSSI and might be expected to be of higher quality. Although only significant at the 90% level, there was a trend for existing sites to have a higher proportion of stress-tolerant species than new sites, which may reflect greater variation in previous management of the new site cohort (some may have been managed previously outside schemes, and others under ESA, Countryside Stewardship or Wildlife Enhancement Schemes.

Soil properties within the sample were broadly in line with those previously reported for Pennine Dales upland hay meadows by Critchley *et al*. (2004). For the sample, N status fell mostly within the ‘medium’ category, available P status in the ‘low’ to ‘moderate’ category and K in the ‘moderate’ category. These values imply that generally, available P will be the limiting nutrient across the sample, but a status of ‘low’ may still provide sufficient to support productive grass growth.

Management information was gathered from farmers by questionnaire and was made available for 86% of sites. Of these, 85% of fields were managed for field dry hay most years, the remainder being managed for haylage or silage. 61% of the sites for which data was received had been under this management for more than ten years and 34% for more than 30 years. Grazing was predominantly by sheep although cattle were also sometimes used. Other data were patchy and incomplete, although there was some suggestion that the typical shut-up date in the spring was shifting towards mid-May, perhaps later than in previous studies.

Looking at possible external drivers of change, long term climate datasets indicated East and North East England have experienced elevated temperatures and rainfall between 1981 and 2010, although 2012 was slightly cooler than the average in this period. The vulnerability of upland hay meadows to climate warming is considered to be high; estimates of atmospheric N deposition within the sample area suggest that critical loads have been exceeded for ‘mountain hay meadows’ with a typical value in Teesdale of 23.1 Kg N/ha/year. Loss of species richness due to chronic atmospheric N deposition has been observed in other infertile grasslands. It is possible that the cumulative impact of N inputs from atmospheric deposition combined with current and/or historic nutrient inputs on the farm may be resulting in nutrient delivery in excess of that considered suitable for maintenance of low-nutrient grasslands.

Upland meadows are naturally stressed communities, by climate (short growing season, low temperatures), by low nutrient availability and (sometimes) thin soils. If these stresses are being slowly and interactively moderated by climate warming and elevated available nutrient levels then vegetation may respond by becoming less stress-tolerant, losing characteristic species as they are out-competed by more vigorous plants e.g. grasses. It is possible that N supplied from atmospheric deposition plus regular manure addition, combined with moderate residual P levels from historic applications of NPK, may be sufficient to increase the vigour of competitive species. The evidence from this survey suggests that site restoration programmes may need to consider additional measures to limit soil fertility for meadows in both the restoration (HK7) and maintenance (HK6) options. Furthermore, seed addition to replace missing species, earlier shut-up dates (at least before May) and cutting after 21 July and into August seem to be practices associated with successful restoration of upland hay meadow communities (e.g. Jefferson 2005, Kirkham & Tallowin 1995, Smith *et al*. 2003); measures to encourage a return to these practices may also support restoration of target vegetation.

ACKNOWLEDGEMENTS

Thanks go to Natural England for funding this project, and in particular to Andrew Cooke and David Martin for their advice and guidance throughout. We also wish to thank Clare Pinches for her detailed comments upon the final report and the Data Management & Geographic Information Team who supplied the extensive GIS basemapping data, particularly Andy Lee.

We would like to thank Henry Adams who worked with our team on the botanical data collection in difficult field conditions, and Simon Poulton of BioEcoSS Ltd who provided all the previous data held on the selected sites. Thanks to all the landowners and managers who readily facilitated access for the field survey and took time to provide management information on their fields. We also acknowledge those Natural England local staff who helped us to locate contacts and provided additional information on some sites.

1. INTRODUCTION

1.1 Penny Anderson Associates Ltd (PAA) was commissioned in April 2012 by Natural England to undertake a survey of the long term effectiveness of Environmental Stewardship in conserving upland hay meadows in the Pennine Dales (contract reference number FST20/70/022). This study was intended to build on a series of previous monitoring studies dating back to 1987. The intention was to collect data from sites with a monitoring history that would allow comparison between data from summer 2012 and historic data and to use the 2012 data to establish a new baseline for hay meadow monitoring under the new Higher Level Stewardship (HLS) schemes now operating in the Pennine Dales.

Background to the Project

1.2 Upland hay meadows have long been considered of high nature conservation value. Now, upland hay meadows are a priority habitat for action under the England Biodiversity Strategy and are also offered protection under Annex 1 of the Habitats Regulations as analogous with 'Habitat 38.3 Northern Hay Meadows'. The habitat is defined by the National Vegetation Classification (NVC) as the 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 altitudes of 200-400m (Rodwell 1992). No distinction is made between the MG3 sub-communities at either Annex 1 or BAP priority level - all communities of MG3 including the more species poor MG3a *Bromus hordeaceus* ssp. *hordeaceus* sub-community are covered by our national and European commitments. However, it is the MG3b *Briza media* sub-community which is generally recognised as the true 'upland hay meadow' vegetation in Britain (Rodwell 1992) as well as some meadows with upland variants of the MG8 *Cynosurus cristatus-Caltha palustris* grassland (O'Reilly 2011). Other important species-rich grassland communities in upland hay meadows also exist but have hitherto been poorly described (O'Reilly 2011). Many of the best upland hay meadow sites have been designated as Sites of Special Scientific Interest (SSSI).

1.3 With such a restricted range and being vulnerable to agricultural improvement, the extent of upland hay meadow priority habitat is small; estimates of the UK extent suggest around 900 ha with the valleys of the North Pennines being the main stronghold. Limited evidence available suggests the habitat has continued to decline, both in extent and condition. A survey of grassland inventory upland hay meadows outside SSSIs in 2001/02 revealed that only 7% were in favourable condition and 42% showed closest botanical similarity to agriculturally improved NVC types (Hewins *et al.*, 2005); more recently further concerns have been raised about deterioration of grassland condition on SSSIs in the North Pennines AONB (O'Reilly, 2009).

1.4 Agri-environment schemes are the major vehicle for delivering management to conserve and restore upland hay meadows. For most sites, this was initially through the introduction of the Pennine Dales Environmentally Sensitive Area (ESA) in 1987; more recently since 2007, through HLS. However, certain SSSI meadows may not have been managed within the ESA scheme as they were already or alternatively being managed under WES[1]. Many ESA

[1] *The Wildlife Enhancement Scheme (WES) was introduced as a pilot scheme in 1991, and was a management agreement scheme for Sites of Special Scientific Interest (SSSIs), to positively maintain and enhance their special interest by combining Natural England's knowledge of wildlife management with the owner or occupier's skills and knowledge of the land. The scheme has now closed to new applicants, and Higher Level Stewardship is now the main scheme used to support the management of SSSIs.*

agreements have now been or will be renewed into HLS, providing a period of continuous management within agri-environment schemes of up to 25 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.

1.5 Defra and Natural England have monitored upland hay meadows since the introduction of Agri-Environment Schemes in various ways.

- From 1987, permanent quadrats were established in a sample of meadows as a framework for monitoring the effectiveness of the ESA scheme. Many sites have been monitored several times since, with the most recent comprehensive survey in 2002.
- ‘Phase 2’ grassland monitoring surveys have been undertaken of many high value meadows, again involving recording of quadrats.
- A common standards monitoring (CSM) rapid condition assessment (RCA) methodology was applied to a sample of non-statutory upland hay meadow sites in 2002.
- Most recently, some upland hay meadow sites have been monitored through Natural England’s ‘Integrated Site Assessment’ programme.
- In addition, various local scale or more informal monitoring activities have also been undertaken on upland hay meadows, for instance by the Haytime Project.

1.6 The existence of data from these surveys ensures a robust quantitative dataset is available for comparison with contemporary data. In the context of new England Biodiversity Strategy targets, 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 HLS and predecessor schemes in their conservation.

Project Objectives

1.7 The study aimed to collect data from a sample of upland hay meadows and to investigate the current condition and nature of change at the whole sample and site level, to see whether the HLS and predecessor Agri-environment scheme options have been effectively targeted and to ensure that HLS tier/option objectives are being met. The current sample includes sites for which there were existing historic data as well as new sites for which the 2012 survey established a baseline.

1.8 The assessment involved field survey, analysis of vegetation and soil data, including comparison where possible with data collected previously, and collection and analysis of site management information.

1.9 The project aimed to:

- Provide an assessment of the current condition of a sample of upland hay meadow sites in HLS management (i.e. the whole sample collected in 2012).

- Compare the current condition of upland hay meadows under maintenance and restoration management regimes (i.e. comparing those in HK6 and HK72 options respectively).

- Assess and compare the change in condition of upland hay meadows that have been under maintenance and restoration management regimes (for sites with past data only).

- Evaluate management, soil and other relevant information and explore the reasons for any change in vegetation condition observed.

1.10 The project also required site-by-site analysis and descriptions to provide a 'pen portrait' of each site in the current sample. Figure 1 shows the geographic spread of the sites.

The Pennine Dales Study Area

1.11 The study area lies mostly within the former Pennine Dales ESA, itself situated in the mid and north Pennines and extending over 46,563ha of the enclosed upper reaches of 26 valleys. These valleys, or dales as they are known locally, occur in 20 discrete blocks of land separated by high moorland. The dales radiate (in all directions) from the main Pennine watershed, north to the River Tyne, south and east to the River Tees and River Ouse, and west to the River Eden. The 23 dales visited in the current survey were Arkengarthdale, Baldersdale, Bishopdale, Coverdale, Crosby Garrett, Dentdale, East Allendale, West Allendale, Langstrothdale, Lunedale, Mallerstang, Mossdale, Ravenstonedale, Rawthey, Raydale, Ribblesdale, Swaledale, Teesdale, Tynedale, Waldendale, Weardale, Wensleydale and Wharfedale. The mean altitude of the ESA area is 228m above sea level and the upland climate can be harsh with high rainfall and a short growing season. However, not all of the study sites were within the former ESA, e.g. some of the areas on the western fringe around Ravenstonedale were never included.

1.12 The Pennine Dales have a predominantly upland pastoral landscape, with hill sheep and some cattle. Although each dale has its own character, there is a strong unifying pattern of enclosure created by traditional dry stone walls and numerous stone-built field barns. It is a tapestry of meadows and pastures; the area contains the greatest concentration of traditionally managed meadows and pastures in England. Meadows and enclosed pasture in upland England support a rich variety of species, including many rare and scarce plants, birds and invertebrates. Indeed, such meadows have outstanding importance for birds (English Nature, 2001).

1.13 Traditionally, upland hay meadow fields were in-bye pastures, grazed in autumn and/or winter, mainly by sheep. In late April to early May the fields would be shut-up for hay while stock was moved to summer grazing on the higher enclosed allotments and open moorland. Hay meadows were usually given a light dressing of farmyard manure after being shut-up. Generations of this practice together with the application of lime has tended to offset the natural leaching of minerals from the soil due to the wet climate in these areas (plus the annual removal of the hay crop), and the two practices together are widely considered to have helped maintain the richness and diversity of the vegetation. Hay cutting would generally start in late July to early August (Rodwell, 1992), although historically dates may have varied widely, depending upon weather conditions, with some fields occasionally cut as late as October (Smith and Jones, 1991). In an analysis of farm records between 1947 and 1986, the sequence of

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[2] HLS options are defined as follows:
HK6 – maintenance of species-rich semi-natural grassland;
HK7 – restoration of species-rich semi-natural grassland.

closure and cut-date was found to largely remain the same from year to year (Smith and Jones, 1991). Cut hay would be left to dry in the field before being transferred to barn for storage as winter fodder, allowing ripe seed to drop out.

1.14 In recent decades management has altered considerably, driven by changes in agricultural policy and practice including increased availability of inorganic fertilisers and improvements in farm technology. Rodwell (1992) states that '*such long-continued practices have been abandoned at an increasing rate in recent years*', citing the past use of chemical fertilisers as mainly responsible for the rapid floristic impoverishment seen since the 1960s. Furthermore, in the past, the time taken from start of cutting until the last field was harvested was longer than in modern times because advances in farm machinery now facilitate quicker cut and harvest, and this has implications on the ability of a number of key upland hay meadow species to set seed before harvest (Smith and Jones, 1991). The more widespread harvesting of haylage and silage crops is also a factor.

1.15 Agri-environment schemes (i.e. the former Pennine Dales ESA and current HLS) have aimed to encourage a return to more traditional practice in order to conserve and restore the upland hay meadow resource for the future by providing incentives to adopt traditional management practices in the face of agricultural change.

1.16 There are 79 Sites of Special Scientific Interest (SSSIs) within the ESA, covering 4,290ha (9% of the ESA). These are largely designated for their botanical interest, although not all have upland hay meadow as the designated feature. Within the whole of England there are only 768 hectares of SSSI upland hay meadow (using the UK BAP definition), and most of this small resource lies within the North Pennines area. Within the sample monitored in this study a total of 23 meadows (75 ha) were within SSSI (see Table 1).

1.17 The description by Ratcliffe (1977) of 'Northern Hay Meadows' formed the baseline for designation of SSSI upland hay meadow sites, and is still broadly followed in identifying this habitat type. In addition to protecting hay meadow communities, SSSI designation in the North Pennines may also address features which are restricted in their national distribution to the limestone pastures of the area. For example, rare arctic-alpine communities occur, particularly in and around Teesdale; additional botanical interest is found in other habitats of small extent, such as those associated with lead spoil and ancient ash woodland. Furthermore, rough grazing land on the dale sides is an internationally important breeding habitat for birds such as Eurasian curlew, common redshank, northern lapwing, Eurasian oystercatcher, common snipe and black grouse.

Table 1 SSSI Within the Sample (and associated site numbers surveyed in 2012)

SSSI Name	Site Number
Arkle Beck Meadows, Whaw	743
Ashes Pasture & Meadows	768
Bowlees & Friar House Meadows	726
Grains o'th' Beck Meadows	605, 606
Greenfield Meadow	627
Hexhamshire Moors	705
Lune Forest	769
SSSI Name	**Site Number**
Mallerstang-Swaledale Head	616
Middle Side & Stonygill Meadows	604, 717
Muker Meadows	744
Town End Meadows, Little Asby	607
Upper Teesdale	718, 720, 721, 722, 724, 734, 738, 771, 772, 773, 774

Agri-environment Scheme History

1.18 Prior to the introduction of the 'Environment Stewardship' scheme, the retention, restoration and enhancement of species-rich meadows was a priority in all the relevant ESAs, namely: the North Peak; South West Peak; Pennine Dales - where upland hay meadows were the main target habitat; and Cumbria. The Pennine Dales ESA was established in 1987. In common with the other ESAs, it aimed to encourage farmers to safeguard areas of countryside where the landscape, wildlife and historic interest is of national importance and considered to be dependent upon certain beneficial farming practices.

1.19 The farming requirements or prescriptions have varied between schemes, with some permitting a low level of manure or fertiliser and with different cutting dates depending on the local traditions in different geographical regions, in turn related to the climatic conditions. The Pennine Dales ESA, when it was first established, included the following (as well as generally no cultivation or drainage and limited use of chemicals):

- hay cutting after 1st July, 8th July or 15th July in different Dales;
- hay to be wilted prior to removal;
- the level of existing inorganic fertiliser could be applied provided it was less than 20 units of N, 10 units of P and 10 units of K per acre per year;
- no slurry or poultry manure was to be added, but up to 12 tons of farmyard manure per acre per year could be applied;
- no lime or slag to be applied;
- a specified minimum closing up period (stock exclusion).

1.20 The initial Pennine Dales ESA offered a single tier of agreement, but revisions in 1992 expanded the areas included and introduced a more prescriptive 'Tier 2' option aimed specifically at managing meadows and prohibiting the use of inorganic fertiliser. Under both tiers, agricultural improvement through ploughing, reseeding or installing new drainage was prohibited. Under 'Tier 1', fertiliser application was restricted to 125kg/ha/year of 20:10:10 NPK, and specific approval was required for any lime application or herbicide use. Permitted farmyard manure (FYM) application rates of 25 tonnes/ha/year set in 1987 were reduced to 12.5 tonnes/hectare/year in 1992. A further requirement for meadows in both Tiers 1 and 2 was periodic late cutting (i.e. not before early August) for each meadow.

1.21 The Pennine Dales ESA has operated for 25 years, but from 2006 was closed to new agreements and replaced by HLS. The cycle of agreement renewal in relation to the original launch of the ESA meant that many agreements transferred to HLS in 2011 or 2012, making 2012 a good time to establish a new baseline against which to monitor the efficacy of the HLS measures (as well as to look at cumulative change to date). Of course, sites which had only recently entered HLS would not have had time to respond to any management change.

1.22 The HLS offers generic options for maintenance and restoration of species-rich semi-natural grasslands, of which upland hay meadows are a key target grassland community - coded 'G09' in the Farm Environment Plan Handbook (Natural England 2010). The process set out in the FEP Handbook includes a suite of keys for identifying the quality and potential of semi-improved and species-rich grasslands, including upland hay meadows. In particular:

- Key 2a To identify semi-improved and species-rich grasslands;
- Key 2b To identify BAP grassland features;
- Key 2c To identify the botanical enhancement potential of species poor grassland.

1.23 Under the HLS, there is greater opportunity to tailor management requirements to each site, reflecting the condition at the time of the FEP, so these are more likely to vary between fields and farms compared with the ESA agreements. In general terms, the requirements for maintenance management (under HK6) are the same as in the ESA in that there should be no ploughing, re-seeding, drainage or application of inorganic fertiliser. Whilst generic guidelines are provided, the amount of FYM, liming and the cutting dates permitted on any one meadow should be informed by the specific conditions which apply there, e.g. soil nutrient status, pH, location. Option HK7, for the restoration of species-rich semi-natural grassland in HLS, would also be applicable to upland hay meadows and seeks to restore land that has been either neglected or semi-improved agriculturally. This option should be targeted at sites with appropriate restoration potential (e.g. identified by FEP Manual keys 2a-c). Additional potential management requirements in association with restoration management include scrub or invasive weed control/removal and seed introduction as well as hay meadow management as in HK6. For some of these actions, additional one-off capital funding may be available.

1.24 There is also an additional supplement (HK18) that is used in conjunction with HK6 and HK7 to support hay-making management: either to encourage pastures to be returned to hay meadow management; or where hay making is at risk of being discontinued for economic reasons.

1.25 Each agreement contains information about the nature of the target feature and includes Indicators of Success that describe progress towards the desired outcome. These provide a framework for comparison when monitoring. These IoS may be set to describe desired attributes of the grassland community, e.g. a threshold for number of target species within the sward, or otherwise in line with the general CSM or HLS criteria.

Overview of Previous Studies

1.26 Between 1987 and 1995, botanical monitoring was carried out in the Pennine Dales ESA as part of the environmental monitoring programme for ESAs in England. A summary of this work is reported in ADAS (1996) with reference to previous studies where relevant. The studies initially aimed to establish a baseline record of grassland condition when the ESA was launched and through delivery of later resurveys to monitor change as a result of the management imposed. Detailed vegetation records were made from a range of grassland types across the Pennine Dales ESA in 1987, 1990 and 1995, and the study as a whole found that characteristic meadow and less improved pasture vegetation had been maintained across the range of vegetation types studied. They also found that, in meadow communities previously managed more intensively, there was some evidence of progress in restoration of characteristic meadow vegetation.

1.27 Importantly, the ADAS studies gathered and analysed data collected via three monitoring studies, that all used methods that were similar albeit with some variation. The 'Indicative' study was a broad-level study across the full range of ESA grassland communities designed to monitor change at the field scale. The 'Validation' survey was more detailed and was targeted at selected grassland communities using a fixed quadrat method. Both these were initiated from the inception of the ESA. A third approach was used when the ESA was expanded in 1992; this 'Extension' survey broadly followed the Indicative method but with minor variation. All studies included a common approach of recording plant species records in five 1m x 1m quadrats, but other sampling and recording methods varied. The details of quadrat placement and recording within these three studies is summarised in Table 2.

Table 2 Details of Previous Studies (after Critchley *et al.* 2004)

Survey	Usual No. Quadrats Per Field	Layout	Relocation	Size	Species Abundance estimates
Indicative	5	Extremities of 'W' pattern	Semi-fixed	1m x 1m	DAFOR
Validation	5	Transect	Fixed	1m x 1m nested within 2m x 2m	Domin
Extension	5	Transect	Fixed	1m x 1m	DAFOR

1.28 Critchley *et al.* (2004) undertook a resurvey in 2002 of 164 of the hay meadows from across these prior ESA samples, to determine whether their condition was being maintained, and whether further progress towards re-establishment of upland hay meadow vegetation in semi-improved and improved meadows had been made. They also looked at the relationship with management practices and soil properties in the 15-year period from 1987 to 2002. For this resurvey, only three quadrats per site were surveyed. At the best hay meadow sites, there was evidence for deterioration in vegetation, relating to declines in herb richness. Few changes were detected in semi-improved hay meadow vegetation although grass species richness increased. Improved hay meadow sites saw increases in total, herb and grass diversity indicating a degree of improvement in the vegetation, but not to the desired MG3 community threshold.

2. METHODS

Field Survey

2.1 The field survey was targeted at sites which qualify as G09 – upland hay meadows Biodiversity Action Plan (BAP) habitat. This is defined in Natural England (2010) as:

- 'Enclosed land on moist or free-draining neutral soils in the Pennines and Dales of Yorkshire, Durham, Northumberland and Cumbria, and in the eastern Lake District.
- Meadows are cut for hay, with aftermath grazing.
- Typical grasses include: cock's-foot, common bent, crested dog's-tail, red fescue, rough meadow-grass, soft brome, sweet vernal grass and Yorkshire-fog.
- Typical wildflowers include: common knapweed, eyebrights, hawkbits, meadow vetchling, pignut and tormentil.'

2.2 Details for 105 sites were provided by Natural England. Two were found at the time of survey to be under permanent pasture and so were not surveyed, meaning that botanical information was collected for a total of 103 sites in 2012.

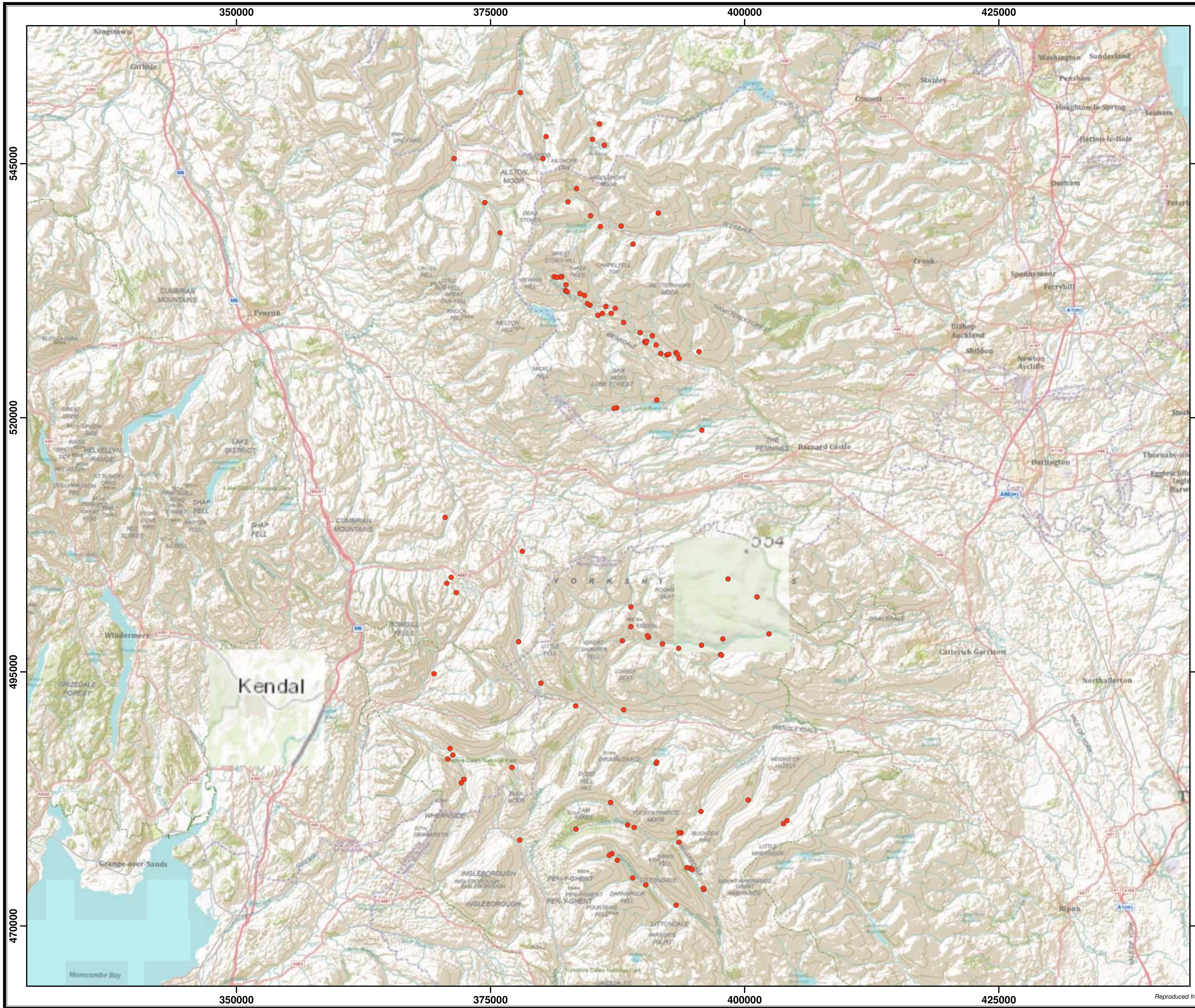
Site Selection

2.3 Sites were selected by Natural England to provide a sample of around 100 North Pennine meadows under the HLS options HK6 'Maintenance of species-rich, semi-natural grassland' and HK7 'Restoration of species-rich, semi-natural grassland'. The sample was framed to address two separate objectives, to:

- provide a baseline for tracking the effectiveness of the HLS management in maintaining or restoring a species-rich grassland community.
- enable a retrospective assessment of the cumulative impacts of agri-environment scheme management to date.

2.4 To meet the second objective the selection of sites aimed to maximise the number of fields with a history of monitoring activity under the ESA programme (ADAS 1996, Critchley *et al.* 2004), that were known to have been in hay-meadow management and had since entered HLS agreement in one of the qualifying options. Around two-thirds of the 2012 sample met these criteria. The remainder were identified randomly from HLS agreements that were in place in the North Pennines at the time of planning the survey and contained the qualifying options, together with the HK18 haymaking supplement. The focus of sampling was to ensure adequate coverage of HK6 and HK7, with a split of about 30:70 in favour of the latter, reflecting the greater frequency of adoption of the restoration option. There was no stratification according to existing meadow quality or the management tier used in any previous ESA or Countryside Stewardship agreement.

2.5 A full list of the sites surveyed is presented in Annex I, Table 1. Figure 1 shows the geographic spread of the sites.



Legend

- Sample site locations

British National Grid
Projection: Transverse Mercator
False Easting: 400000.000000
False Northing: -100000.000000
Central Meridian: -2.000000
Scale Factor: 0.999601
Latitude Of Origin: 49.000000

N

ISO A3

0 1 2 4 6 8 10 km

NATURAL ENGLAND

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Telephone 01298 27086

Project Name	Upland Hay Meadows Survey 2012
Discipline	Ecology
Title:	SAMPLE SITE LOCATIONS OVERVIEW
Scale 1:350,000	Drawing No. Figure 1
Drawn By DR	Originator HH
Date	17/01/2013
PAA Ref. G:\NATE18_Hay_Meadows_Survey\Maps	Revision A

Access

2.6 Access details were provided by Natural England for all the sites, comprising agreement holder name and contact telephone number. Telephone calls were made in advance to arrange a suitable time for the survey. All landowners and tenants contacted were helpful and forthcoming with access permission, and all sites were visited.

Management Questionnaire

2.7 Many of the agreement holders were met on site and about 30% of management questionnaires completed in the field. However, given the poor weather throughout all of June and July, *c*.30% of questionnaires were completed over the telephone from the office after the surveys had finished. The remaining 30% of farmers who were more difficult to contact were sent the questionnaire with a self-addressed envelope for completion and return.

2.8 A copy of the farmer management questionnaire is presented in Appendix 1.

Botanical Methods

2.9 Field surveys were mainly completed by botanical surveyors working in pairs as this was found to be most efficient. The field survey comprised:

- Site overview and pen portrait;
- Mapping of the G09 feature;
- Rapid Condition Assessment (RCA) by a Structured Walk;
- Soil sample collection;
- Site photograph;
- Botanical quadrats.

2.10 Generally, the first five activities were completed by one surveyor while the other completed the quadrats.

2.11 A copy of all the field survey proformas used is presented in Appendix 1.

2.12 Botanical nomenclature followed Stace (2010), with only vascular plants being recorded, as previously.

Site Overview and Pen Portrait

2.13 The site overview recorded information on: site number; surveyor names; date; area; HLS option code (HK6/HK7/HK18); previous survey history (e.g. indicative/validation/new site); topography; slope and aspect; photograph number and location and notes on quadrats (i.e. new, relocated with certainty – markers found, relocated with uncertainty – orientation unclear, not relocated - good match with bearings and pacing information, not relocated - poor match).

2.14 A field description of the site or 'pen portrait' was also prepared for each site, covering aspects such as positive and negative indicators, species at edge, overall species richness and diversity, other notable species (DAFOR) from W-walk, evidence of management (e.g. grazing), negative indicators, feeding locations, etc. Notes on field survey limitations, weather conditions and other relevant details were also made.

Mapping G09 Feature

2.15 The boundary of the G09 feature was drawn onto a printed aerial photograph. Mown and non-mown areas were noted, together comprising the G09 feature. Apart from the two unsurveyed sites which were discarded as permanent pasture, all fields were found to qualify as the G09 feature as described in the FEP manual (Natural England 2010), including mowable areas, steep banks and marshy ground. G09 mown areas were digitised from field maps for supply to Natural England with this report.

Rapid Condition Assessment RCA Walk

2.16 The RCA walk followed the standard methods, recording onto the proforma provided by Natural England for either 'MG3' or 'MG8-related (north), MG3-related'. Appropriate proforma selection was based upon the nature of the field and was decided on site by the surveyor. The surveyor followed a 'W' shaped route across the field taking in as much variety as possible. Fifteen to 20 evenly-spaced stops were made and presence-absence data collected on listed species present at each stop. The pot-auger for soil sampling (see below) was used as the centre for the 1m radius search for the listed species. Surveyors aimed to complete 20 stops, and this was achieved in most fields.

2.17 Some data were not collected in the field but calculated from the quadrat data, e.g. grass/herb ratio and average height of sward.

Soil Sample Collection

2.18 A standard pot-auger was used to collect soils from approximately 20 locations across each field. Surveyors aimed to collect 20 soil plugs in each field. The pot auger was found less effective at collecting soils in wetter ground, so these areas may not be fully represented in the soil dataset.

2.19 Soils were bulked into one bag for each site, labelled and stored in the dark and cool for a short period until despatch to the laboratory for analysis. Despatches were made on a weekly basis during the field survey season. A standard analysis package was carried out by Natural England's contractor (NRM laboratories) and included:

- Soil pH (Water);
- Olsens P (mg/l);
- Soil K (mg/l);
- Soil Mg (mg/l);
- Total N (%);
- Loss on Ignition;

- Total P;
- Organic Carbon;
- Soil texture.

2.20 Data from the soil analysis were provided by Natural England in spreadsheet format, with indices for P, K and Mg calculated. Natural England's Technical Information Note TIN036 was used in the interpretation (Natural England 2008).

Site Photo

2.21 A single site photo was taken at each site and the location noted on the field map. These have been supplied in JPEG format.

Botanical Quadrats

2.22 Three botanical quadrats were either relocated (existing sites) or established (new sites) in each field. These were then marked and data collected. The methods for locating quadrats at existing and new sites differed slightly, as outlined below. However, actual botanical data collection methods were standardised across all sites to maximise comparability of the data between sites and between years (because previous surveys consisted of either 1m x 1m or 2m x 2m datasets, depending upon the survey methods followed at the time).

2.23 At all sites, botanical quadrat data was collected, providing full vascular species list and % cover for a 1m x 1m quadrat. With its y-axis oriented north, this quadrat formed the origin for a 2m x2 m quadrat within which only presence-absence data was collected. See Figure 2.

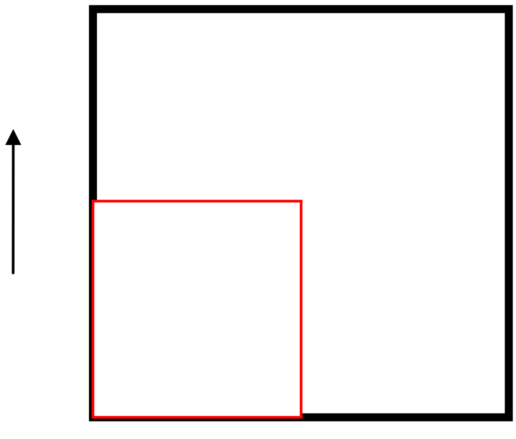

Figure 2 Botanical Quadrat Arrangement at All Sites (arrow points North, red=1m x 1m, black=2m x 2m)

2.24 The following indices were also recorded at all quadrats:

- Vegetation height (in cm);
- % cover of Bare Ground, Litter, Bryophytes, Grass, Forbs, Sedge and Rush.

Existing Sites

2.25 Existing sites were those for which quadrat information had previously been collected. At most sites, the original survey had comprised five quadrats. On some of these sites, subsequent assessments had also been undertaken; however, at the most recent resurvey exercise in 2003, only three of the five original quadrats were sampled. The current survey also aimed to collect data from three quadrats, either repeating the same three from the previous study, or selecting the three quadrats that best reflected the G09 feature present at the site.

2.26 Existing quadrats were relocated using a combination of techniques, depending upon the information provided, which included either:

- GPS coordinates pre-loaded onto the differential GPS (information only became available part-way into the field survey);
- Copies of previous survey maps, usually showing bearings and pacings, or just the latter.

2.27 The GPS was used to relocate quadrat locations where these matched with the other survey information provided. Where there was a mismatch, appropriate reselections were made. For example, where three GPS points were provided but one was found to be unsuitable for monitoring, a replacement would be selected from the original five points. Approximately twenty minutes was spent trying to locate each quadrat accurately, and then an appropriate position was chosen for the survey.

2.28 Where the three quadrats were not pre-selected, the selection of three quadrats from the original five was based upon choosing those most representative of the vegetation at the site, within the mown hay meadow vegetation, aiming to avoid areas unlikely to be mown e.g. steep banks or wet ground, and also field edges, walls, telegraph poles, tree shade, gates and paths.

2.29 Once the approximate location of the existing quadrat had been found, a metal detector was used to locate the four marker pins and orient the quadrat; however the detectors became ineffective in taller vegetation especially when wet, which was most of the time. Therefore, at many sites, no markers were found, and older bearing and pacing information was used if available to position the quadrat. All quadrats were oriented with their axis pointing north.

2.30 At all existing quadrats, differential GPS coordinates were collected for the bottom left (BL) and top right (TR) of the 2m x 2m quadrat, usually oriented with the origin in the southwest corner. No quadrat markers were placed at existing sites.

New Sites

2.31 New sites had no pre-existing quadrats. Therefore, three new quadrats were placed within homogeneous stands representative of the wider vegetation at the site, within the mown hay meadow vegetation, avoiding areas unlikely to be mown e.g. steep banks or wet ground, and also avoiding field edges, walls, telegraph poles, tree shade, gates and paths.

2.32 The new quadrats were marked with metal pins to aid future relocation. Five or six inch iron nails were used with 1.5 inch diameter metal washers, placed at each corner of the 1m x 1m quadrat, installed just below the soil surface so that no injury to stock or mowing equipment could occur.

2.33 Differential GPS coordinates were collected for the BL and TR of the 2m x 2m quadrat, usually oriented with the origin in the southwest corner.

Problems Encountered During the Field Survey

2.34 Several issues were experienced during the field element of the study that impact on the use of the data.

2.35 The main issue was that relocation of fixed quadrats at indicative and validation sites was not successful apart from in a few isolated cases. This was due to a number of factors:

- Lack of accurate GPS data for some sites, particularly at the commencement of the survey;
- Poor quality of mapped relocation information in terms of bearings and pacings – sometimes these were plainly wrong and at other times critical information, such as date and use of magnetic or grid north, was missing. Pace lengths were never defined and direction of travel rarely noted (uphill paces are generally shorter). In general, quadrats placed on diagonal transects where both corners could be seen were easier to re-find;
- Poor operation of metal detector in long wet grass.

2.36 In addition, several farmers (e.g. site 704) reported finding metal quadrat marker plates in the hay crop, so some at least may no longer be *in situ*.

2.37 Despite a poor relocation rate for fixed quadrats, the same areas of the fields were sampled and statistical comparisons with past data can still be carried out at the field level. The difficulties with quadrat relocation were frustrating and even though search times were limited to twenty minutes per quadrat, across the whole study much wasted time was spent trying to relocate quadrats at all previously surveyed sites.

2.38 Another issue encountered during the survey was the extremely wet weather throughout the survey period from the start of June to mid-July. Although visibility was often poor and conditions difficult for surveyors, this was not considered likely to affect the botanical species recording in any meaningful way; it did, however, impact upon quadrat relocation success.

2.39 The final limitation related to completion of the farmer questionnaires. About 30% of farmers completed the questionnaire face-to-face with a surveyor; a further 30% were completed over the telephone. The final 30% of farmers were sent the questionnaire for return with a self addressed envelope – but a proportion has not been received. Therefore, management information was obtained for 89 out of 103 sites (c. 86%).

Data Entry and Checking

2.40 Data entry of the botanical information, field notes and management questionnaires was undertaken manually in the office. Datasets were checked for accuracy and completeness by the field worker responsible for that site.

Data Analysis

Individual Sites

National Vegetation Classification Community

2.41 For each site, NVC communities and sub-communities for the 2012 data were assigned from the botanical quadrat data using MATCH software (Malloch 1999, Thomson 2004). Cover estimates (%) for the three 1m x 1m quadrats were used in place of DOMIN values, and the affinities to main communities and sub-communities presented. The links and affinities to the relevant vegetation communities are outlined in the individual site Pen Portraits (Annex 1). The presence of key indicators is also discussed, together with the implications for the vegetation quality and condition. Ellenberg values for light, moisture, reaction, nitrogen, nutrients and grazing were also calculated (after Hill 1999).

2.42 For the Pen Portraits, the NVC categorisation was evaluated further against the detailed upland hay meadow communities described in O'Reilly (2011).

2.43 It should be noted that NVC communities were not attributed in the field but from the quadrat data collected during the field survey. This deviates from the method recommended by Rodwell (1992) but is a commonly used and accepted technique.

Characterising the Dataset

Initial Processing

2.44 For the purposes of analysing the data, some standardisation was required in order to enable comparisons to be drawn between years, and thus to infer measures of community change at the individual site level. To achieve this, quadrat information for both the Indicative and Validation datasets were collated and converted to presence/absence values, as was the 2012 data for 1m x 1m quadrats. Additionally, all other data collected within the Validation survey from the larger 2m x 2m quadrats were excluded. Because previous cover data in the form of Domin categories was only available for the 'validation' dataset, this could not be used to compare all sites across time – the current dataset and this subset of sites could be analysed for changes in domin categories in a future investigation, but this specific analysis was outside the scope of this study. However, it should be noted that looking at trends in categorical data is much less meaningful, and ordination analyses (e.g. DCA plots) cannot be performed.

Descriptive Statistics

2.45 A range of metrics were calculated for each site using both the 2012 field survey data and the available historic data. These included the calculation of average species richness, average Grazing Suited Species Scores and the average Nutrient Availability Suited Species Scores (see below) across each quadrat for each site. Average species richness for each site was derived as the average across 3 quadrats of the number of species/quadrat. In addition, the change in species richness between the baseline year (see Table 1) and 2012 was also calculated.

2.46 In order to investigate the changing status of the hay meadow sites a number of statistical comparisons were made using the metrics detailed above. It should be noted that a one-sample Kolmogorov-Smirnov test was used to determine the validity of using parametric tests (i.e. where the data were confirmed as normally distributed). One-way Analysis of Variance was employed to look at whether significant differences occur between various classifications of the data. This included the following: HLS groups HK6 (species-rich semi-natural grassland sites) and HK7 (restoration of species-rich grassland sites). In order to more fully understand the reasons behind any differences, further exploratory analyses were carried out as follows: ESA Tiers 1B (meadows, pastures and allotments) and 2A (herb rich meadows); ESA agreement years; SSSI versus non-SSSI, NVC classification (MG3, MG6 and MG8), and finally comparisons between the subset of new sites surveyed in 2012 and all other sites.

Suited Species Scores

2.47 Average grazing and Nutrient Availability Suited Species Scores were calculated for each site in each year using information provided from http://www.suitedspecies.com. These values provide a measure of the dominance (or otherwise) of species suited to either high levels of grazing intensity or high nutrient availability and can, therefore, be used as a direct measure of the impact of management change for suites of sites. For example, changes in a grazing regime as a result of management prescriptions applied through agri-environment schemes, such as a reduction in grazing intensity, might ideally be represented as a decrease in the average Grazing Suited Species Score for a site through time as the proportion of species favoured by grazing declines. A suited species score, therefore, provides a quantitative measure that is directly related to the management objectives of any given site. For each site, a suited species score was calculated as the average score of all species present in the sample (where each species has a score of -1, 0 or +1). These data were analysed in relation to overall trends across all sites, and also to inform the interpretation of temporal changes in vegetation for each site individually.

Comparing New Sites

2.48 The subset of new sites included in the 2012 sample was assessed to establish the degree to which they conformed to the wider set of sites in terms of species richness, average Grazing Suited Species Scores and average nutrient availability suited species scores. In each case, the null hypothesis was that the new sites did not differ from all other sites.

Soil Properties

2.49 Data collected from all samples were collated, described and analysed using independent samples t-tests, assuming unequal variance, in order to determine any significant differences between sites under HK6 and HK7. Where possible, descriptive comparisons were made between the 2012 data and data summaries presented by Critchley (2004). It should be noted that, although between years comparative analyses would have been desirable, insufficient data were available with which to do so.

Assessment of Condition

2.50 The aim was to assess vegetation condition using Natural England's Integrated Site Assessment (ISA) method, using the data collected during the RCA survey and analysed using a bespoke database. In addition, the current dataset was also to be assessed using the criteria set out in the Farm Environment Plan for site selection for inclusion in HLS.

2.51 The RCA data generated from the structured W-walk was collected on the most appropriate proforma for the vegetation community present at each site, i.e. the surveyor had to identify the most appropriate form from 'MG3' or 'MG8-related (north), MG3-related'. However, it was found that the limitations of the database used to store and analyse these data meant that data collected on different proformas could not be analysed together. This compromised the value of these data in their raw form in terms of the objectives of this study. Once the flaw in the database is addressed, these data can be analysed to provide a quick assessment of vegetation condition across all the 2012 dataset.

2.52 The whole botanical dataset (quadrat and W-walk data) was, however, analysed according to the relevant grassland keys (2a, 2b and 2c) in the Farm Environment Plan Manual (Natural England 2010). These keys allowed sites to be defined as:

- Good quality species-rich grassland (upland hay meadow BAP habitat, G09 feature) – suitable for HK6 management;
- Species-rich grassland, not BAP habitat – HK7 management;
- Semi-improved grassland – HK7 management;
- Improved grassland – HK7, subject to confirmation of potential for restoration, or ELS options.

2.53 Much of the analysis using Keys 2a and 2b was completed using a Microsoft Excel spreadsheet programmed to extract the necessary information from the data. Key 2a was straightforward. A list of anomalies for Key 2b is presented with the results. Key 2c required more qualitative interpretation and each site reaching this stage of the analysis was processed manually. Some notes on working through Key 2c are provided below. Results were tabulated for analysis.

2.54 In Key 2c, quantitative data were not collected on Drought, Steepness or Waterlogging, so therefore the opening couplet was ignored in the key. Following a moderate soil P result requires a similar couplet to be ignored further down the key. In Low P cases, it was assumed livestock were available for management. In Moderate P cases, it was assumed the farmer would be willing to cut for hay and graze the aftermath. Information on aggressive species and injurious weeds present was taken from the data collected on the W-walk and the vegetation sampling.

2.55 The aggressive species used in the key were limited to: *Bromus hordeaceus, Holcus lanatus, Ranunculus repens,* and *Trifolium repens.* A quantitative measure of these was taken across the quadrat data such that: if the combined cover of these four species was less than 50% it was considered that aggressive plants were not dominant.

2.56 The injurious weed species were taken from those identified on the RCA form. If two or more species were present and at least one was frequent and one occasional (or three rare), or three were occasional, then they were considered to be ‘throughout the sward’.

Quantification of Change

Multivariate Analysis

2.57 Temporal changes within each vegetation type at both sites were analysed using detrended correspondence analysis (DCA) run in the CANOCO 4.5 software package (Ter Braak and Smilauer 2002). DCA was chosen as the most appropriate analytical tool for species data for which there is no directly corresponding environmental data pertaining to each quadrat. In the analyses, rarely recorded species were down-weighted.

2.58 DCA allows the investigation of changes in species composition over time. Where at least three years of survey data were available, the initial survey year for each site was taken as the baseline against which samples from subsequent years (see Table 1 for a list of the baseline years for each site) were compared.

2.59 This method allows any temporal divergence in the data collected in later years to be compared against the baseline. The mean DCA ordination position of all samples in each year was calculated to assess any patterns in the movement of vegetation communities around the baseline ordination diagram. Where there is close correspondence in movement direction and pattern for vegetation types it is considered that temporal changes may be attributed to environmental or management factors.

2.60 Each site for which at least three years of data have been collected since 1987 has been analysed and the results presented as part of the individual site descriptions ('pen portraits'). In total, 74 sites were assessed in this way.

Limitations to the Analysis

National Vegetation Classification Community

2.61 The standard method set out in Rodwell (1992) for NVC determination uses a 2m x 2m quadrat (rather than 1m x 1m as used, and is carried out in the field). The analysis for this project was completed after the field survey, using the botanical data only. This can mean that other characteristics of sites are not available for use to help decide on the most appropriate community. However, it is considered that good confidence can still be placed in the method used:

- all sites were under hay meadow management;
- good coefficients of fit were generated for the expected communities;
- swards were at least locally quite homogeneous so that the 1m x 1m quadrat contained most if not all of the species in the 2m x 2m, so the number of species recorded would not be greatly affected;
- in addition, detailed site descriptions were taken and were referred to in selecting the NVC communities, sub-communities and variants.

Data Consistency

2.62 Various limitations within the individual data sets have important implications for the analysis of community level changes in response to management actions. In particular, additional environmental variables should ideally be incorporated into analyses in order to understand the degree to which residual variation can be attributed to particular management actions. In this regard, although soils data are available for some years, this information cannot be included within the DCA plots given the lack of availability for all sites in all years. This means that any conclusions drawn as regards the success or otherwise of management prescriptions must take this into account. This does not, however, preclude making any such conclusions and all available information, including the farmer questionnaires, has been taken into account when interpreting the results of the DCA plots.

Variable Baselines

2.63 As alluded to in previous sections, individual sites have been surveyed in different years. This means that the baseline for analysis is inconsistent across the dataset. In addition, there is variability across sites in the numbers of years for which data are available for analysis. In this regard, to assess community level changes, only those sites for which there are at least three survey years of data have been analysed using DCA. This means that no assessment of community level changes have been made for the following sites: 602, 607, 608, 617, 618, 620, 623, 624, 627, 632, 702, 703, 708, 709, 713, 714, 736, 737, 738, 739, 740, 741, 743, 744, 748, 768, 769, 770, 771, 772 and 774.

Quadrat Accuracy

2.64 The difficulties with relocation of quadrats and use of different surveyors and methods across all years (from 1987) invariably introduces some potential errors into the dataset. Although these do not preclude analyses, the interpretation of observed trends in community change and species richness must take these issues into account when drawing conclusions. It is for this reason that quadrat-level comparative analyses have not been conducted.

Limitations of Statistical Analyses

2.65 It is important to note that, although important inferences can be made from the statistical analyses presented, subtle differences in community changes and composition are not necessarily identified in this way, particularly where high levels of within and between site variability are recorded. Furthermore, in the absence of consistent environmental information, any statistical trends cannot be confidently attributed solely to management practices.

Data Management

2.66 All data as follows has been supplied back to Natural England in the requested format:

- GPS location of all quadrats – GIS files;
- Extent of G09 feature – GIS files;
- Soil data – Microsoft Excel spreadsheet;
- Botanical quadrat data – Microsoft Excel spreadsheet;
- Management data – Microsoft Excel spreadsheet;
- RCA ‘W-walk’ data – Microsoft Access database files;
- Site photos – jpegs;
- Original field data – paper.

2.67 In addition, all 2012 botanical, soils, management and RCA data was supplied to Simon Poulton at BioEcoSS Ltd for incorporation into the hay meadow database which he manages on behalf of Natural England. Accurate location details for all quadrats were also supplied.

3. RESULTS

3.1 This study examines the results of the field survey and data analysis in a number of ways: at the individual site level and across the whole dataset to assess condition and quantify change.

Individual Sites

3.2 For each individual site, a 'Pen Portrait' has been prepared that includes the current field description from 2012 and where possible examines the evidence for change over time, relative to previous data, using DCA analysis. In addition, all sites were compared across the whole dataset to:

- Check newly established sites fall within the variety of existing sites surveyed in 2012;
- Compare the quality of fields under HK6 and HK7 options;
- Compare sites that are designated as SSSI with those that are not.

3.3 The Pen Portraits are presented in Annex 1 and include the field description from the recent survey as well as individual discussion of results depending upon the data available and looking at current condition and changes over time. They also include tabular data on soils and data from descriptive indices including Ellenberg values (Hill 1999) and suited-species scores (Grime *et al*. 2007) for grazing and nutrients.

Characterising the Dataset

3.4 The final database of 1m x 1m quadrat records comprised 103 sites, each of which was surveyed at least once between 1987 and 2012. The table below shows the baseline year for each site.

Table 3 Baseline Years for Each Site Analysed

Baseline Year	PSU Site Codes 2012
1987	603, 604, 611, 612, 613, 614, 615, 616, 619, 626, 628, 631, 710, 711, 712, 715, 716, 717, 718, 720, 721, 722, 723, 724, 726, 727, 728, 730, 731, 732, 733, 734, 735, 742, 745, 746, 747, 750, 751, 752, 753, 754, 757, 758, 759, 760, 761, 762, 763, 773
1988	623,744
1992	605, 606, 609, 610, 621, 622, 625, 629, 630, 701, 704, 705, 706, 707, 725, 749, 755, 756, 764, 765, 766, 767
2012	602, 607, 608, 617, 618, 620, 624, 627, 632, 702, 703, 708, 709, 713, 714, 736, 737, 738, 739, 740, 741, 743, 748, 768, 769, 770, 771, 772, 774

3.5 It should be noted that parametric statistics can be used for all variables as the results of one-sample Kolmogorov-Smirnov testing indicate all variables conform to the normal distribution.

Species Richness

3.6 Taking account of all data for 2012, there was no significant difference ($F_{1,103}$ = 2.48; P = 0.118) between the mean species richness of HK7 (19.9 ±5.4) compared to HK6 (21.6 ±3.4). The data do indicate a weak signal of grasslands under restoration management (HK7) being less diverse compared with those being managed to maintain species-rich grassland (HK6); see Figure 3.

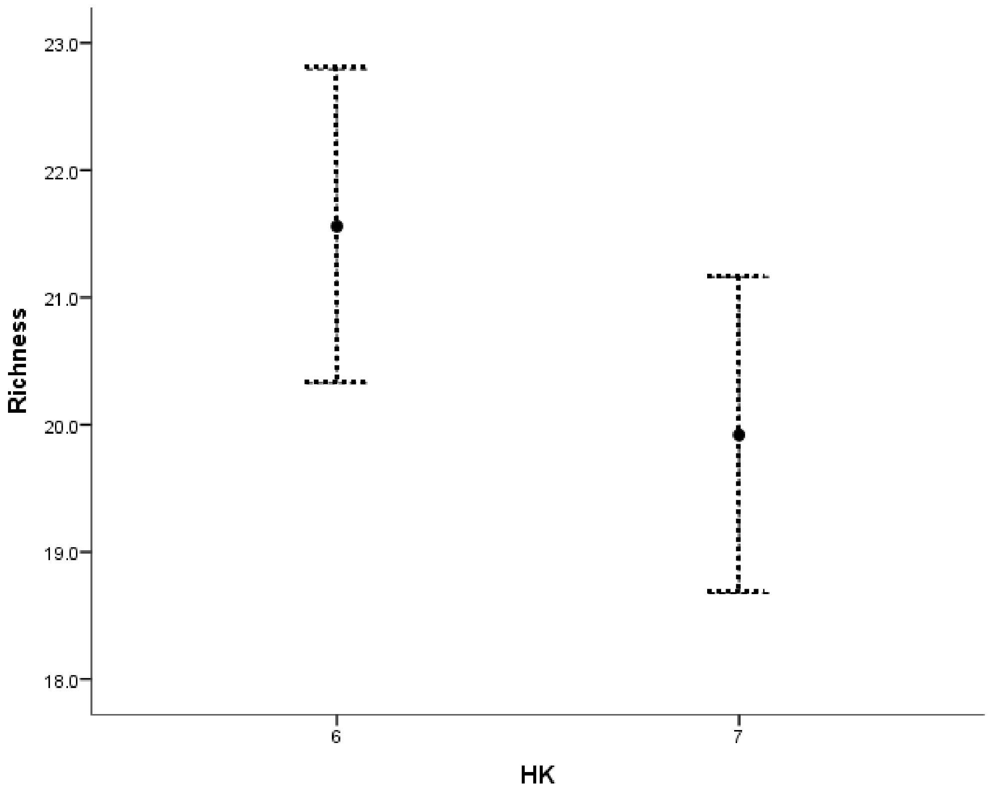

Figure 3 Mean and 95% Confidence Intervals for Species Richness for All Sites Surveyed in 2012

3.7 When data for the baseline year only were considered, there was a significant difference in species richness between HK6 and HK7 sites. Those sites that were subsequently entered into HK6 supported a greater species richness than those later entered into HK7 ($F_{1,103}$ = 7.54; P < 0.05), with an average baseline diversity of 21.9 (±3.3) for HK6 as compared with 20.0 ((±3.2) for HK7 sites. Overall, this suggests a pattern that is consistent from the baseline year to 2012; HK6 sites started out with greater species richness (as would be expected) than HK7, with a trend for HK6 to remain higher in 2012, but the difference is small.

3.8 There was a significant difference in total species richness between sites notified as SSSI and all others ($F_{1,103}$ = 5.27; P <0.05). Sites notified as SSSI contained (Figure 4), a mean of 22.4 (±3.2) species compared to non-SSSI with a mean of 19.8 (±5.2). However, the non-SSSI sites appeared to encompass a greater variability in species numbers, with a higher standard deviation.

3.9 There was no significant difference in species richness with ESA agreement year ($F_{7,92}$ = *0.45;* *P* >0.05). Post hoc tests demonstrated that no significant differences exist both between and within each of the year groups.

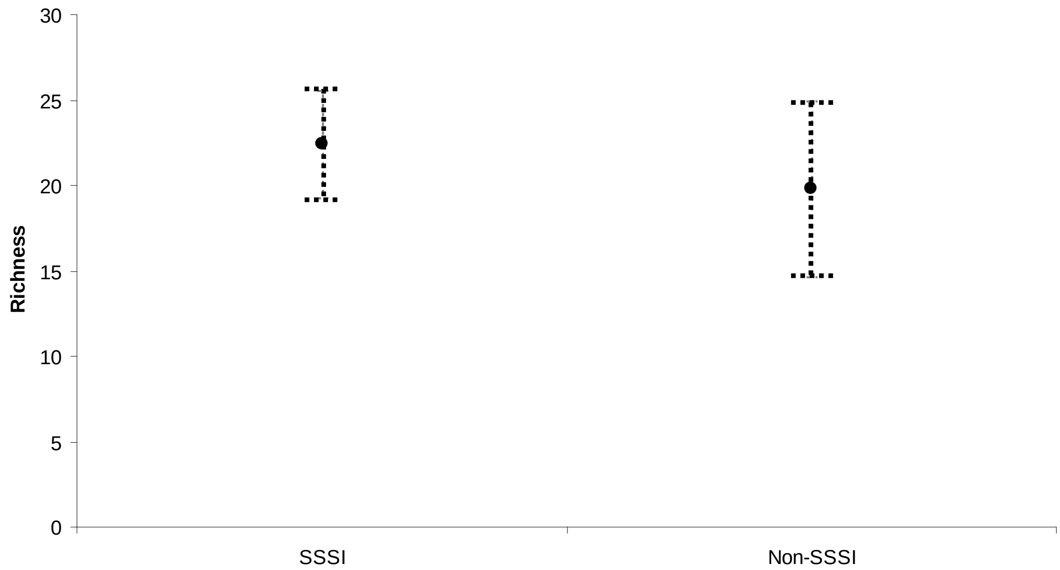

Figure 4 Mean and 95% Confidence Intervals for Species Richness for SSSI and non-SSSI Sites in 2012

3.10 On exclusion of new sites, those that had previously been in ESA Tier 1B exhibited greater species richness than those sites that had previously been in Tier 2A, with a mean species richness of 21.1 for 1B sites as compared to 19.3 for 2A, though this result was only significant at the 90% level ($F_{1,98}$ = 3.36; *P* = 0.07).

3.11 The subset of 29 new sites were typically more species-rich than those which had previously been part of the ESA monitoring programme (see Figure 5) though this result was only significant ($F_{2,102}$ = 2.60; *P* = 0.08) at the 90% level. Of these new sites, nine were also SSSI, and most would have also been subject to prior positive management, either through the ESA scheme, Countryside Stewardship or WES. We can infer that although approximately 30% of the new sites were SSSI the intrinsically high quality of these sites may have influenced the overall relative species richness of the new cohort of sites.

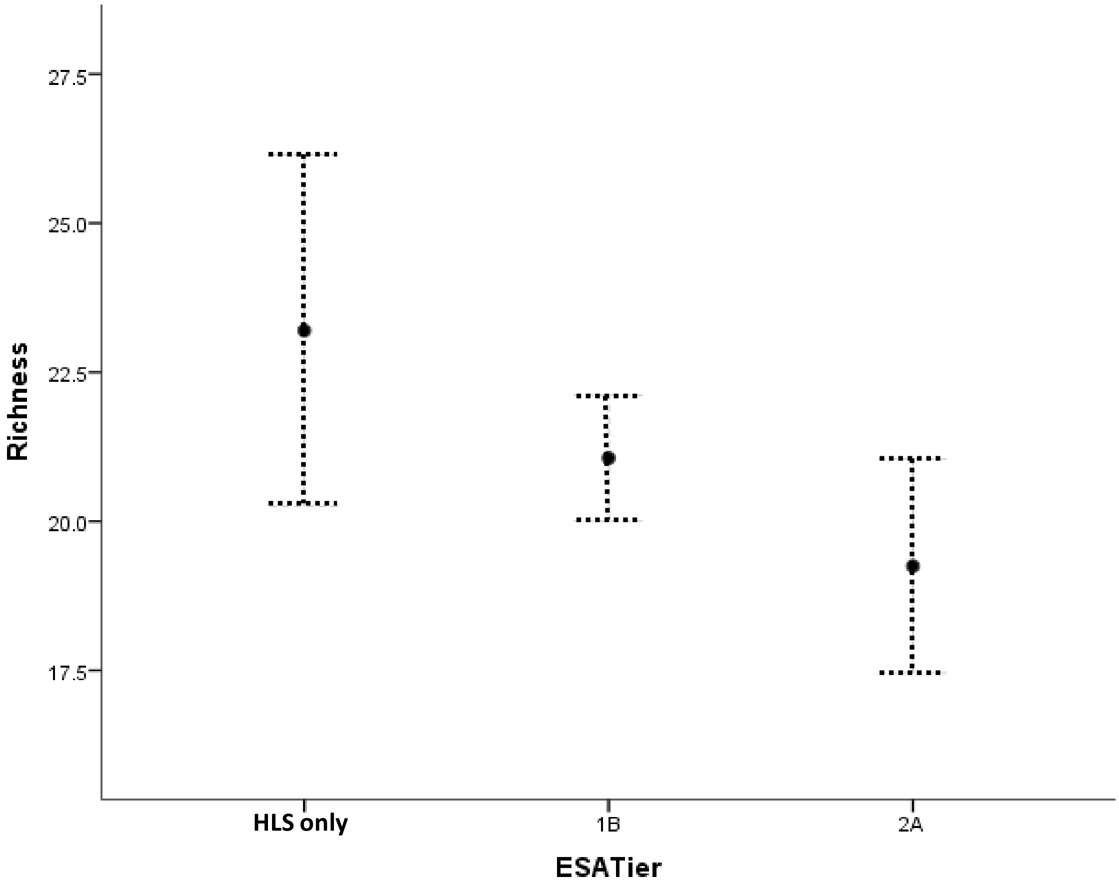

Figure 5 Mean and 95% Confidence Intervals for Species Richness for All Sites Surveyed in 2012 Grouped by ESA Tier (1B and 2A)

Herb Richness

3.12 One way ANOVA revealed no significant difference in herb species richness between sites categorised as HK6 and HK7 meadows ($F_{1,101}$ = 1.30; P = 0.26). The mean herb richness for HK6 meadows was 12.7 ±2.8 species compared to 12.0 ±3.2 species in the HK7 meadows.

3.13 Grouping herb species richness by ESA agreement year did not reveal any significant difference ($F_{8,94}$ = 1.0; P = 0.44) and post hoc tests demonstrated that no significant differences exist both between and within each of the year groups.

3.14 Excluding new sites, there was no significant difference in herb species richness between sites previously in ESA Tiers 1B and 2A ($F_{1,\ 96}$ = 0.60; P = 0.44). Tier 2A sites had a mean herb richness of 11.8 ±3.1 compared to 12.3 ±2.8 species for Tier 1B.

3.15 Considering SSSI and non-SSSIs, although only significant at the 90% level, ($F_{1,\ 101}$ = 3.29; P = 0.07), sites that were at least in part notified as SSSI had a higher herb richness (13.2 ±2.6 species) compared to non-SSSIs (11.9 ±3.2 species). It is also worth noting that non-SSSI sites exhibited a greater level of variability than SSSIs (see Figure 6).

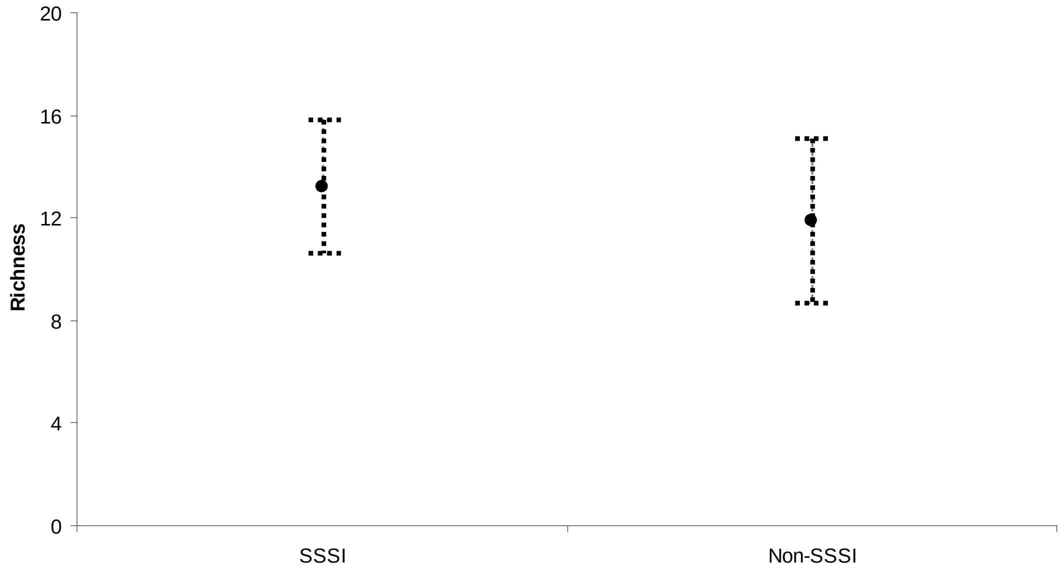

Figure 6 Mean and 95% Confidence Intervals for Herb Species Richness for All Sites Surveyed in 2012 Grouped by SSSI Designation

Grass Richness

3.16 One way ANOVA revealed no significant difference in grass species richness between sites categorised as HK6 and HK7 meadows ($F_{1,101}$ = 1.46; P = 0.23). The mean grass species richness of HK7 meadows was 7.9 ±1.2 species compared with 8.2 ±1.3 species for HK6 meadows.

3.17 Grouping grass species richness by ESA agreement year did not reveal any significant differences ($F_{8,94}$ = 1.54; P = 0.20) and post hoc tests demonstrated that no significant differences exist both between and within each of the year groups.

3.18 Excluding new sites, there was no significant difference in grass species richness between meadows formerly in ESA Tiers 1B and 2A ($F_{1, 96}$ = 0.78; P = 0.38), Sites formerly in 2A had a mean grass species richness of 7.9 ±1.1 compared with 8.2 ±1.4 species for Tier 1A sites.

3.19 Considering SSSI and non-SSSIs, there was no significant ($F_{1, 101}$ = 0.001; P = 0.96) difference in grass species richness for those sites that are at least in part notified as SSSIs as compared with non-SSSIs. The mean grass species richness was 8.1 species in each case.

Sedge and Rush Richness

3.20 One way ANOVA revealed a significant difference in sedge and rush richness between sites categorised as HK6 and HK7 meadows ($F_{1,101}$ = 6.82; P = 0.01). The sedge and rush diversity for HK6 sites, although very low in both, was significantly greater (0.94 ±1.2 species) compared with HK7 sites (0.45 ±0.7 species) (Figure 7). This fits with the expectation of greater species diversity in HK6 sites.

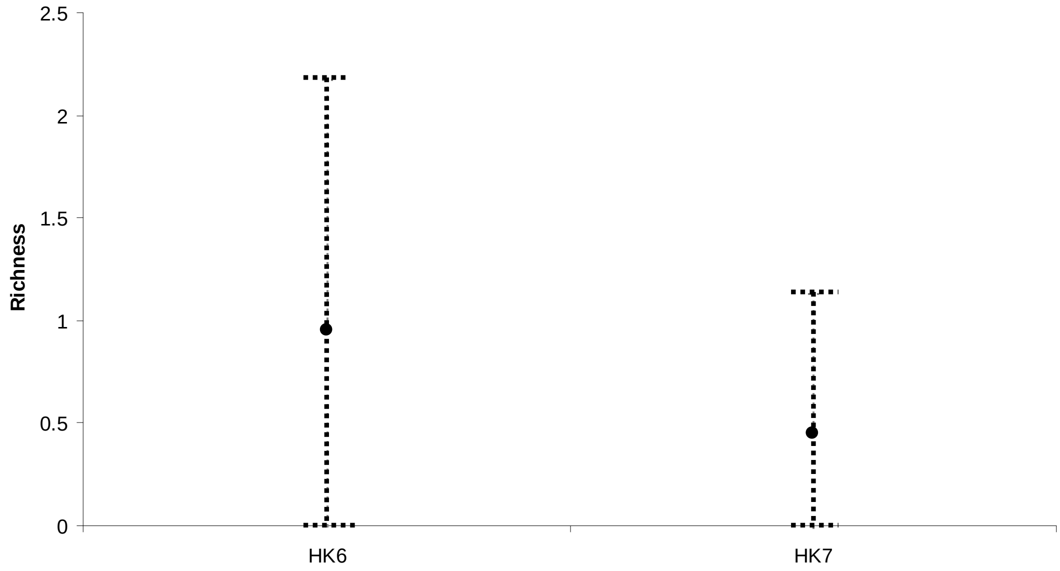

Figure 7 Mean and 95% Confidence Intervals for Sedge and Rush Species Richness for All Sites Surveyed in 2012 Grouped by HK6 and HK7

3.21 Grouping by ESA agreement year revealed no significant differences ($F_{8,94}$ = 0.86; P = 0.56*)* in sedge and rush richness across all sites.

3.22 Excluding new sites, there was no significant difference in sedge and rush species richness between sites that had been in ESA Tiers 1B and 2A ($F_{1,\ 96}$ = 0.36*;* P = 0.55*.* Tier 1B sites had a mean diversity of 0.58 ±0.9 species compared with 0.70 ±0.9 for Tier 2A sites.

3.23 Considering SSSI and non-SSSIs, there was a highly significant ($F_{1,\ 101}$ = 0.001; P = 0.96*)* difference in species richness for those sites that were at least in part notified as SSSIs compared with non-SSSIs. Those sites notified as SSSI had a significantly higher sedge and rush species richness of 1.1 ±1.2 compared with 0.5 ±0.8 for non-SSSI sites (Figure 8). This finding fits with the expectation of greater diversity at SSSI sites.

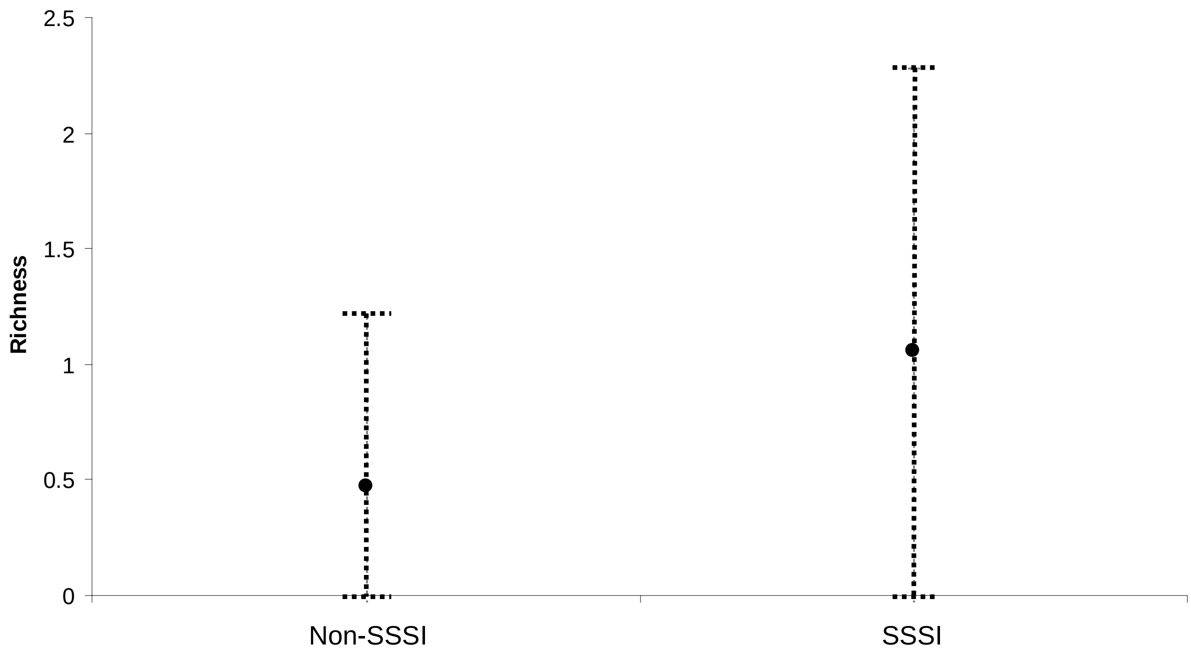

Figure 8 Mean and 95% Confidence Intervals for Sedge and Rush Species Richness for All Sites Surveyed in 2012 Grouped by SSSI Designation

Change in Species Richness

3.24 There was no significant change in species richness between the baseline year and 2012 (excluding new sites). $F_{1,73} = 0.02$; $P = 0.88$). Similarly, there was no significant difference in the change in species richness between the nominated baseline year (Table 1) and 2012 between meadows in HK6 and HK7 ($F_{1,73} = 0.02$; $P = 0.50$). Whilst not significant, the general trend observed (that sites now in HK6 may have declined in species richness by, on average 0.6 species, whereas sites now in HK7 may have shown a slight increase of 0.5 species; see Figure 9) corresponds with the previous findings of Critchley *et al*. (2004) who reported an overall decline in herb species richness in unimproved hay meadow vegetation.

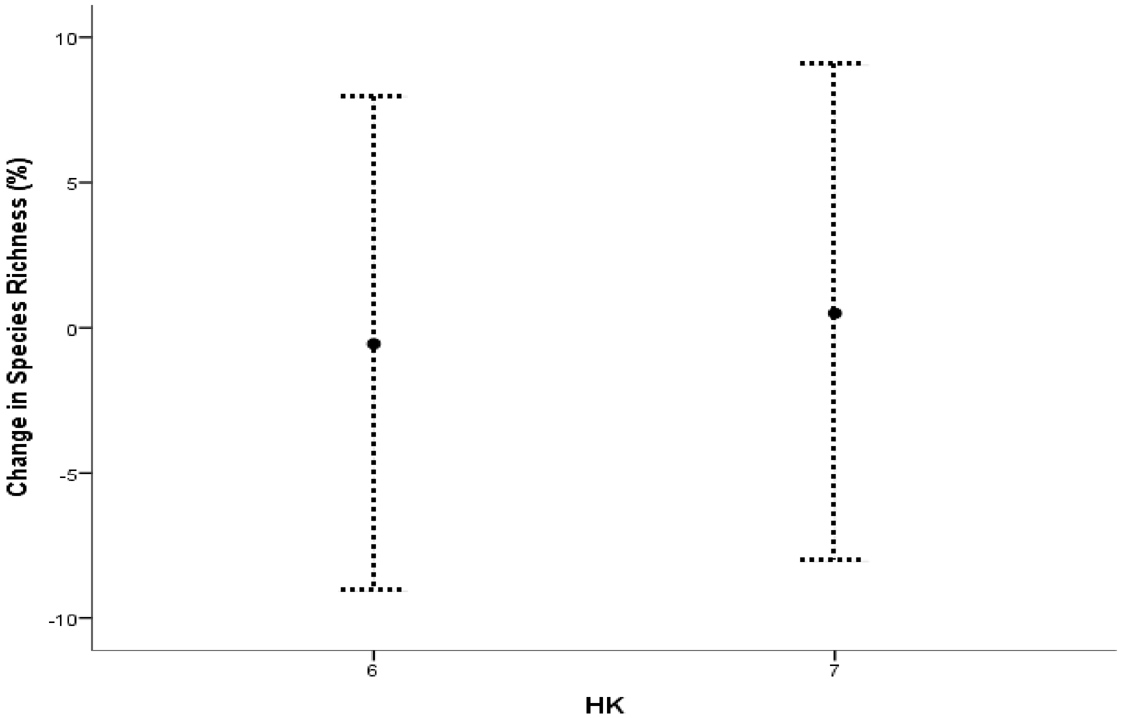

Figure 9 Change in Species Richness between the Nominated Baseline Year (Table 1) and 2012 Subdivided by Site-Type (HK 6 and HK 7)

3.25 Similarly, there was no significant difference in change in species richness between ESA Tiers ($F_{1,73}$ = 0.46; P > 0.5); the trend observed was for sites previously in Tier 1B to have increased in species richness by an average of 2.5 species, whereas those previously in Tier 2A decreased by an average of 1.9 species. It seems that, in the 2012 dataset, declines in the higher quality Tier 2 sites may have increased in comparison to the lower grade Tier 1 sites where declines in species richness are slightly slower (perhaps because the most sensitive species are already gone), although these changes were not statistically significant.

3.26 Finally, there was no significant difference in change in species richness for sites separated by ESA agreement year ($F_{5,69}$ = 0.66; P = 0.65). This finding suggests that, statistically, sites that went into ESA earlier were no less likely to see declines in species richness than those that did not.

Grazing Suited Species Scores

3.27 The average Grazing Suited Species Scores for each site provide a measure of the dominance (or otherwise) of species classified as tolerant of high levels of grazing. In terms of the HLS category, there was no significant difference in Grazing Suited Species Score between the HK6 and HK7 sites ($F_{1,103}$ = 0.87; P = 0.36), with both groups showing broadly similar scores.

3.28 Similarly, a comparison taking into account former ESA Tiers showed no significant difference between sites that were previously in ESA Tier 1B or ESA Tier 2A (*F*1,73 = 1.58; P = 0.21), neither were there significant differences in average Grazing Suited Species Scores with ESA agreement year ($F_{7,92}$ = 1.26; P = 0.28).

Nutrient Suited Species Scores

3.29 The average Nutrient Availability Suited Species Scores for each site provide a measure of the dominance (or otherwise) of species deemed to be tolerant of high levels of nutrient availability. There was a significant difference between HK6 and HK7 sites in Nutrient Availability Suited Species Score ($F_{1,103} = 11.88$; $P < 0.01$), with HK6 sites demonstrating a higher proportion of stress tolerant species (those indicative of low nutrient levels) than HK7 sites (see Figure 10).

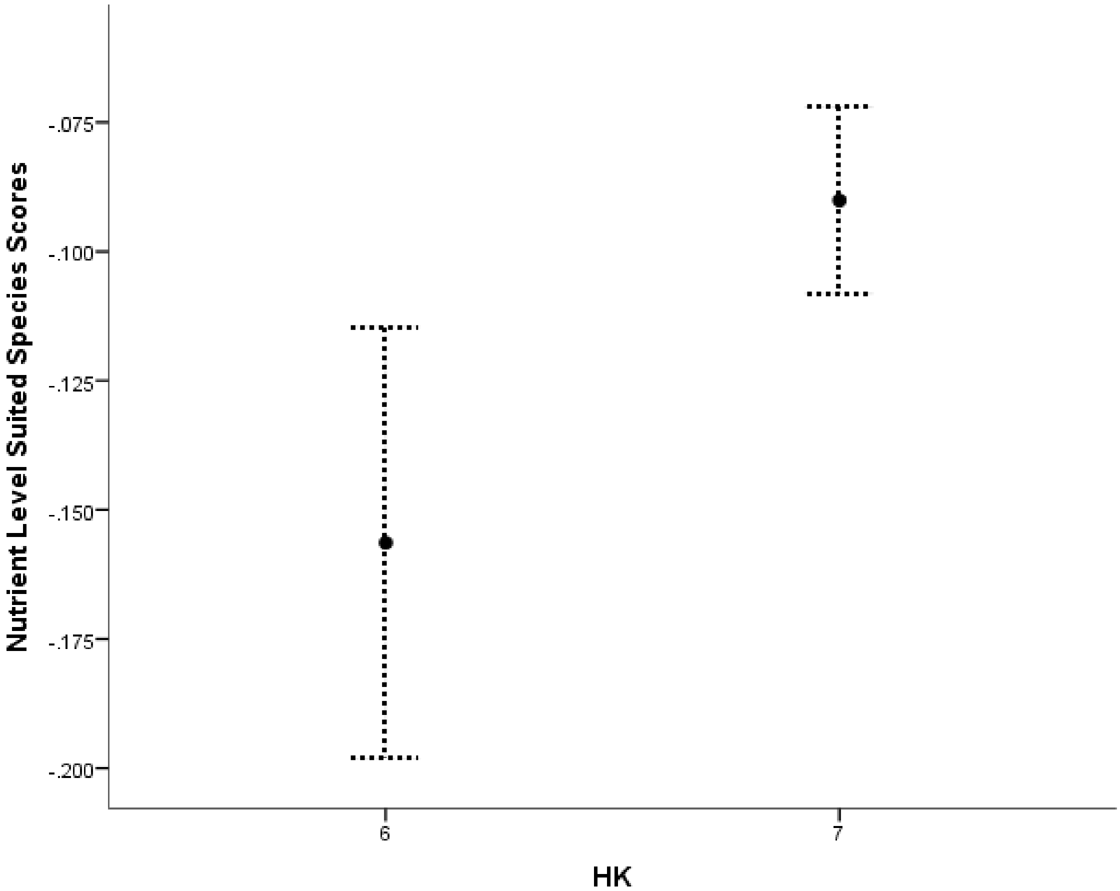

Figure 10 Mean and 95% Confidence Intervals for Average Nutrient Availability Suited Species Score for All Sites Surveyed in 2012 Grouped by HLS Category

3.30 Similarly, although only significant at the 90% confidence level, there was a higher proportion of stress-tolerant species present within former ESA Tier 2A sites compared to Tier 1B ($F_{1,98} = 3.21$; $P = 0.08$)(Figure 11).

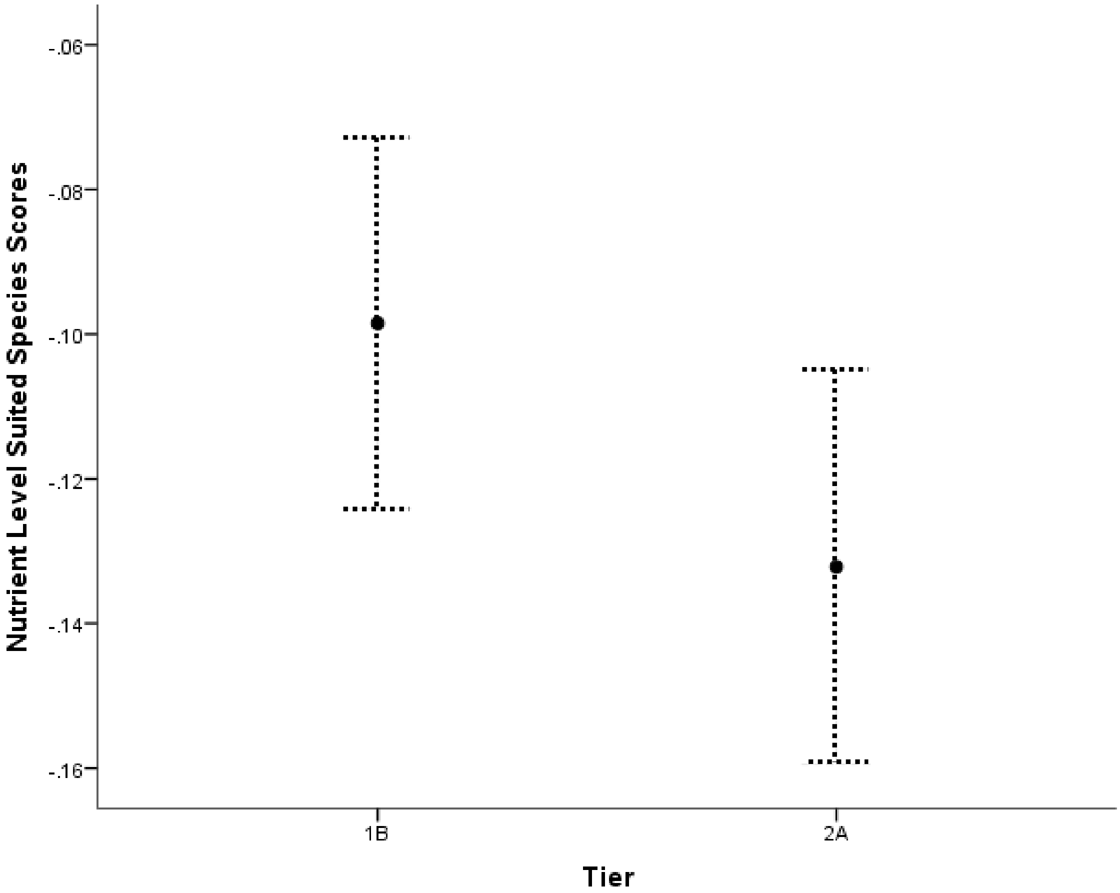

Figure 11 Mean and 95% Confidence Intervals for Average Nutrient Availability Suited Species Score for All Sites Surveyed in 2012 Grouped by ESA Tier

3.31 Finally, there was no significant difference in average Nutrient Availability Suited Species Score with ESA agreement year ($F_{7,92}$ = 0.78; P = 0.60), with all groups showing broadly similar values.

Comparing New Sites with All Others

3.32 In terms of species richness, the subset of new sites surveyed in 2012 were not significantly more species-rich than the existing sites ($F_{1,103}$ = 2.46; P = 0.80). However, the trend was for average richness to be greater (21.6 ±3.5) for the new sites compared to the pre-existing study sites (19.9 ±5.3). The latter were more variable ranging from 18.7 to 21.2 species, compared with a range of 20.3 to 23.0 species for the newly surveyed sites (see Figure 12). This may reflect the fact that a higher proportion of new sites were in SSSI before coming into HLS.

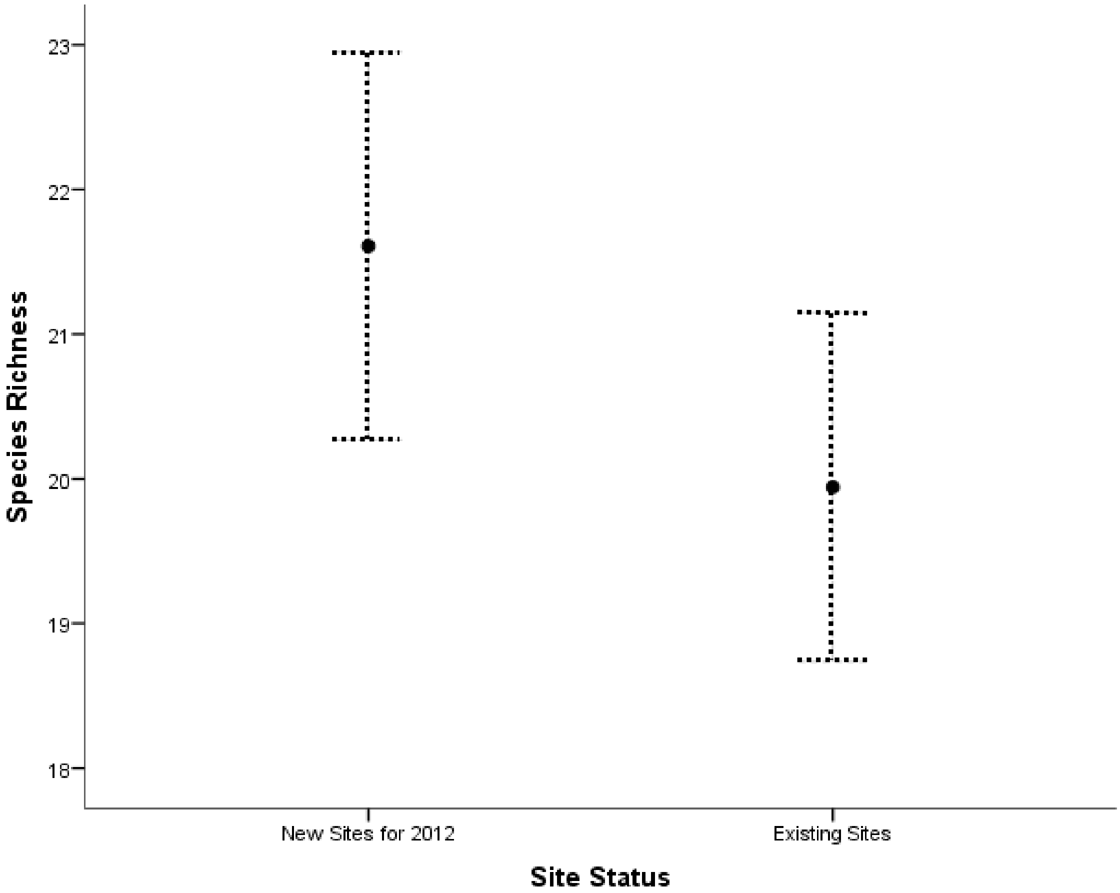

Figure 12 Mean and 95% Confidence Limits in Species Richness for Newly Surveyed Sites in 2012 and All Other Sites

3.33 Considering the average Grazing Suited Species Scores, no significant difference was observed between the new sites and all others ($F_{1,103}$ = 0.78; P = 0.12), with both groups showing broadly similar values (Figure 13).

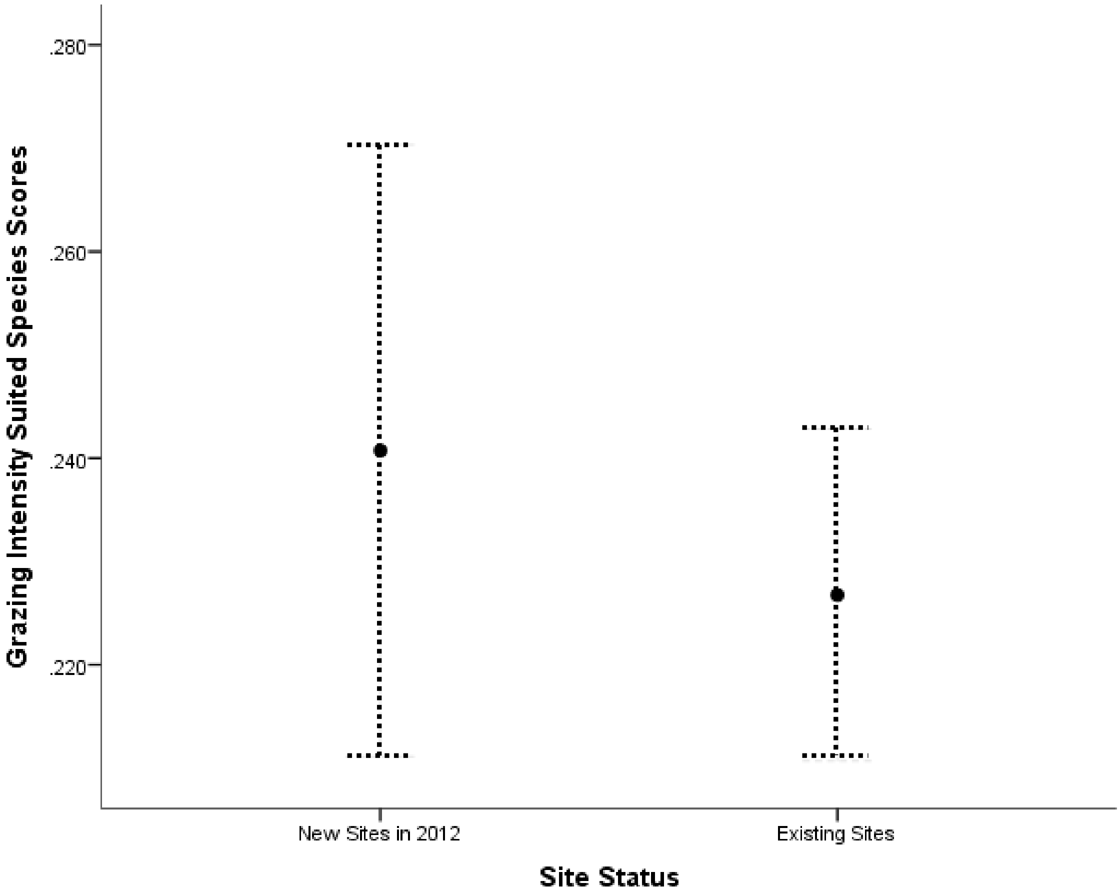

Figure 13 Mean and 95% Confidence Limits in Average Grazing Suited Species Scores for Newly Surveyed Sites in 2012 and All Other Sites

3.34 There was no significant difference in average Nutrient Availability Suited Species Scores for new sites compared with existing sites ($F_{1,103} = 2.09$; $P = 0.15$). Nonetheless, the pre-existing sites had a greater proportion of stress tolerant species compared with the new sites (Figure 14).

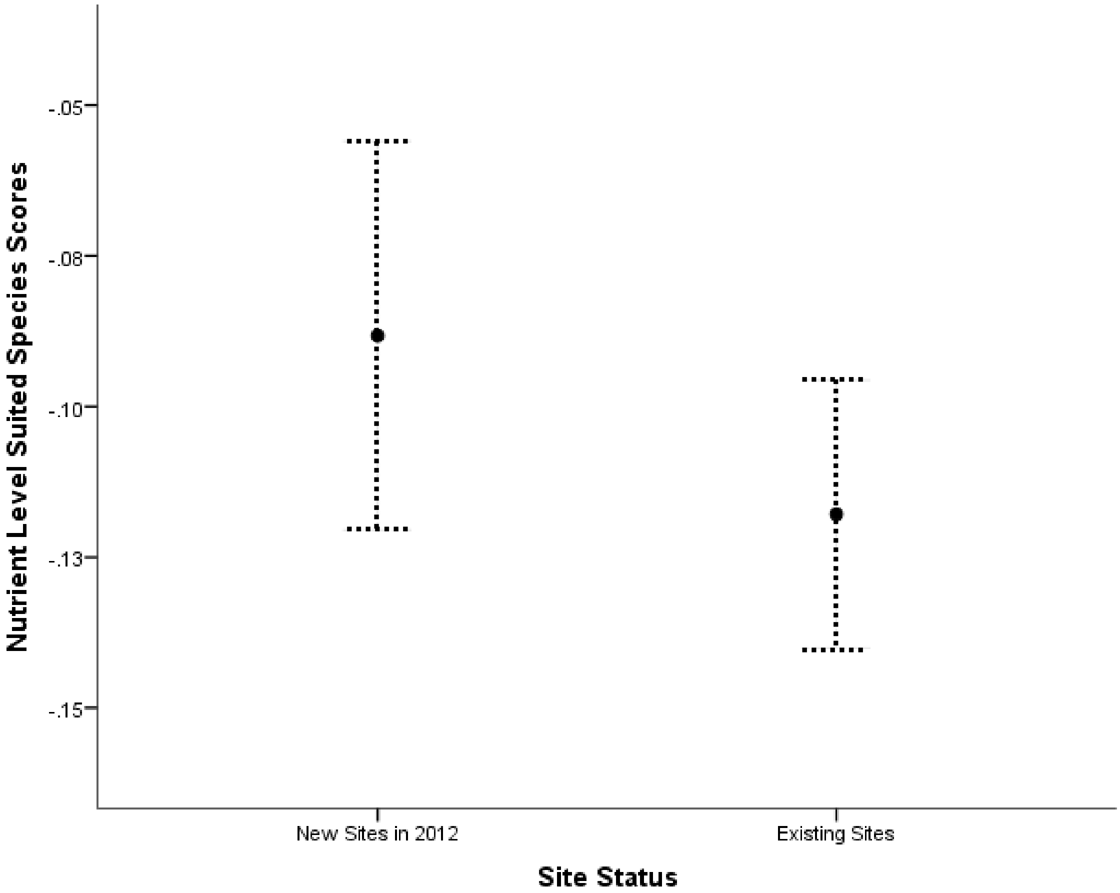

Figure 14 Mean and 95% Confidence Limits in Average Nutrient Availability Suited Species Scores for Newly Surveyed Sites in 2012 and All Other Sites

3.35 Considering grass species richness, the subset of new sites surveyed in 2012 was not significantly more species-rich than the existing sites ($F_{1,103}$ = 1.53; P = 0.322). New sites showed an average richness of 11.8 ±2.8 whilst pre-existing survey sites showed an average richness of 12.0 ±3.3.

3.36 Herb species richness was not significantly different between new sites surveyed in 2012 and existing sites ($F_{1,103}$ = 0.72; P = 0.40), with an average of around eight species in both cases.

3.37 Finally, new sites for 2012 were not significantly different in terms of sedge and rush species richness compared with existing survey sites ($F_{1,103}$ = 0.36; P = 0.55).

DCA Analyses

3.38 DCA plots were compiled for all sites and presented as part of the Pen Portraits, and the trends presented in the data discussed on a site by site basis. All plots are included in Annex 2.

Soil Properties

3.39 Soil samples were collected from all UHM sites surveyed in 2012 (*N*=103). There was little variation in soil texture, with most samples (92 of 103) being categorised as sandy loam (Figure 15). A further ten sites were classed as loamy sand and one as sandy silt loam. This result corresponds closely with that reported by Critchley (2004), where 150 of the 164 sites analysed comprised sandy loam.

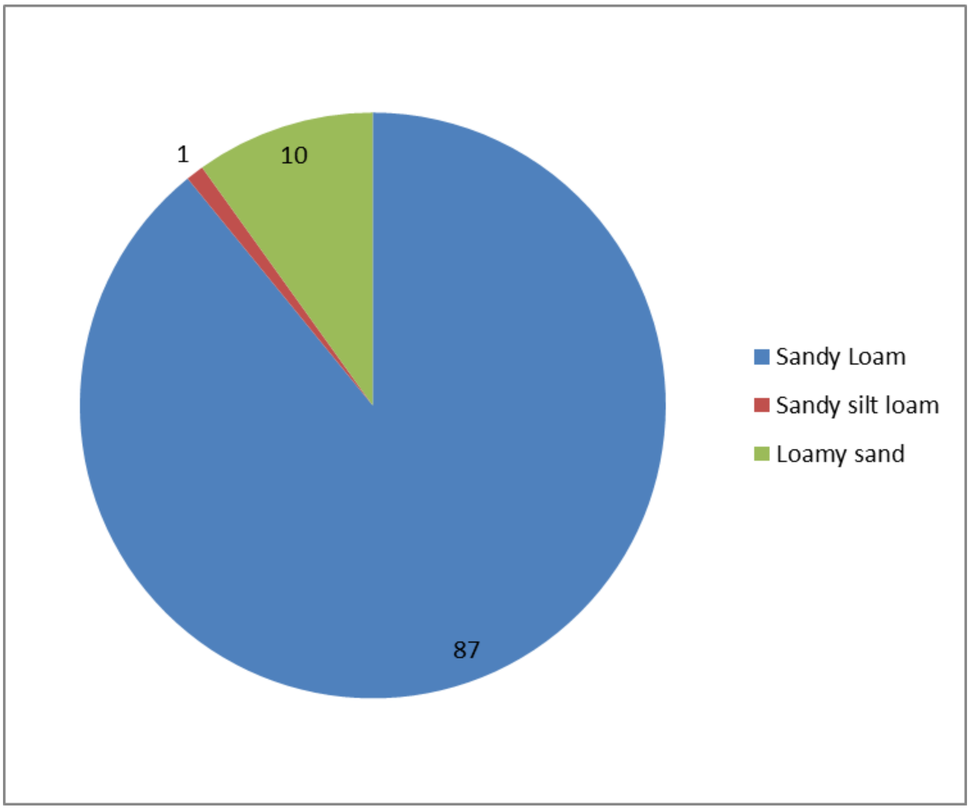

Figure 15 Percent of Upland Hay Meadow Sites (N=103) in Each Soil Type Category

3.40 Figure 16 shows the distribution of average pH values across the sample – it can be seen that across the whole sample, pH is normally distributed, with both HK7 and HK6 subsets also broadly following this pattern. Soil pH ranged from 4.9 to 6.7, with a mean of 5.6 (Table 4). Again, this is in line with previous analyses which reported a mean pH of 5.7. There was no statistically significant difference in pH (using a two-sample t-test assuming unequal variance) between sites under HK6 and HK7 ($P > 0.05$), with a mean value of 5.6 in each case.

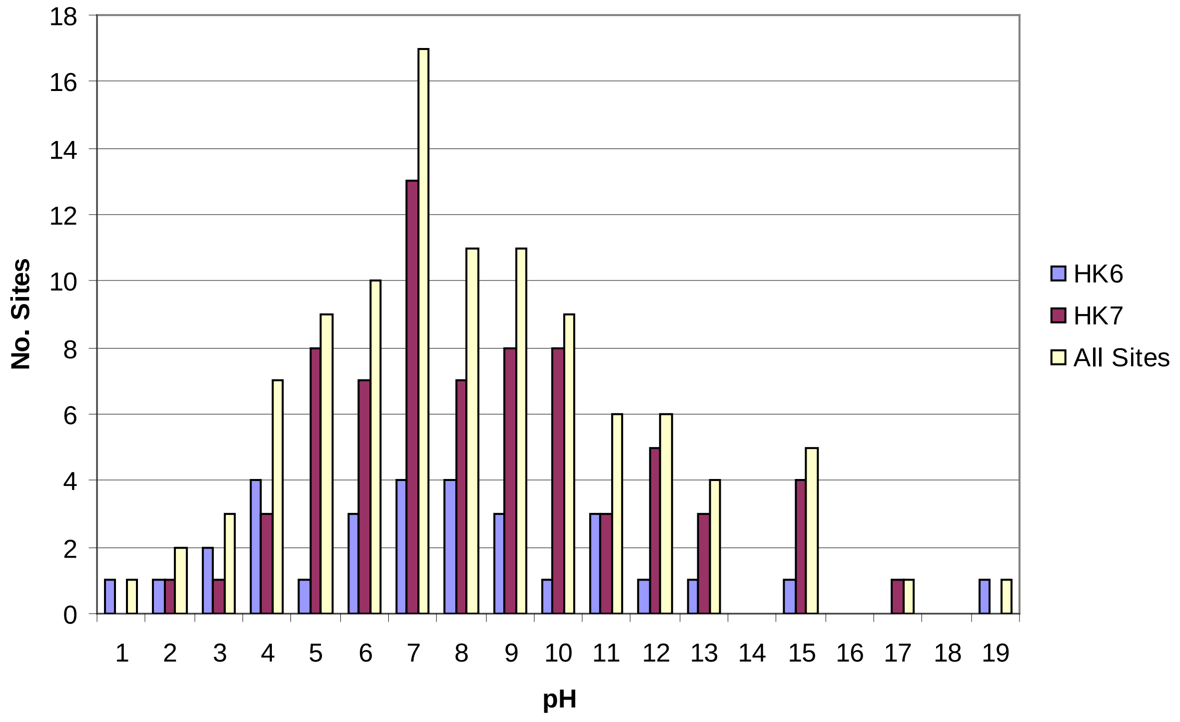

Figure 16 Number of Sites in Average Soil pH Categories Across All Sites (N=103), HK6 (N=31) and HK7 (N=72)

Table 4 Summary of Soil Properties

Sample		**Soil pH (Water)**	**Olsens P (mg/l)**	**Total N (%)**	**Soil K (mg/l)**
Total n = 103	Mean	5.62	12.83	0.67	153.42
	Stdev	0.34	4.1	0.17	43.8
	Max	6.7	27	1.24	352
	Min	4.9	6	0.38	81
HK6 n = 31	Mean	5.56	11.71	0.65	157.55
	Stdev	0.35	3.44	0.14	27.35
	Max	6.3	19	0.96	239
	Min	4.9	7	0.47	110
HK7 n = 72	Mean	5.58	13.32	0.67	151.64
	Stdev	0.64	4.33	0.19	49.57
	Max	6.5	27	1.24	352
	Min	0.9	6	0.38	81

3.41 Natural England's TIN045 (Walsh *et al*. 2011) refers to neutral grassland as having pH in the range 4.9 to 6.5, but without specific reference to MG3 stands. Jefferson (2005) describes the typical range of soil pH within MG3 upland hay meadows as lying between 5.1 and 6.6, with the traditional practice of liming helping to offset loss of calcium and other plant nutrients through leaching and removal in the hay crop. Although 96% of the sites from the 2012 dataset were within Jefferson's expected pH range for MG3, 3% exhibited pH values below this, which might be explained by a reduction in liming practice seen at all sites since commencement of the ESA, and indeed no lime had been applied at sites 621, 622 and 725. The pH of 1 of the sites (1% of sample) was just above this range (at 6.7) which may either be due to greater local influence of limestone geology on the soils, or to recent liming practice – unfortunately no management questionnaire was completed for this site (602).

3.42 The distribution of Olsen's extractable phosphorous (P) is presented in Figure 17, showing the numbers of sites in value categories. The majority of sites have 'low' P levels (79/103) corresponding to a P status of <16 mg/l, which is fairly low. By contrast, 22 sites were found to have 'moderate' P levels (16-25mg/l) and the remaining two sites (703 and 705) returned 'high' P levels (26-45mg/l). There was a statistically significant difference in extractable P between sites under HK6 and HK7 management, with the HK6 sites having, on average, lower extractable P compared to HK7. It should, however, be noted that the mean value for each corresponds to a 'low' status only.

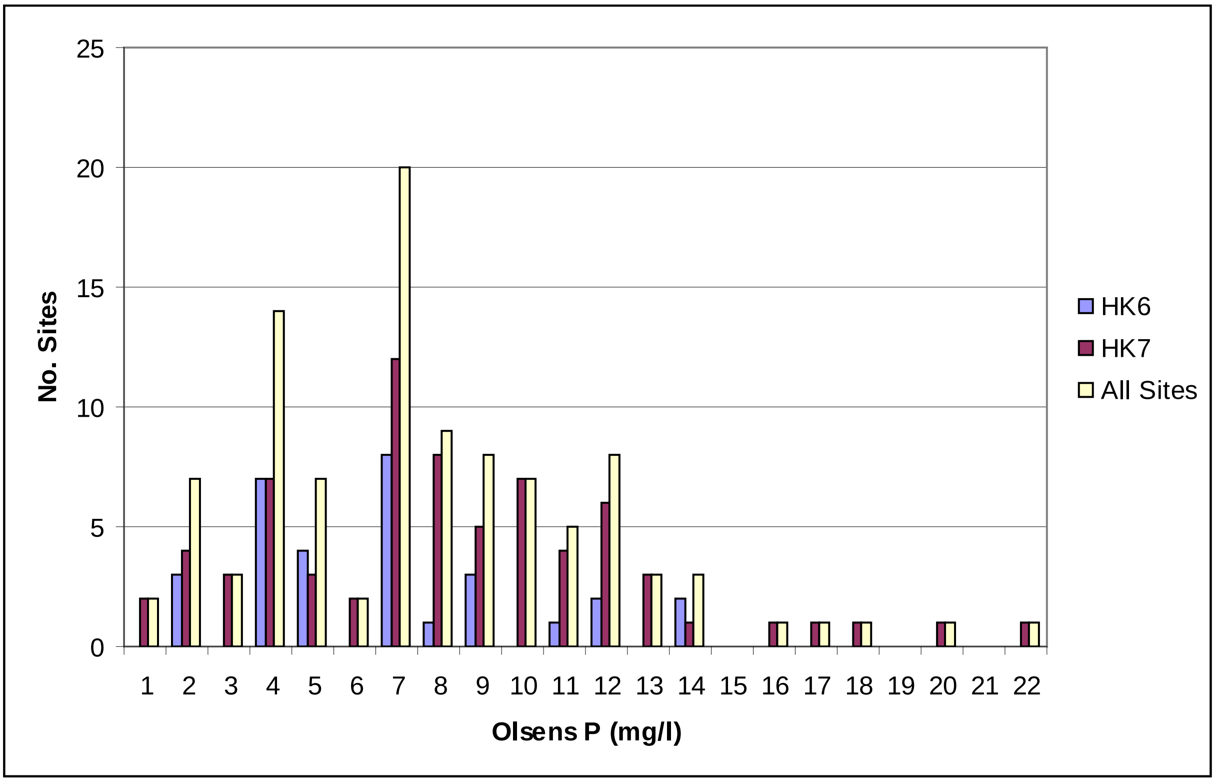

Figure 17 Number of Sites in Each Value Category for Olsen's Extractable Phosphorous (P) in mg/l

3.43 The distribution of sites by soil potassium (K) categories is presented in Figure 18. The majority of sites had 'moderate' levels of soil potassium (K) (79/103), corresponding to 121-240mg/l. By contrast, 21 sites had 'low' K levels (61-120mg/l) and the remaining three sites (732, 733 and 745) returned 'high' K levels (241-400mg/l). There was no statistically significant difference in K levels between sites under HK6 and HK7. HK6 sites did, however, on average have slightly lower values than HK7. In each case, the average values equated to moderate levels.

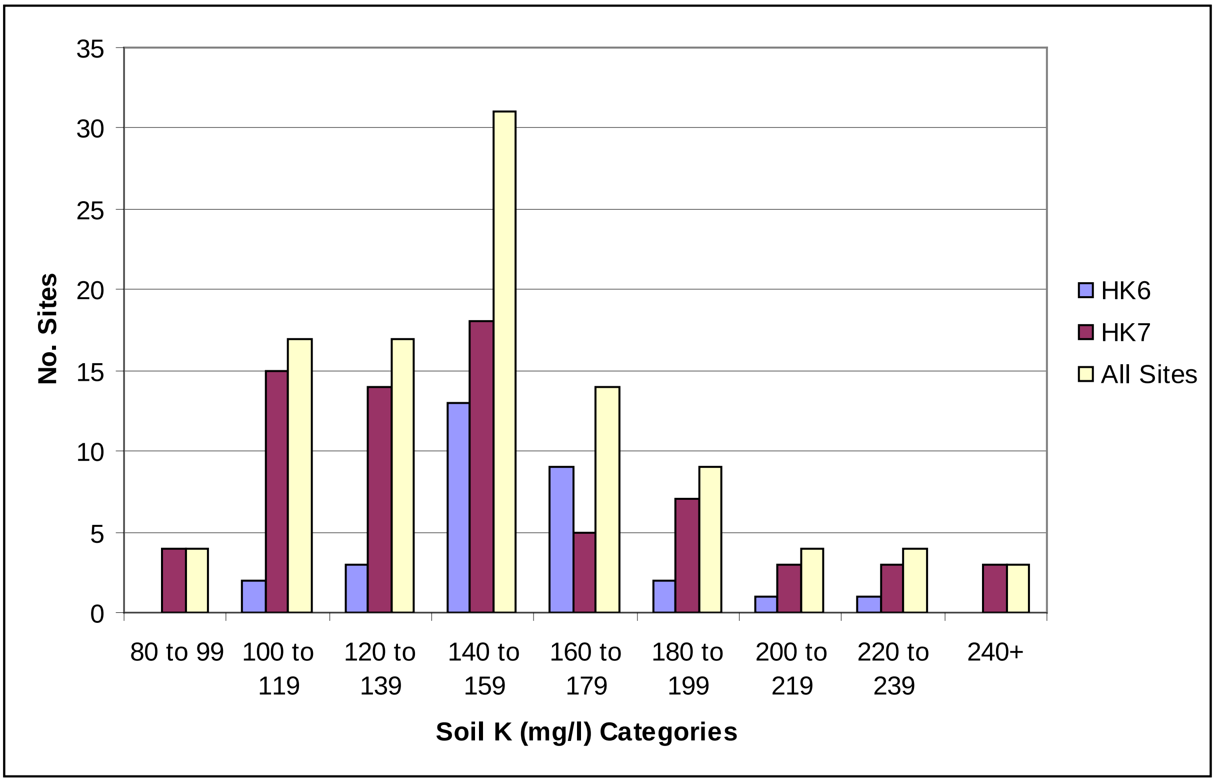

Figure 18 Number of Sites in Each Value Category for Soil Potassium (K) in mg/l

3.44 Jefferson (2005) cites typical average levels of soil-extractable P and K of 8 and 128 mg/l respectively for MG3 upland hay meadow communities. In Natural England's FEP Manual (2012), key 2c, soil P and K levels are used (together with other factors) to determine the suitability of sites for restoration to upland hay meadow. The manual defines available P levels as: high (>25 mg/l); medium (16-25 mg/l); and low (<16 mg/l). Sites with highest potential for restoration would be expected to have low levels of available P. Sites with moderate to high soil P may still be suitable for restoration where other constraints apply, and where P is high, K must be very low (<61 mg/l). In upland hay meadows, P and K are usually limiting nutrients because traditional management has typically included the annual addition of farmyard manure (providing N).

3.45 The distribution of total nitrogen (N) values for the sample sites is presented in Figure 19. The majority of sites (87/103) had total nitrogen (N) values 0.5% to 1% ('medium' status), with five sites (716, 760, 761, 762 and 763) returning values greater than 1% ('high'). Of note is that sites where total N is 'high' (i.e. >1%) and P is 'very low' maybe considered to be well suited to the restoration of species-rich grasslands (i.e. for inclusion in HK7). Overall, there was no significant difference in total N between sites managed under HK6 and HK7, with average total N values of 0.7% in each case.

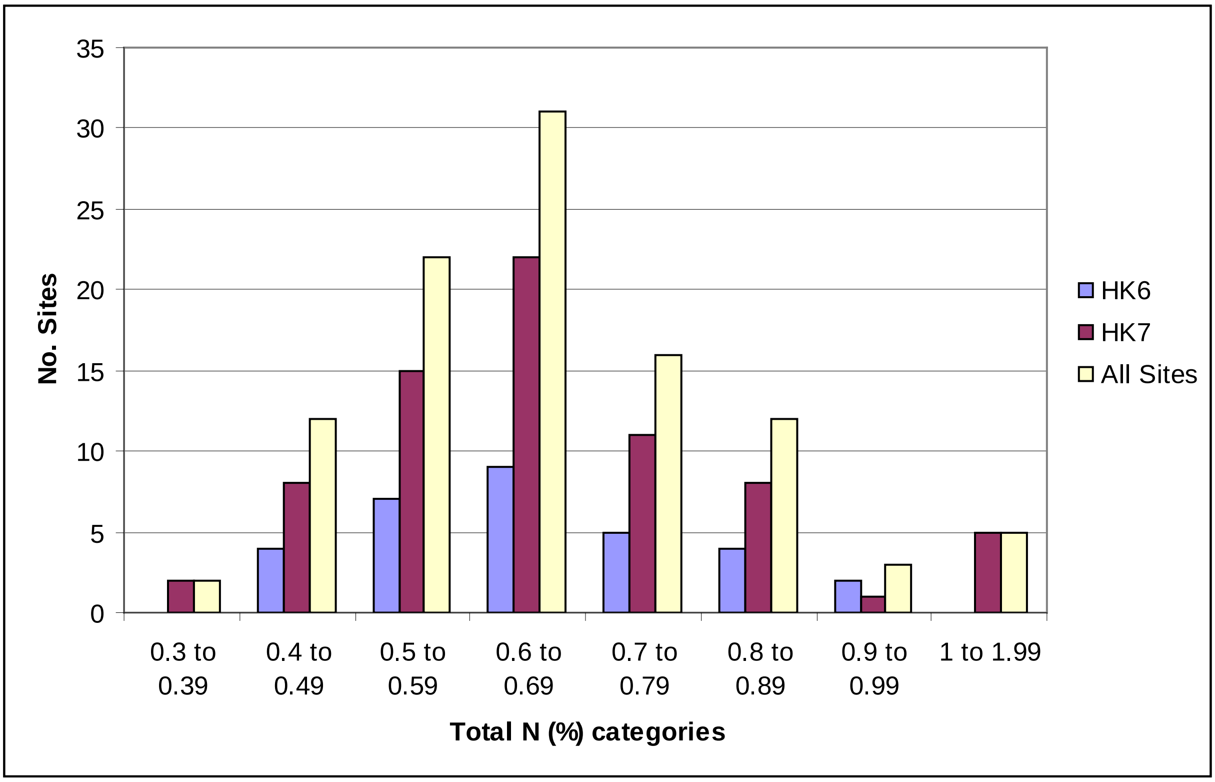

Figure 19 Number of Sites in Each Value Category for Total Nitrogen (N) in %

National Vegetation Classification

3.46 Table 5 lists the full range of NVC communities identified for the 103 sites, using the classifications set out in Rodwell (1992) and modified by O'Reilly (2011). The total of eleven communities encountered includes examples of typical upland hay meadow vegetation, e.g. MG3b, and higher diversity MG8 swards, but also has representation of grassland communities more usually associated with semi-improved sites, e.g. MG6, MG7 and MG10. The O'Reilly (2011) classification resulted from analysis of data from upland hay meadows in the North Pennines and produced a refined NVC classification with further differentiation between variants of MG6 and MG8 and these are shown in the table. Many sites showed close affinities with several communities, and the full range of these is also reflected in the table.

Table 5 NVC Communities Represented in the Sample

	Community (Rodwell 1992)	Sub-community (Rodwell 1992)	Variant (O'Reilly 2011)
MG3a	*Anthoxanthum odoratum-Geranium sylvaticum* grassland	*Bromus hordeaceus hordeaceus* sub-community	
MG3b		*Briza media* sub-community	
MG6bi	*Lolium perenne-Cynosurus cristatus* grassland	*Anthoxanthum odoratum* sub-community	*Rumex obtusifolium-Ranunculus repens* variant, lower diversity
MG6bii			*Festuca rubra-Veronica chamaedrys* variant, mid-range quality
MG6biii			*Trifolium pratense-Rhinanthus minor* variant, herb rich
MG7d	*Lolium perenne* leys and related grasslands	*Lolium perenne-Alopecurus pratensis* grassland	Most common MG7 meadow in the Pennine Dales
MG8-	*Cynosurus cristatus-Caltha palustris* grassland		Least species-rich variant
MG8o			Relatively species-poor variant
MG8+			Moderate quality variant
MG8n			Most species-rich variant
MG10a	*Holcus lanatus-Juncus effusus* rush-pasture	Typical sub-community	

3.47 Figure 20 shows the relative proportions (%) of sites falling into each NVC category, for all sites (N=103), HK6 (N=31) and HK7 (N=72). The pie charts are based on an overall NVC community selection made for the FEP key analysis, but most sites showed close affinities to several communities across the three quadrats sampled. The charts clearly show the predominance of the MG6biii sub-community in the sample (45%). In the HK6 sample, strong evidence is also shown of MG8 communities, MG8+ and MG8o. In addition, both MG3a and MG3b (the highest quality upland hay meadow community) are represented. In the HK7 samples, MG6bii is well-represented – considered to be mid-range in terms of herb richness (O'Reilly, 2011).

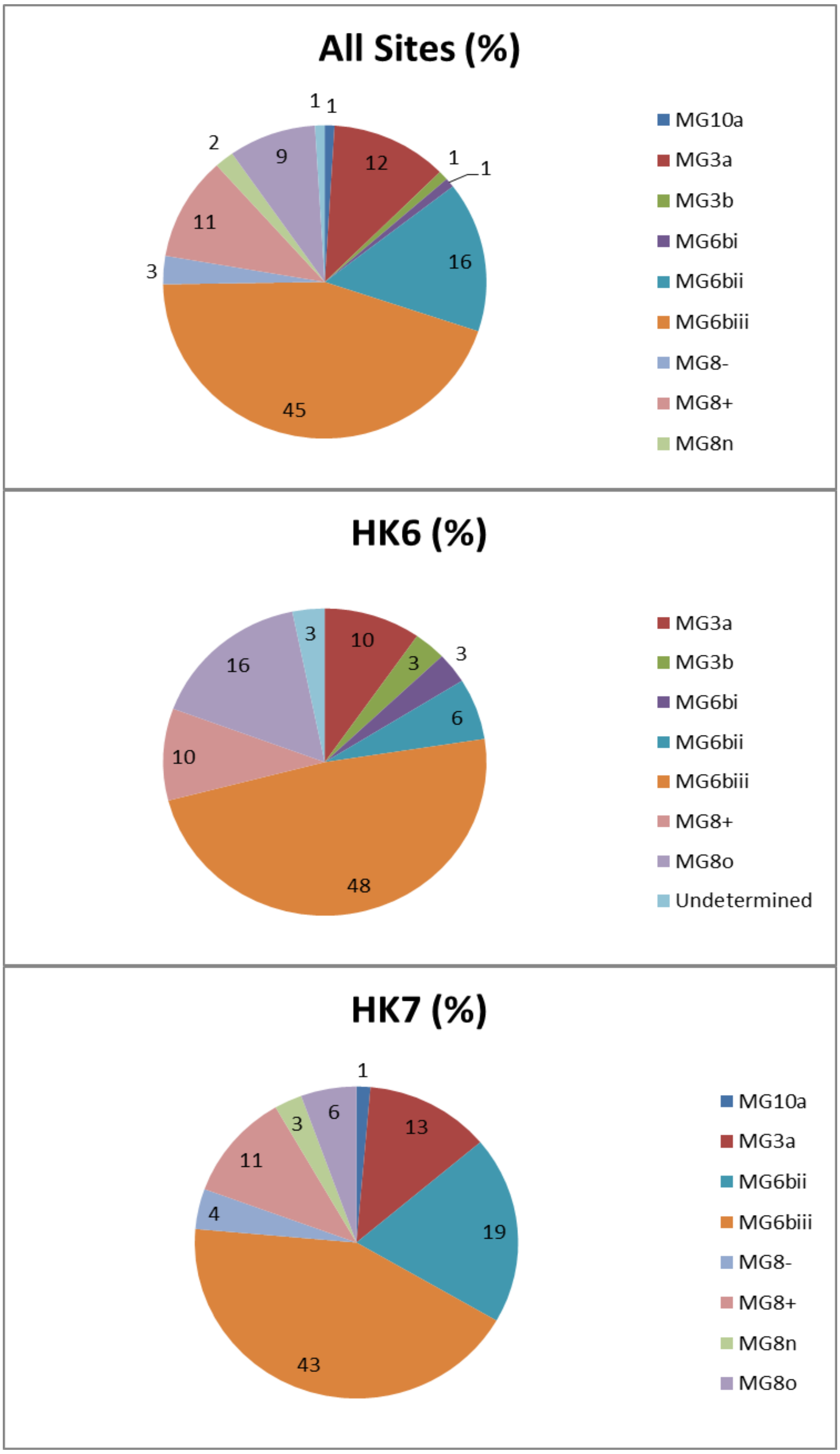

Figure 20 Proportions of Sites Falling into Each NVC Category

3.48 Looking at the sub-set of the sample which is SSSI (N=23), Figure 21 shows the percentage of sites falling into NVC categories. The most abundant communities are MG3a (22%), MG8+ (22%) and MG6biii (17%) - all good quality herb rich grasslands, but not the target community type MG3b, which was only represented by a single site.

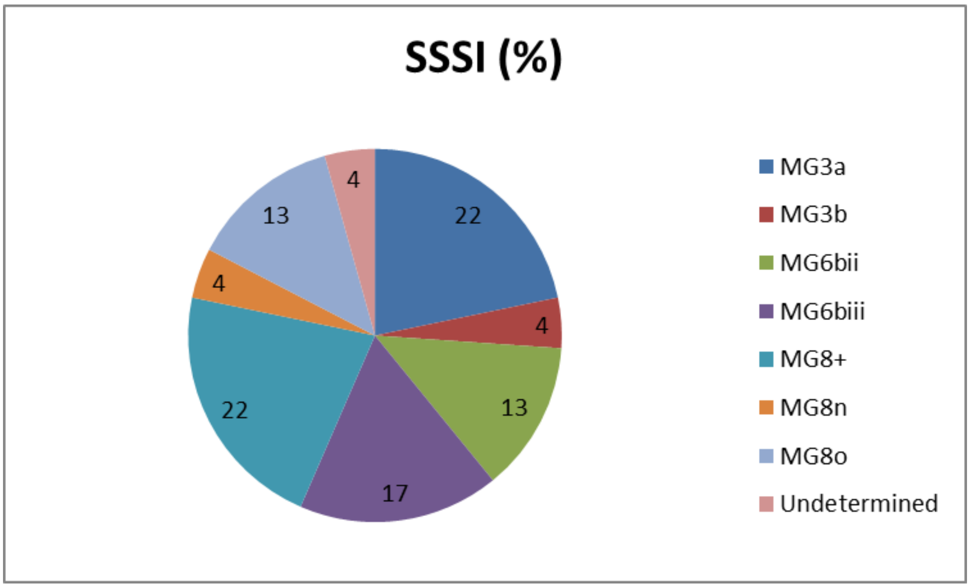

Figure 21 Percentage of Sites Falling into Each NVC Category, for SSSI (N=23)

3.49 Looking in more detail, Table 6 identifies the number of sites corresponding to each community, or group of communities. The first listed community was predominant, but because of the variability across some sites, several communities might be present and these could be defined because each quadrat was analysed individually[3].

3.50 Overall, the most frequent NVC community found within the sample was MG6biii which is O'Reilly's (2011) *Trifolium pratense-Rhinanthus minor* variant of the *Lolium perenne-Cynosurus cristatus* grassland, *Anthoxanthum odoratum* sub-community (Rodwell, 1992). This vegetation type was present at 17 of 31 HK6 sites and 32 of 72 HK7 sites, i.e. 47%. MG6biii is intermediate between MG6b and MG3 in its species composition. It is undoubtedly a semi-improved community, but at the higher end of the semi-improved grassland quality spectrum, with a high cover of herbs (particularly *Euphrasia* and *R. minor*) and including some true upland hay meadow indicators. This community is therefore of conservation significance and these fields are considered to be very well suited for restoration to MG3 upland hay meadow.

3.51 The MG6bii sub-community was found at 17 HK7 sites and 2 HK6 sites. This *Festuca rubra-Veronica chamaedrys* variant is a semi-improved type of grassland with a lower % cover and diversity of herbs than MG6biii.

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[3] NB only three quadrats were taken per site.

3.52 Of the MG3 *Anthoxanthum odoratum-Geranium sylvaticum* grassland sub-communities present, the MG3b *Briza media* sub-community is the highest quality community, and was present at two sites; one HK6 and one HK7. The MG3a *Bromus hordeaceus hordeaceus* sub-community was more frequent, occurring at four HK6 sites and 11 HK7 sites. In MG3a grasslands, some species found in unimproved sites have been replaced by species indicative of agricultural improvement, e.g. *Lolium perenne, Phleum pratense, Bromus hordeaceus hordeaceus* (Rodwell 1992), and the cover of upland hay meadow indicator herbs is reduced (O'Reilly, 2011).

3.53 All four variants of MG8 identified by O'Reilly were also present in the sample, with most sites corresponding to the medium quality types (MG8o and MG8+) whilst the highest quality MG8n vegetation was overall rare. A total of 11 MG8 sites were present in the HK6 sample, of which six were relatively species-poor (MG8o), four were moderate quality (MG8+) and one was the most species-rich type (MG8n). Of the HK7 sample, 20 sites also contained variants of MG8, including three of the poorest (MG8-), five MG8o, nine MG8+ and three MG8n.

Table 6 Summary of NVC Communities Determined from Quadrat Data for 31 HK6 and 72 HK7 Sites

HK7		HK6	
NVC Community (G09)	***No sites***	***NVC Community (G09)***	***No sites***
MG3a	7	MG3a	3
MG3a / MG6biii	1	MG3b	1
MG3a / MG7d	1	MG6bi	1
MG6bii	13	MG6bii	1
MG6bii / MG8+	1	MG6bii / MG8o / MG8+	1
MG6biii	27	MG6biii	14
MG6biii / MG3a	1	MG6biii / MG8n	1
MG6biii / MG3b	1	MG8+	2
MG6biii / MG8n	1	MG8+ / MG3a	1
MG6biii / MG8o	1	MG8o	3
MG8-	2	MG8o / MG6biii	2
MG8- / MG6bii	1	Undetermined	1
MG8+	6	*Total*	*31*
MG8+ / MG3a	1		
MG8+ / MG6b	1		
MG8n	2		
MG8o	2		
MG8o / MG6bii	2		
MG10a	1		
Total	*72*		

Assessment of Condition

3.54 The Higher Level Stewardship Farm Environment Plan (FEP) Manual (Natural England, 2010) provides technical guidance to support completion of the FEP. The FEP is undertaken at the application stage and involves an audit of features present, and their condition, to help identify features eligible for management under HLS. Upland hay meadow Priority Habitats are coded as G09 within the FEP, whilst semi-improved and improved grasslands are coded G02 and G01 respectively. Keys 2a, 2b and 2c are used within the FEP to identify grassland types, their condition and their potential for restoration. In this study the keys were used to evaluate field data gathered to explore whether features were eligible and whether they had been correctly allocated to HK6 or HK7.

3.55 The full data are summarised in Tables 7 and 8 (below).

3.56 Of the 31 sites in HLS under the HK6 option, a total of 16 were identified as ‘good quality species-rich grassland’. The FEP manual indicates that these sites should be entered into the ‘maintenance of species-rich grassland’ management option. Hence the analysis suggests approximately 50% of the sites were correctly allocated to the HK6 option. Affinities to seven upland hay meadow NVC communities (O’Reilly, 2011) were represented in this category (Table 7). These included several variants of MG3 and MG8 including the classic upland hay meadow vegetation types, MG3b and MG8n.

3.57 Twelve of the HK6 sites were allocated to the ‘species-rich grassland’ category, suggesting that they might have been better suited to the ‘restoration’ option, HK7. For these, the assessment of restoration potential found that 75% had high potential and 25% medium potential. A subset of four of the upland hay meadow NVC communities found in the good quality sites were represented in this group, including variants of MG3 and MG8.

3.58 The remaining three sites keyed out as ‘semi-improved grassland’, suggesting that the allocation to HK6 was incorrect; of these sites, the assessment of potential suggested that two would be suitable for immediate entry into HK7 whilst the third would require weed control and re-assessment after 1-2 years. Two NVC communities were represented, both variants of MG6, generally considered to be a semi-improved grassland community.

Table 7 HK6 - Summary of Analysis - FEP Keys 2a, 2b and 2c for 31 Sites

HK6 - Total no sites		***31***		
			NVC (after O'Reilly)	**Predicted HLS category**
Species-rich (28 sites)	good quality species-rich grassland	16	MG3a, MG3b, MG6bii, MG6biii, MG8+, MG8o, MG8 & undetermined	HK6
	species-rich grassland	12	MG3a, MG6bii, MG6biii & MG8o	HK7: 9 high restoration potential, 3 medium
Semi-improved		3	MG6bi & MG6biii	Possible HK7: 2 sites with high restoration potential Unsuitable: 1 control weeds and re-assess in 1-2 years

Table 8 HK7 - Summary of Analysis - FEP Keys 2a, 2b and 2c for 74 Sites

HK7 - Total no sites		***74***		
			NVC (after O'Reilly)	**Predicted HLS category**
Species-rich (56 sites)	good quality species-rich grassland	31	MG3a, MG3b, MG6b, MG6bii, MG6biii, MG8-, MG8+, MG8n, MG8o	HK6
	species-rich grassland	26	MG3a, MG6b, MG6bii, MG6biii, MG8-, MG8+, MG8o	HK7: 17 high restoration potential, 7 medium Unsuitable: 1 high P, 1 control weeds & re-assess 1-2 years
Semi-improved		15	MG3a/MG7d, MG6bii, MG6biii, MG8-, MG8+, MG8o, MG10a	Possible HK7: 14 with medium to high restoration potential Unsuitable: 1 high P
Not surveyed (Pasture)		2		

3.59 Of the 74 sites under the HK7 option to 'restore species-rich grassland', two sites were under permanent pasture and not surveyed. Thirty-one sites (~40%) keyed out as 'good quality species-rich grassland' implying that they might have been eligible for HK6 - maintenance of species-rich grassland. Amongst these sites, a range of NVC upland hay meadow communities were identified, including two variants of MG3 and four of MG8 (Table 7).

3.60 A further 26 sites were identified via the keys as 'species-rich grassland', comprising 35% of the HK7 sample. According to this assessment, these sites were correctly allocated to HK7, with 65% of sites having high suitability for restoration and 27% medium. The remaining 8% keyed out as being less suitable due to elevated phosphorous or high weed cover. The six NVC communities identified for this group include variants of MG3 and MG8 which are close to the target upland hay meadow community types.

3.61 Fifteen sites keyed out via the FEP method as 'semi-improved', representing approximately 20% of sites in the HK7 category. The appropriate HLS option for these sites would be HK7, provided that there was sufficient potential for restoration. All but one site was considered to have medium to high restoration potential. The remaining site appeared unsuitable due to high soil phosphorous levels. Of the seven NVC communities represented in this group, several variants of MG3 and MG8 were present reflecting better upland hay meadow vegetation, whilst the occurrence of MG7 and MG10 reflects the more semi-improved nature of some fields.

3.62 Overall, the study looked at 103 upland hay meadow sites, 31 under HK6 and 72 under HK7. Using the keys mechanistically, our data suggest that 47 of the sites would have qualified for HK6, 16 from the original selection and 31 from the original HK7 category. A total of 52 sites would have qualified for HK7, comprising 14 of the original HK6 sites, and 38 of those already in HK7. The remaining four sites appeared unsuitable at this stage and might have been considered to be unsuitable for an HLS species-rich grassland option.

3.63 This analysis indicates that in most cases, the sites have been correctly selected for inclusion in the species-rich grassland management options HK6 and HK7, albeit there is some variation in consistency with which the maintenance or restoration option is chosen. Overall, at face value it appeared that sites are more likely to be undervalued, i.e. placed in HK7 when they could potentially have qualified for HK6. However, observations made by field surveyors, and the relative scarcity of the highest value swards support the view that most, if not all, of the sites surveyed might benefit from some degree of restoration management, hence this bias may be appropriate.

3.64 Indeed, feedback from the surveyors following the completion of survey work in June 2012 suggested that they felt there was little obvious difference in quality between the majority of HK6 and HK7 sites other than that generally the poorest sites were under HK7 management. This impression is borne out by the analysis of the data using the FEP keys, showing that although 50% of sites in HK6 were allocated correctly (according to the keys), the remaining may have been more suitably placed under HK7, and conversely, approximately 40% of those fields under HK7 management would qualify for HK6. In both categories, only very few sites (c. 5%) were really not of sufficient quality to merit either HK6 or HK7.

Quantification of Change

3.65 Quantification of change has been carried out at the individual site level using DCA plots as described above. This information has been incorporated into the individual Pen Portraits for each site. The change in community composition over time (across all quadrats surveyed) has been described and attributed to management options or environmental factors where possible.

Management Practices

3.66 Of the 103 sites surveyed in 2012, management data were provided through farmer questionnaires for 88. Of these, 27 were under HK6 and 61 under HK7. The numbers of questions answered varied between respondents, and based upon the detail of information they could recall during the short interview, either in person, over the phone or for a minority, on paper. Although the information provided is patchy and incomplete, a number of inferences can be made. About 31% of sites for which information was provided are within HK6 and 69% within HK7. In addition, 41% of sites reported receiving the haymaking supplement HK18.

3.67 The majority of sites (83%) were reported to have been consistently managed for dry hay, with just over 17% stating that this is not the case (Table 9). However, more detailed analysis of the responses revealed that although for 93% of farmers field dried hay is the objective, only 48% always make hay, the remaining 45% may make hay, haylage, and/or silage, depending upon the weather. Haylage was more popular as an alternative crop (31%) than silage (11%), and only 3% made a combination of all three crop types. Only 6% of respondents only ever made haylage from their meadows, and only 1% (a single site, 720) made only silage.

3.68 Looking at crop type by HLS category, 33% of sites under HK6 were only ever cropped for hay, with the largest proportion (37%) making either hay or haylage. For HK7 sites, the proportion where hay was the only crop was higher, at 54%, while only 28% of respondents made hay or haylage depending upon the weather. These findings seem to indicate that sites under HK7 are being managed more closely to the traditional method of only harvesting field-dry hay, but the reason for this is not clear.

Table 9 Crop Types at 88 Upland Hay Meadow Sites for Which Management Information Was Received

Crop Type	**Total Sites**	*%*	**HK6**	*%*	**HK7**	*%*
Hay	42	*48*	9	*33*	33	*54*
Hay & haylage	27	*31*	10	*37*	17	*28*
Hay & silage	10	*11*	5	*19*	5	*8*
Hay, haylage & silage	3	*3*	2	*7*	1	*1.5*
Haylage	5	*6*	1	*4*	4	*7*
Silage	1	*1*	0	*0*	1	*1.5*
Total UHM	**88**		**27**		**61**	
Pasture	2					
No questionnaire	15					

3.69 Of the 63 sites for which additional details were provided, all stated that the site had been managed consistently for field dry hay for more than ten years and 34 of them for more than 30 years. A further six sites had been under the current management for less than 10 years.

3.70 Cutting dates were not generally provided in detail. However, Table 10 shows that the majority of farmers had cut their fields in July during the period 2008 to 2011, with proportions between 57% and 61%. The next most popular month for cutting was August, with 31% to 41% cutting in this month. No September cuts were reported although some farmers did mention cutting this late in other years. June cuts were very rare (0 to 1%). The increase in numbers of responses reflects the fact that farmers were asked to recall off-the-cuff dates for cutting and their recollection was, naturally, clearer for more recent years.

Table 10 Timing of Hay Cut by Month, 2008 to 2011, at Sites for Which Management Information Was Received

Hay cut month	**2008**	*%*	**2009**	*%*	**2010**	*%*	**2011**	*%*
June	1	*1*	1	*1*	1	*1*	0	*0*
July	45	*67*	47	*67*	42	*57*	47	*47*
August	21	*31*	22	*31*	30	*41*	29	*29*
September	0	*0*	0	*0*	0	*0*	0	*0*
Total responses	67		70		73		76	

3.71 Only four sites reported a significant change in cutting date in recent years – sites 621, 625, 708 and 753. The remainder reported no change in cutting date. This suggests that patterns of cutting have remained largely similar across 95% of the sites for which responses were received, i.e. little change has occurred in this factor and it is therefore unlikely to be affecting the vegetation. Three of the four sites where change was reported related to cutting dates getting later, the fourth was not specific. Similarly, specific rush cutting only took place at six sites, and is unlikely to be a factor in vegetation change across the sample.

3.72 Information on the timing of grazing was reported by 83 farmers, but the variability in the level of detail provided meant that data had to be categorised for analysis. Categories were broadly defined as follows: spring (March to May, before shut-up), aftermath (post-cut where specifically mentioned, July/August), autumn (Sept-October) and winter (November to February). The findings are presented in Table 11, and show the majority of sites (80% or more) receive spring and autumn grazing with proportions similar between HK6 and HK7. However, while 88% of HK6 sites have the aftermath grazed, only 49% of HK7 sites do. Furthermore, winter grazing is less frequent on HK6 sites, with 35% grazed in winter as opposed to 44% of HK7 sites.

Table 11 Number of Sites Grazed in Different Seasons, for all Sites, HK6 and HK7

	Spring	***%***	**Aftermath**	***%***	**Autumn**	***%***	**Winter**	***%***
All (N=83)	74	*89*	52	*63*	72	*87*	35	*42*
HK6 (N=26)	23	*88*	23	*88*	24	*92*	9	*35*
HK7 (N=59)	51	*86*	29	*49*	48	*81*	26	*44*

3.73 More detail on shut-up dates is given in Table 12, which presents information provided for 76 sites on timing of spring grazing, with shut-up occurring at the end of this grazing period. The most common time to shut-up hay meadows in the study was mid-May.

Table 12 Information Provided on Shut-Up Dates

Response Category	**Shut-up dates (N=76)**	**%**
No spring grazing used	10	13
Spring grazing used, not specific about when	28	37
Early April	3	4
Mid-April, around the 15th	1	1
Late April/Early May	4	5
Mid-May, around the 15th	26	34
End May	1	1
May, not specified when	3	4

3.74 For 86 respondents who provided information on their livestock types, Table 13 summarises the numbers of sites under different grazing livestock by HK6 and HK7. It can be seen that either mixed sheep and cattle or just sheep were the most favoured grazing livestock. Breeds were only patchily reported upon, but by far the most popular breed of sheep was Swaledale, with other breeds mentioned including Jacobs, Leicester, Texel and Suffolk. A wide range of cattle breeds were in use with no clear favourite; breeds included pure-bred and crosses of (Belted) Galloway, Limosin, Highland, Aberdeen Angus, Dairy Holsteins, Fresian, Blonde Aquitane, Simmental, Belgian Blue, British Blue, Luings and Charolet. Horses were only mentioned at one site. No coherent information was collected on stocking rates or duration of grazing.

Table 13 Number of Sites (N=86) Grazed by Cattle, Sheep and Combinations

Livestock type	**HK6**	*%*	**HK7**	*%*
Cattle only	1	*4*	3	*5*
Mixed sheep & cattle in year	12	*46*	33	*55*
Sheep only	13	*50*	21	*35*
Sheep some years, cattle others	0	*0*	3	*5*
Total Reponses	26		60	

3.75 Figure 22 summarises the proportions of sites where lime has been used, looking at all sites and sites entered into HK6 and HK7. Sites were categorised as: 'Never' where lime was reported to never have been used; 'No' where no information on past use was given; 'Yes' where lime had been used in past 10 years; 'Yes but not in past 10 years'; and 'Don't know'.

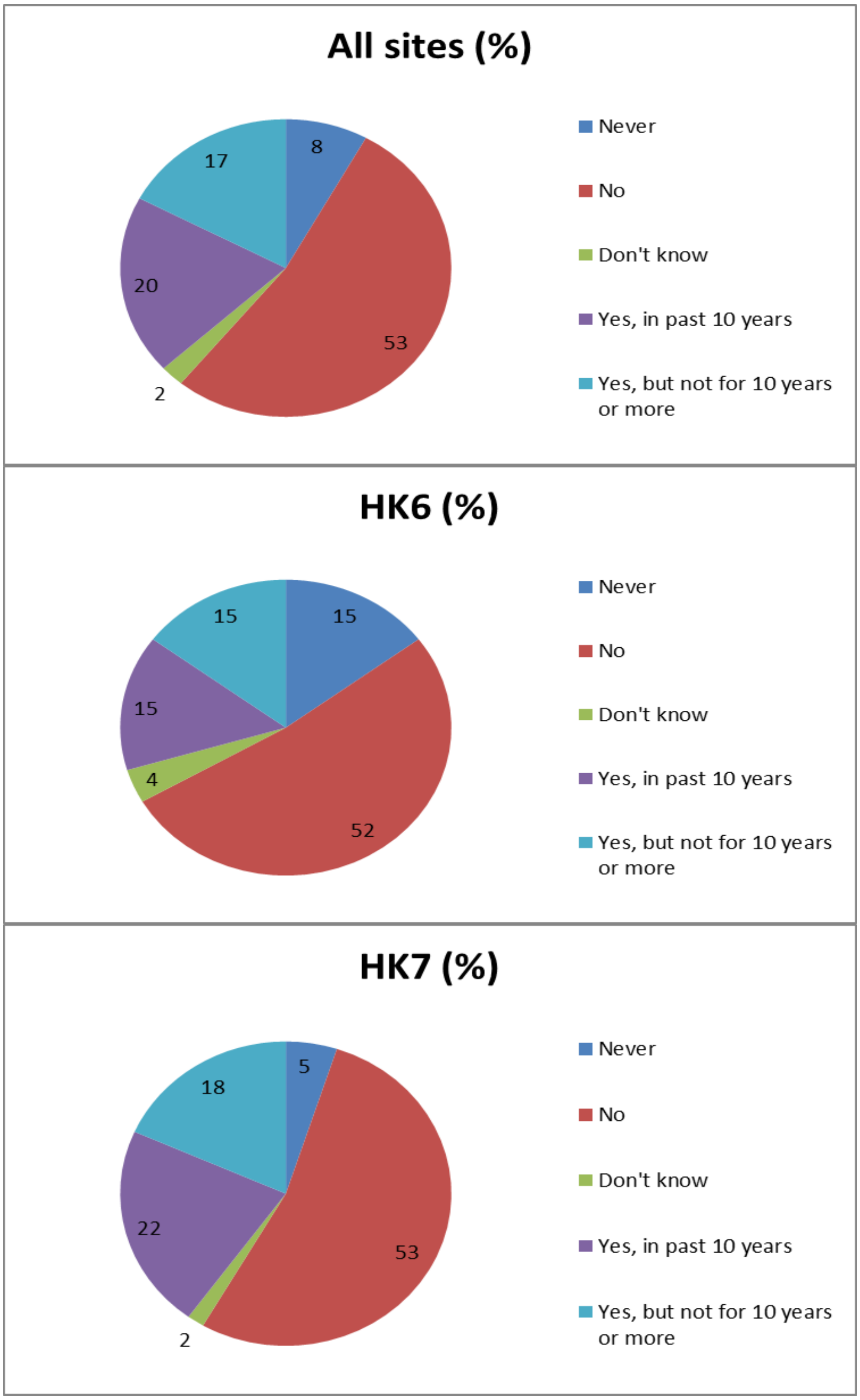


Figure 22 Summary Charts Showing % of Sites (N=87) Where Lime has been Used, As Well As % Of HK6 (N=27) and HK7 (N=60) Sites

3.76 Only seventeen meadows were reported to have received lime within the past decade, and at those sites for which quantities were reported (2) this was between 1 and 2.5 tonnes/ha. Figure 23 illustrates the proportion (%) of these 17 sites falling into NVC communities. 45% of the full dataset of sites fall into the MG6biii category, compared to 35% of sites where lime has been applied in the past decade, and this is broadly comparable. However, 25% of all sites fall into one of the MG8 categories, while 47% of sites receiving lime in the past decade are in this group of NVC communities, perhaps because managers of these sites (which are naturally more acidic) are more likely to wish to use lime.

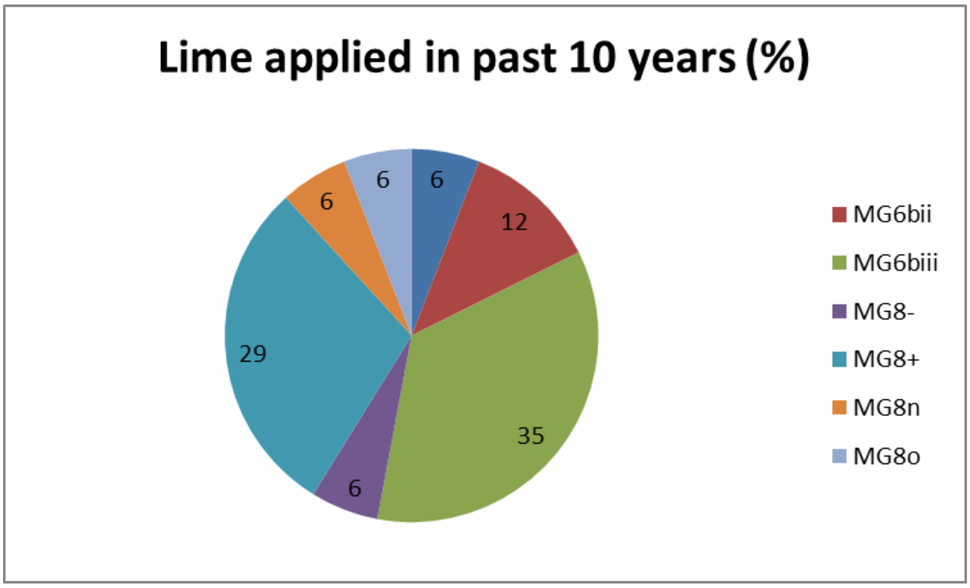


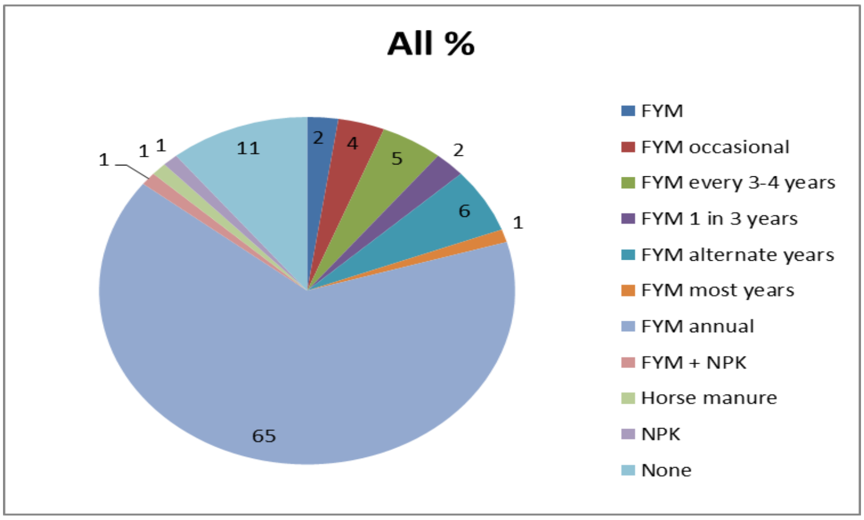
Figure 23 Percentage of Sites Where Lime has been Applied in the Past Ten Years Falling into Each NVC Community (N=17)

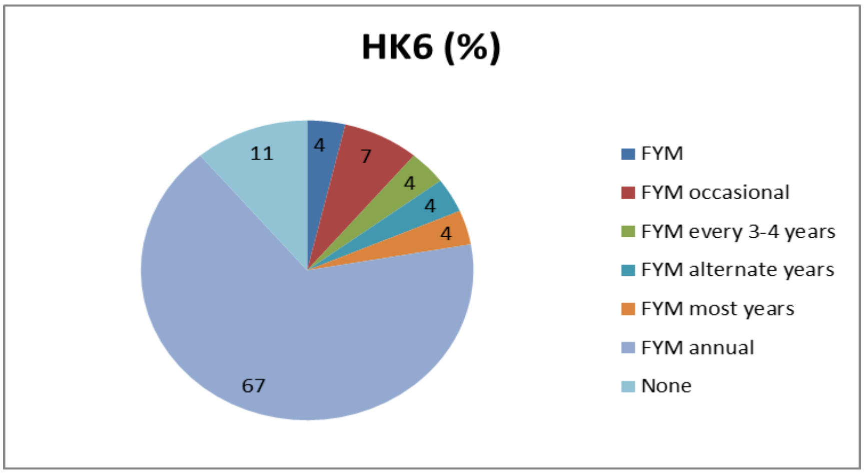
3.77 Just over half (52%) the 73 sites for which information on weed control was provided specified that there had been herbicide applications to treat weeds, with 47% stating no application. Of those sites for which herbicide application was specified, the majority used spot treatments for species such as docks, thistles and nettles, while the remainder did not specify the techniques used. Four sites also stated that hand pulling of ragwort was necessary.

3.78 The majority of sites had some level of nutrient addition, with 24 HK6 sites and 48 HK7 sites specifying farmyard manure (FYM). Only two sites specified that inorganic NPK fertiliser (sites 722 and 748) had been used. A single site received horse manure. A total of three HK6 and six HK7 sites had no fertiliser inputs at all. The results are summarised in Table 14, and relative proportions of sites in each category for all sites, HK6 and HK7 sites are presented in Figure 24, and show comparable patterns of occurrence across the sample.

Table 14 Summary of Fertiliser Applied to Sites (N=83)

Fertiliser Type & Frequency (where known)	HK6	HK7	All Sites
FYM	1	1	2
FYM occasional	2	1	3
FYM every 3-4 years	1	3	4
FYM 1 in 3 years	0	2	2
FYM alternate years	1	4	5
FYM most years	1	0	1
FYM annual	18	36	54
FYM + NPK	0	1	1
Horse manure	0	1	1
NPK	0	1	1
None	3	6	9
Total responses	27	56	83





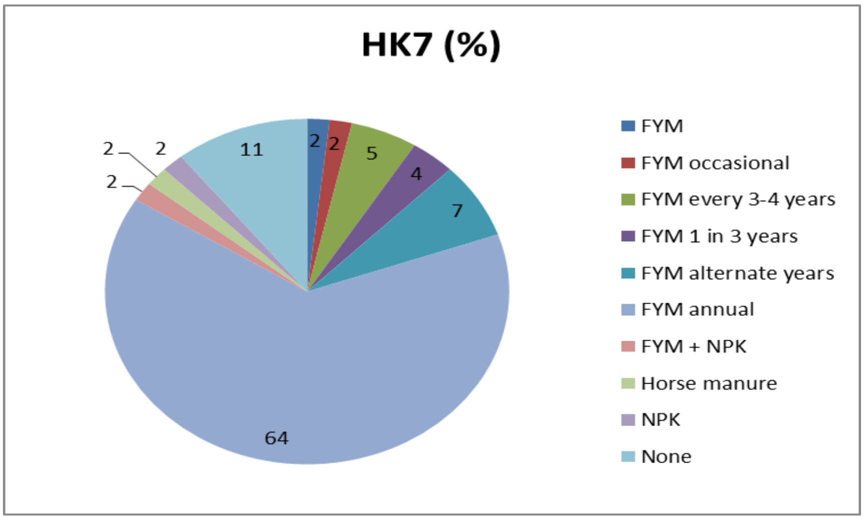


Figure 24 Percentage of Sites Receiving Different Fertiliser Treatments, All Sites N=83, HK6 N=27, HK7 N=56

3.79 Only limited information on FYM application rates was supplied (for 32 sites), but broadly indicated that rates of less than 10 tonnes per hectare are typical (reported by 31 responses), while the single alternative supplied was 10-15 tonnes per hectare (site 703). Many respondents stated that they put on what was available and sometimes did not have enough FYM to dress all fields annually.

3.80 Supplementary feeding was applied at 28 sites, with salt lick provided at 22 in the form of feed blocks, as needed, depending on the weather conditions.

3.81 Restoration management was completed or planned at a total of 18 sites for which questionnaires were received. Of these sites, eight were funded through the 'Haytime' project, and the remainder through other sources including HLS, although this was not always specified. All but two of these sites were under HK7, as would be expected. Most of the works had been completed, but several sites were expecting to complete the re-seeding activities in the next few years. Several other sites were reported to be actual or potential donor sites for hay meadow restoration – 605 (MG6bii), 606 (MG8o), 724 (MG3a) and 738 (MG8n) – but these sites do not appear to be especially species-rich examples compared to other sites within the sample and equivalent or better sources of seed for restoration could probably be found for future projects.

4. DISCUSSION

4.1 This study set out primarily to explore the long term effectiveness of Environmental Stewardship in conserving upland hay meadows in the Pennine Dales and secondly to provide an updated sample to facilitate future resurveys. The project aimed to:

- Provide an assessment of the current condition of a sample of upland hay meadow sites that are in HLS management (i.e. the whole sample collected in 2012);
- Compare the current condition of upland hay meadows under maintenance and restoration management regimes (i.e. comparing those in HK6 and HK7 options);
- Assess and compare the change in condition of upland hay meadows that have been under maintenance and restoration management regimes (for sites with past data only);
- Evaluate management, soil and other relevant information and explore the reasons for any change in vegetation condition observed.

4.2 In addition, recommendations are made for more in-depth analyses of the existing data, future monitoring surveys, and site selection and management.

Current Condition of the Sample

4.3 The 2012 dataset provided a sample of 103 sites in HLS management under either option HK6 (31 sites) or HK7 (72 sites). The condition of these sites was assessed in various ways:

- Examination of NVC communities represented in the sample;
- Use of the FEP Keys for identifying species-rich grasslands (Keys 2a, 2b and 2c).

4.4 In terms of NVC, only two sites (one HK6 and one HK7) out of the whole sample were found to support the highest quality upland hay meadow community, MG3b *Anthoxanthum odoratum-Geranium sylvaticum* grassland *Briza media* sub-community. This represents <2% of the sample and although site selection was intended to provide a good cross-section of the resource, and not to target the best meadows, this does seem to indicate that this community is now very rare. The more impoverished MG3a *Bromus hordeaceus hordeaceus* sub-community was present at about 14% of sites, and in similar proportions in both HK6 (13%) and HK7 (15%); this community is thought to reflect improvement; the diversity-reducing effects of measures such as nutrient and grass seed addition (Rodwell, 1992).

4.5 MG8 *Cynosurus-cristatus-Caltha palustris* grassland variants (O'Reilly, 2011) were present on about a quarter of sites but only four (from both HK6 & HK7) were found to support the richest type MG8n, making the highest quality examples rare within the sample (present at <4% of sites). The medium-quality types MG8o and MG8+ accounted for 32% of the HK6 sample and 19% of the HK7, showing that most MG8 swards have received some measure of improvement, although O'Reilly considers that both MG3a and MG8+ may be 'naturally' unimproved types, just not as rich to start off with as MG3b/MG8n.

4.6 The most frequently occurring NVC community across both HK6 and HK7 samples was MG6biii *Lolium perenne-Cynosurus cristatus* grassland, *Anthoxanthum odoratum* sub-community, *Trifolium pratense-Rhinanthus minor* variant (O'Reilly, 2011). This vegetation type is semi-improved, although at the more species-rich end of the spectrum. Other communities of semi-improved (and even improved) grasslands were also present in the sample, including other variants of MG6b, MG7d and MG10a.

4.7 The NVC analysis suggests that the overall condition of the sample is degraded relative to the highest quality upland hay meadow vegetation communities. It is not clear from the NVC analysis whether further degradation has occurred over time due to a lack of comparable data from previous surveys.

4.8 Examples of high quality upland hay meadow grassland were very rare within the 2012 sample. Many sites contained high-diversity semi-improved grassland of significant conservation value. Few sites (<2%) contained vegetation more typical of improved pastures and meadows (i.e. MG7 and MG10). A comparison of the proportion of samples in broad NVC categories in three surveys in 2002, 2006-8 and 2012 is provided in Table 15. The comparison with Critchley *et al*. (2004) is not straightforward, as that study included many 2012 sites but also many others including more improved swards that have not entered qualifying HLS options and hence were not included in the 2012 survey. As a result, their sample encompassed a wider range of grassland types with more 'improved' sites e.g. 60% of their quadrats were allocated to MG7. While the O'Reilly (2008) study is more comparable in terms of the types of sites analysed, it does not offer a good time-series for comparison of trends.

Table 15 Comparison of Relative Proportions of Samples in 2002 and 2012 in Broad NVC Categories

Broad NVC Community	2002 Critchley (2004) (N=492 quadrats)		2006-8 O'Reilly (2008) (N=429 sites)		2012 (N=103 sites)	
	Number of Quadrats	***%***	***Number of Sites***	***%***	***Number of Sites***	***%***
MG3	20	*4*	56	*13*	13	*13*
MG6	160	*33*	265	*62*	63	*61*
MG8	4	*1*	56	*13*	25	*24*
MG7	293	*60*	52	*12*	0	*0*
MG10	9	*2*			1	*1*
Other	5	*1*			1	*1*

4.9 The use of the FEP manual keys 2a, b and c to explore the condition of the grasslands surveyed provided further insight into the sample. Of the 31 sites that were being managed under HK6, our analysis indicated that 47 met the quality threshold for this option, comprising only 16 from the existing HK6 sample but 31 from the HK7 sample. A total of 52 sites would qualify as HK7, comprising 14 of the original HK6 sites, and 38 of those already in HK7. On the basis of assessment via the keys, only four sites were considered unsuitable for species-rich grassland restoration or maintenance under HLS.

4.10 This analysis suggests that overall most sites are being targeted correctly for upland hay meadow management under either option HK6 or HK7, and that on the basis of the sites sampled in this study, the FEP keys 2a, 2b and 2c are broadly effective at identifying suitable sites for management.

4.11 However, whilst HK6 is aimed at maintaining the condition of the very best sites, the NVC analysis suggests that most sites in this option show some indications of past improvement and are, in fact, examples of upland hay meadow vegetation which have been degraded through some degree of agricultural improvement. The soil analysis would also support this – see paragraph 4.19, below. Therefore, it may be that the threshold for entry to HK6 is set too low, and that upland hay meadow conservation would be better served if many of these sites were managed under restoration options (i.e. HK7) with clearer targets for an increase in diversity and/or reduction in nutrients.

4.12 With regard to the overall suitability of the sample as a baseline for HLS management, it appears to provide a good selection of grassland types allied to upland hay meadow, and includes sites of high conservation value, as well as a spectrum from hardly improved to semi-improved. What the sample lacks are examples of the very best unimproved upland hay meadow vegetation, as only two supported true MG3b and four MG8n.

Comparison of Samples by HK6/HK7, ESA Year, ESA Tier and SSSI

4.13 As would be intuitively expected, taking account of all data for 2012, those sites included as restoration grasslands (HK7) have, on average, lower species richness than those being managed to maintain a species-rich sward (HK6), although there was a large degree of overlap. There was a statistically significant difference in the Nutrient Availability Suited Species Score between HK6 and HK7 sites, with HK6 sites demonstrating a higher proportion of stress tolerant species (i.e. indicative of low nutrient levels) compared to HK7 sites. This would seem to support a pattern of higher overall quality at sites allocated to HK6 maintenance of species-rich grassland management.

4.14 There was no significant difference in overall species richness in relation to the nature of the previous ESA agreement. However, although only significant at the 90% level, a higher proportion of stress-tolerant species were present within former ESA Tier 2A (Herb-Rich Meadows) sites compared with Tier 1B (Meadows, Pastures and Allotments). Excluding new sites, there was a trend (significant at the 90% level) for former Tier 1B sites to exhibit greater species richness than Tier 2A, with a mean species richness of 21.1 for 1B sites compared to 19.3 for 2A. This implies that past entry into Tier 2A may not have provided significant added benefit, but this cannot be verified without looking at changes in specific species (especially key indicators) through the times-series dataset. The subset of new sites had a weak trend of higher species richness (*c*. 23) than the pre-existing sites. However, a higher proportion of these were SSSI, and had been managed under WES and other schemes.

4.15 Herb species richness showed no significant difference between HK6 and HK7 sites, or by ESA agreement year or Tier. However, there was a slight difference (at 90% confidence level) between SSSI (N=23) and non-SSSI (N=80), with the former being higher, as would be expected. Variability was greater in the non-SSSI selection (also to be expected as these encompassed 78% of the dataset). Grass richness was not significantly different for HK6 versus HK7, ESA year or Tier, or between SSSI and non-SSSI.

4.16 Sedge and rush species richness was higher at HK6 sites than HK7 sites. In addition, a significant difference was also found between SSSI and non-SSSI, with SSSI containing significantly more sedge and rush species than non-SSSI. Both findings are in line with expectations of greater diversity on sites selected as SSSI.

4.17 No significant difference in Grazing Suited Species Score was observed between HK6 and HK7 sites, between ESA Tiers or ESA agreement year. Given that all sites are subject to a similar management pattern of grazing and cutting, this is broadly to be expected. Furthermore, there was no significant difference in average Nutrient Availability Suited Species Score with former ESA agreement. A higher (significant at 90% level) proportion of stress-tolerant species were found within sites formerly under ESA Tier 2A as opposed to Tier 1B, the former contained the more demanding agreements regarding hay meadow management and hence this finding might be expected.

4.18 In terms of soil properties, the statistical analyses revealed little difference between HK6 and HK7 samples, as follows:

- There was no significant difference in pH between sites under HK6 and HK7, with a mean value of 5.6 in each case, at the acidic end of 'neutral mesotrophic' status (Natural England, 2008).

- There was a significant difference in extractable P between sites under HK6 and HK7, with HK6 sites showing, on average, lower values than HK7. However, it should be noted that the mean value for each corresponds to 'low' status as opposed to the preferable 'very low'.

- There was no significant difference in K levels between sites under HK6 and HK7. However HK6 sites did, on average, show slightly lower values than HK7. In each case, these average values equated to 'moderate' status.

- There was no significant difference in total N between sites under HK6 and HK7, with average total N values of 0.7% in each case, equating to 'medium' status.

4.19 Overall, despite a high degree of overlap in various attributes, the 31 HK6 sites have slightly greater species richness, stress-tolerant species composition, and lower soil P levels than their 72 HK7 counterparts. This confirms that the subset of HK6 sites is in slightly better condition overall than the HK7 sites, which is to be expected given that the former have been selected for maintenance of hay meadow vegetation rather than restoration. However, it is of some concern that P levels in many HK6 sites remain at or above the typical value suggested in the literature as desirable for maintenance (and even restoration) of species-rich vegetation, and because the key communities and some indicators of upland hay meadows are rare (see above).

Change in Condition Over Time

4.20 Although many of the individual site Pen Portraits (Annex I) reported some change over time (from the DCA analysis), no clear overall trend in the individual site data was observed. Changes at individual sites could have been related to reduced sampling intensity in the later years of survey, e.g. some sites surveyed in 1987 recorded 10 quadrats and subsequent surveys were typically 5, whereas in the later 2002 and 2012 surveys only three were recorded per site. Indeed this may have contributed to the apparent homogenisation of the data found at many individual sites.

4.21 Looking at the whole dataset, no significant change in species richness was observed between baseline years and 2012 either when all sites were assessed or when sites in HK6 and HK7 were examined individually. There was also no significant difference in the change in species richness for sites separated by ESA agreement year. Although not significant, the trends in average species richness observed reflect the findings of Critchley *et al*. (2004) whereby herb species richness in unimproved hay meadow vegetation showed an overall decline.

4.22 An ongoing decrease in species richness at the higher quality sites may reflect losses of desirable species, i.e. a decline in quality of the best upland hay meadows, or could reflect losses of undesirable species. However, the latter seems less likely as higher quality sites tend to have lower incidence of negative species. The nature of this change in species richness is not known but could be investigated through analysis of changes in abundance over time of key indicator species.

Comparing New Sites with All Others

4.23 In terms of species richness, the subset of new sites surveyed in 2012 on average supported greater species richness (21.6 ±3.5) compared with the pre-existing survey sites (19.9 ±5.3). However, care is needed in interpretation of this difference as it could be an artefact of the way the new sites were chosen. In particular, that a higher proportion of the new sites were SSSI meadows.

4.24 Considering the average Grazing Suited Species Scores, no significant differences were observed between the newly surveyed sites and all others, with both groups showing broadly similar values.

4.25 Finally, there was no significant difference in average Nutrient Availability Suited Species Scores for new sites compared with other sites. Nonetheless, overall the pre-existing sites had fewer stress-tolerant species compared with the new sites. This is again likely to be a reflection of a higher proportion of the new sites being of SSSI quality.

Possible Causes of Change

4.26 Upland meadows are naturally stressed communities, by climate (short growing season, low temperatures, wetter summers), intrinsically low nutrient availability and (sometimes) thin soils. The relatively high number of generally stress-tolerant species found in them is a reflection of these conditions and relates to their botanical interest. They are potentially vulnerable to changes in any or all of these factors which might reduce the stresses that control the more competitive species.

4.27 Therefore, climate change, nutrient additions and other alterations to soil properties could all affect the vegetation individually and in combination. In addition, Rodwell (1992) considers that it is the management of the vegetation which primarily influences the community composition, so changes to management practice such as the time of hay-making, the time and intensity of grazing, and the livestock type used could also have a profound influence on the vegetation community over time.

4.28 Some of these factors are discussed below, in the context of the findings of the study.

Soil Properties

4.29 Upland hay meadow soils are usually in the pH range 5.1 to 6.6 but may often have been modified by past liming and manuring practice (Jefferson, 2005). In upland hay meadows, P and K are usually the limiting nutrients because traditional management has typically included the annual addition of farmyard manure (providing N).

4.30 The soil properties within the sample seem to be broadly in line with those previously reported (e.g. Critchley *et al.,* 2004) and with those expected for sites in HK6 and HK7 management. Soil texture is also broadly consistent with the previous study. The soil properties of the 103 sites sampled are summarised in more detail in Chapter 3, but a number of concerns relating to soils are outlined below.

4.31 The analysis of the soils dataset for 2012 revealed pH ranging from 4.9 to 6.7 with an average of 5.6 – this is broadly similar to Critchley *et al*. (2004) who reported a mean pH of 5.7. 99% of the 2012 soil samples were within the expected range for MG3 stands of 5.1 to 6.6 (NE 2011, Jefferson 2005), but with the average falling towards the lower side of this spectrum. It is possible that some low pH sites may benefit from the addition of lime. No target values for pH are given for MG8 stands.

4.32 Soil phosphorous (P) is a major plant nutrient, but only small amounts are needed by plants, and levels in UK soils are naturally very low. The availability of P directly favours grass growth over broad-leaved species and therefore moderate to high levels of available P are undesirable in meadows being managed for conservation of their flora. The main source of P is from fertiliser and animal dung. A typical average value for P in MG3 was considered to be 'very low' at 8mg/l (Jefferson, 2005). Levels of soil P were 'low' (10-15 mg/l) for 76% of sites, 'moderate' (16-25 mg/l) for 22% and 'high' (26-45mg/l) for 2% of sites. On this basis, P levels for all of our sites exceeded a published average value considered appropriate for the MG3 community, albeit in many cases by a relatively small amount[4]. Once the P status has been raised in soils it declines only very slowly, even in the absence of further fertiliser or manure additions. Although HLS requires the cessation of inorganic fertiliser application, most sites are still subject to application of farmyard manure, so levels of soil P are unlikely to fall substantially. Botanical diversity is better supported by an index of 'low', and studies by Smith *et al.* (2003, meadow) and Walker *et al.* (2004, lowland grassland) have shown that sward diversity is best restored through nutrient depletion and in the absence of fertiliser, combined with appropriate cutting and grazing regimes. In addition, significant evidence exists showing that typically high P, low N situations favour nitrogen-fixing legumes, e.g. white clover, especially where soil N status is low.

4.33 Soil potassium (K) is essential for efficient plant growth, but is widely accepted as being a less critical limitation when considering grassland restoration because it is more easily lost from soils by leaching. Soil K was 'low' (16-120 mg/l) at 20% and 'moderate' (120-180 mg/l) at 77% of sites. 'Moderate-high' K (181-240 mg/l) levels were recorded at 3% of sites. A typical average value for K in MG3 is considered (Jefferson 2005) to be 128mg/l. This broadly equates to the bottom of the 'moderate' category, meaning that only sites categorised as 'low' or 'very low' have appropriate levels of K. 74% of sites have soil K of 128 mg/l or above, and 26% below. Moderate levels of K are of lower concern than N or P, but overall the findings suggest that most of the meadows sampled are well-supplied with the three essential 'NPK' nutrients used in agriculture to promote plant growth for fodder and crops.

4.34 N is the dominant nutrient determining plant growth. A moderate or high total soil N may reflect high inputs of animal manures. Quite high nitrogen values (N) were reported for the sample, with the majority falling into the 'medium' category (Natural England, 2008). Soil nitrogen (N) status was 'medium' at 84% of sites (values 0.5 to 1%) and 'high' (>1%) at 5%.

4.35 Available P is considered to be the most important nutrient influencing sward diversity (Natural England 2008), and it is of note that sites where total N is considered 'high' (i.e. >1%) and P is 'low' are considered to be ideally suited to the restoration of species-rich grasslands (i.e. for inclusion in HK7) because grass-growth will be naturally limited. Some examples of sites from this study where this is the case include 716, 760 and 763. Other sites such as 761 and 762 have higher P status and may not be so suitable for restoration until soil P is reduced.

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[4] *Natural England's (2008) indices for Olsen's P are: 'very low' 0-9mg/l; 'low' 10-15mg/l; 'moderate' 16-25mg/l; 'high' 26-45mg/l.*

4.36 The addition of manure or mineral fertiliser (particularly P) is known to damage botanical diversity in meadows. Kirkham *et al.* (1995, 1996) studied the effects of N, P and K addition in a meadow in the Somerset Levels and showed that P was dominant in determining botanical change, and that botanical changes were small where P was limited even when N and K were relatively high. Changes included very significant increases in biomass and severe reductions in diversity. The change from ESA to HLS management has driven a change in management of some meadows, where small and/or occasional applications of mineral fertiliser were previously permitted, but are not allowed under HLS. It is too soon to see any response to these changes in the current dataset.

Management

4.37 Traditional hay meadow management to maintain the MG3b *Briza* sub-community generally comprises the following (after Rodwell, 1992):

- Fields are grazed in winter, usually by sheep;
- Fields are shut-up from late April to early May (although some studies, e.g. Smith and Jones 1991 report dates as early as 1st February from the 1950s and 60s);
- Mowing generally takes place late July to early August although may be delayed as late as September;
- Meadows are given a light dressing of farmyard manure immediately after being shut-up.

4.38 Information gathered from 88 completed farmer questionnaires suggests that:

- 42% of the sample was grazed in winter;
- Fields were usually shut-up in May, with dates as early as 1st May quoted, but more usually around the 15th or later;
- Mowing is carried out in July (57 to 67%) and August (31% to 41%);
- The most common nutrient addition was via annual dressing of FYM (54%) of all sites, although a range of combinations and frequencies were reported.

4.39 In the questionnaires, 93% of respondents had management for field dry hay down as their objective, but only 48% make only hay, with a similar proportion (45%) making hay, haylage or silage depending upon weather and other factors. A higher proportion of HK7 sites were exclusively managed for field dry hay (54%), compared to 37% for HK6 sites. Consistency of management was good, with 70% of sites reporting consistent management for 10 years or more. The move from the tradition of always collecting field-dry hay to taking haylage or even silage in most years could be a potential cause of change. Farmers did report that recent wet summers had resulted in more haylage crops, and a climatic shift toward wetter summers could result in haylage rather than dry hay becoming the normal crop. There would presumably be a reduction in seed dropped from partially dry or baled and wrapped fodder, and this could dramatically affect annual species such as *Rhinanthus minor* or *Euphrasia* species, or those with a with a short-lived seed bank. *R. minor* is a facultative hemi-parasite on vigorous species such as *Trifolium, Lolium, Festuca* and *Holcus* (Westbury, 2004) and *Euphrasia* also has a hemi-parasitic habit.

4.40 Changes in cutting dates, shut-up time and livestock type could potentially drive subtle changes in the vegetation. Cutting and grazing regimes have been found to have an impact upon species richness, with cuts after about 21st July and autumn and spring grazing associated with the greatest increases in species diversity consistent with restoring an MG3-type community (Smith *et al.,* 2003), although in that study seed was also added. Exact cutting dates were not provided with the 2012 questionnaires, but responses revealed that most farmers cut their fields in July during the period 2008 to 2011, with proportions between 57% and 61%. The next most popular month for cutting was August, with 31% to 41% cutting in this month. This is evidence of a change in cutting practice in recent decades. Work by Smith and Jones (1991) has shown that the period over which modern hay cutting takes place has become significantly shorter than 50 years ago due to increased mechanisation. This has been related to the phenology of hay meadow herbs and their likely ability to flower and set seed before harvest.

4.41 Studies by Smith *et al.* (2012) have found later spring grazing and shutting-up dates are associated with a decline in wildlife interest. Adverse effects of grazing sheep beyond a shut-up time of February 1st (designed to mimic the absence of spring grazing) were late flowering of species such as *R. minor, C. majus* and *T. pratense* meaning seeds were not ripe at hay-cut time. Farmer responses indicate that the most common time to shut-up hay meadows in the study was mid-May. This remains broadly in line with traditional practice of shutting up in early to mid-May, although the 2012 dates do give some indication that a later mid-May shut-up is now favoured. However, it is possible that a combination of spring grazing plus normal shut-up dates, but with a more rapid harvest, usually in July could leave hay meadow species insufficient time to flower and set seed at the rates which used to maintain the diversity of the flora in the past.

4.42 Mixed sheep and cattle or just sheep were the most favoured grazing livestock. However there were differences between HK6 and HK7. On HK6 sites, ‘sheep only’ were reported from 50% of sites, while ‘mixed sheep and cattle’ were used on 46%. On HK7 meadows, ‘mixed sheep and cattle’ were more popular (55%) with ‘sheep only’ making up 35% of sites. Subtle deviations from the more traditional ‘sheep only’ described by Rodwell (1992) could drive changes in vegetation composition over time, e.g. a move toward more cattle and fewer sheep. Cattle are heavier and graze in different ways to sheep (Jefferson, 2005). There are also likely to be differences between beef cattle and dairy.

4.43 A light dressing of farmyard manure coupled with the occasional application of lime, is thought to help maintain the richness and diversity of the MG3b *Briza* sub-community (Rodwell, 1992). Furthermore, Askew (1994, in Jefferson, 2005) relates that management factors associated with greater nature conservation interest in upland meadows were: hay meadow management (as opposed to management for silage), absence of improved drainage, lack of slurry application, sustained autumn/winter and moderate spring grazing, later cutting dates and occasional lime applications.

4.44 Lime applications to fields in this sample appeared to have largely ceased under the ESA scheme and only six farmers reported adding lime under ESA or HLS schemes. However, unfortunately not all farmers were able to recall the amounts of lime previously used or the dates of application, so the effect of stopping this practice could not be analysed in detail. Overall, the soil pH analysis appears to indicate that little change has occurred over the past decade or so (in comparison with Critchley *et al*. (2004) data), although pH levels may be on the low side within the target limits. It may be that occasional addition of lime to suitable sites may be beneficial, especially at species-rich sites where there is a risk of undesirable botanical change due to acidification or where there is a history of liming (Walsh *et al.,* 2009).

Climate and Pollution

4.45 The Met Office[5] has summarised the weather experienced across the UK and on a regional basis during 2012, and provides a comparison with the 20-year (1981-2010) and 30-year (1961-1990) averages.

4.46 A comparison between the Met Office East & North East England regional values for temperature, sunshine and rainfall and the averages for 1981-2010 and 1961-2009 reveals that:

- Maximum, mean and minimum temperatures were 0.1°C below the 1981-2010 average, but respectively 0.6°C, 0.5°C and 0.4°C above the 1961-1990 average;
- Sunshine was at 100% of the 1981-2010 average, and at 104% of the 1961-1990 average;
- Rainfall was 137% of the 1981-2010 average, and 141% of the 1961-1990 average;
- Days of air frost were 1.9 below the 1981-2010 average and 9.4 below the 1961-1990 average, which is likely to imply a longer growing season.

4.47 Across the UK, the mean temperature of 8.8 °C was 0.1 °C below the 1981-2010 average. It is worth noting that only two years (2010 and 2012) of the last 16 have had annual temperatures below this average. March 2012 was the third warmest on record for the UK. The summer was a little warmer than 2011, but otherwise the coolest since 1998, and it was the coolest autumn since 1993.

4.48 The UK annual rainfall total was 1331 mm (115% of average), the second highest in the series from 1910, narrowly beaten by 2000 (1337 mm). England had its wettest year in the series. 2012 was the third wettest year in the England and Wales series since 1766, behind 1872 and 1768. Many locations from the south-west to the north-east received over 135% of average annual rainfall, and 2012 included the wettest April and June in England and Wales since records began in 1766, while the summer period (June, July and August) was the wettest since 1912.

4.49 In summary, long term datasets seem to indicate the UK, including the East and North East of England is experiencing elevated temperatures and rainfall, although 2012 was slightly cooler than the 1981-2010 average.

4.50 The vulnerability of upland habitats to impacts from climate warming is considered to be high, because there is nowhere cooler for the species to go, (e.g. Berry *et al*., 2003). Impacts on upland hay meadow vegetation could stem from longer growing periods, higher temperatures and elevated rainfall as well as changes in atmospheric composition e.g. raised N availability, some of which could be directly taken up by leaves (Jacky Carroll personal communication). In terms of the botanical dataset, the data was not analysed for trends relating to climate change due to lack of detailed data.

[5] www.metoffice.gov.uk/climate/uk/2012

4.51 However, dry weather in spring reduces grass growth, while wet spring weather has the reverse effect (Penny Anderson personal communication). As most grass growth occurs in spring, wetter weather later in the summer may have less effect.

4.52 Atmospheric deposition of N is a further factor that could be contributing to vegetation change in upland hay meadows. APIS[6] has assigned critical loads based on empirical estimates for different habitats, including several grassland ecosystems such as ‘mountain hay meadows’ (the Habitats Directive Annex 1 habitat which equates to upland hay meadows). These estimates have been derived from a range of experimental studies. For N deposition, the critical load (or point at which changes in species composition and sensitivity of vegetation to environmental stresses can occur) for mountain hay meadows is 10-20 Kg N/ha/year. It is likely that these levels are being exceeded in some areas of the North Pennines. Using the APIS data, within the sample area at Middleton-in-Teesdale, actual N deposition is estimated at 23.1 Kg N/ha/year giving a potential exceedance range for the critical load for mountain hay meadows of between 3.1-13.1 Kg N/ha/year. Loss of species richness from chronic N deposition has been shown in infertile grasslands (Maskell *et al.*, 2009, Stevens *et al.*, 2004, 2006).

Conclusions

4.53 In meadows where there is enough P already, i.e. the levels are elevated above ‘very low’ as in most of the sample, then with increased temperatures and adequate rain there is the potential for greater growth and this is most likely to favour competitive species at the expense of the stress-tolerators. This is likely to slow, inhibit or even reverse the impacts of management designed to increase numbers or populations of stress-tolerators. The addition of manure is adding additional N and P, thus maintaining nutrient levels at a level which is above the optimum for conservation of upland hay meadows. The data for the study area gathered from APIS appears to show that there is also a steady input of atmospheric N, which is added irrespective of management by the farmer, and that this on its own is at or above the recommended critical level for upland hay meadows. Acid deposition and ammonia could also be factors and are also monitored and reported on through APIS.

4.54 Upland meadows are naturally stressed communities, by climate (short growing season, low temperatures), by low nutrients and (sometimes) thin soils. If these stresses are being slowly and gradually moderated by climate warming and ongoing nutrient inputs then vegetation will reflect this through loss of characteristic stress-tolerant species as they are out-competed by more vigorous species, especially grasses. Regular manure addition/and in some cases, past application of inorganic NPK appears to have left soils with residual levels of P that are available for utilisation when other soil conditions are right, e.g. enough N is available. This effect has been seen in studies of several meadow communities, e.g. Kirkham *et al*. (1996), Smith *et al*. (2003) and Mountford *et al.* (1993). It is possible that these cumulative effects are visible in the sample of upland hay meadows surveyed in this study.

4.55 In the light of this, particularly where restoration is an objective, management agreements may need to consider further limiting soil fertility. Quite a body of literature supports further reduction or cessation of farmyard manure application, e.g. Smith *et al.* (2003) and Smith and Jones (1991). This approach coupled with seed addition to restore missing species has been successfully used at other sites (Cornish and Hooley, 2012). In addition, earlier shut-up dates

[6] http://www.apis.ac.uk/

(at least before May) and cutting from mid-July and into August seem to be practices associated with successful restoration of upland hay meadow communities (e.g. Jefferson, 2005, Kirkham & Tallowin, 1995, Smith *et al*., 2003).

Recommendations

4.56 A number of recommendations follow from this study. These are outlined below.

4.57 Pacha and Petit (2007) and Bradshaw (2009) have identified declines in characteristic upland hay meadows species such as *G. sylvaticum, Trollius europaeus, Cirsium heterophyllum* and the *Alchemilla vulgaris* aggregate. Trends in these and other influential species such as the facultative hemi-parasites *R. minor* and *Euphrasia* species, as well as *C. majus, S. officinalis, R. acris* and *Holcus lanatus,* could be examined from the data available to this study to examine change over time at the site level as well as relative abundance across the dataset in the past and now.

4.58 In addition, the RCA W-walk data was considered by the field surveyors to provide a good measure of site quality at many sites and surveyors collected information on all MG3 and MG8 indicators, adding them to the forms where necessary. However, the automated analysis of these data via the database was constrained by the need to allocate each site to a single NVC community (MG3 or MG8) at the outset of the field survey. Some sites were difficult to define at first and some did not fit easily into either category. The database as it stands does not allow additional species to be added to the analysis. As a result the overall quality of a site might not have been accurately reflected in the condition assessment provided by the database and therefore this analysis was not used for this study. Amending the database to have a single proforma for upland hay meadow type vegetation which encompasses the key indicators for both MG3 and MG8 types would enable a more useful quick assessment method for upland hay meadows. The existing 2012 data should be re-entered into any revised system so that there is a baseline for this potentially quick and useful monitoring tool.

4.59 In future surveys, as well as continuing the botanical monitoring, the following could also be considered:

- Collect environmental data with the botanical quadrats to allow more detailed examination of the effects of various factors upon the vegetation.
- Ensure that more detailed management information is gathered, to address inputs and outputs, plus grazing exact shut-up, and cutting dates, stocking levels etc. Previous studies, e.g. Critchley *et al*. (2004) made use of agronomists to collect the farmer information while botanists collected the data from the fields. This approach, together with a more structured and detailed questionnaire, would allow for more detailed analysis of botanical data with management information. In addition, it would be advisable to ensure that all farmers are included.
- Continue to collect % cover on 1m x 1m quadrats (to allow detailed comparison in 10 years time with the current baseline).
- Collect RCA W-walk data on a dedicated ‘upland hay meadow’ proforma that encompasses both broad community types in upland hay meadows i.e. MG3 and MG8, ensuring that assessments of condition using database routines take into account the full variety to be found in many high quality sites and are not too strongly tied to individual NVC communities.

- In the light of soil nutrient status being considered (from the findings of this study) to be above the recommended levels for upland hay meadows, future studies may wish to examine nutrient balances and dynamics in these communites in more detail.

4.60 Our findings suggest that for upland hay meadows, the use of the FEP keys for a preliminary assessment of the feature and its condition (as set out in the FEP Manual (Natural England 2010)) may result in sites being included in the 'maintenance' option (HK6), that would benefit from restoration management (HK7). The statistical analysis identified a high degree of overlap between the HK6 and HK7 datasets collected in 2012 (see Figure 3), supporting the idea that sites can be wrongly allocated to these HLS options. Despite this, in a larger number of cases the actual choice of HK6 or HK7 option erred towards placing them into HK7, suggesting that FEP and scheme advisors were generally good at judging when restoration options would be suitable.

4.61 Although this study only assessed a sample of 103 fields from across the upland hay meadow resource, the dataset aimed to provide a reasonably representative cross-section of the vegetation type. Therefore, any revisions to the FEP manual keys 2a, 2b and 2c should look carefully at the distinctions.

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6. ABBREVIATIONS

ANOVA	Analysis of Variance
BAP	Biodiversity Action Plan
BL	Bottom Left
CSM	Common Standards Monitoring
DCA	Detrended Correspondence Analysis
ESA	Environmentally Sensitive Area
FYM	Farmyard Manure
HLS	Higher Level Stewardship
NPK	Nitrogen Phosphorus Potassium
NVC	National Vegetation Classification
PAA	Penny Anderson Associates Ltd
RCA	Rapid Condition Assessment
SSSI	Sites of Special Scientific Interest
TR	Top Right

APPENDIX 1

Field Survey Proformas

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:

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

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.

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)	

NATE18 Environmental Stewardship and Upland Hay Meadows
Farmer Management Questionnaire (Surveyor to complete)

Date________________ **Interviewer __________**

Site ID______________ **Respondent name_______________**

Question	Answer choices			Response
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. IF NECESSARY, COMPLETE ONE QUESTIONNAIRE PER SITE.				
1. CURRENT & PREVIOUS SCHEME DETAILS				
Current scheme	HLS/ESA/OTHER			
	HK6 Maintenance of species-rich semi-natural grassland			
	HK7 Restoration of species-rich semi-natural grassland			
	HK18 Haymaking supplement			
	Previously in ESA/CSS? Which one? (Pennine Dales/other_______________________________)			
Additional information				
2. CUTTING MANAGEMENT				
Cutting management - hay	Has field been consistently managed for field dried hay? Yes/no			
	If **yes,** how long?			
	If **no,** what has been done instead? (grazed / haylage / silage / other ____________________________)			
Additional information				
Recent cutting dates	2011			
	2010			
	2009			
	2008			
Has this changed significantly in past 10 years? How?				
Other cutting management	*Have you cut rushes? Yes/No*	*Last year cut*		
	Other species?	*Last year cut*		
Additional information				
3. GRAZING MANAGEMENT INCLUDING SUPPLEMENTARY FEEDING				
Timing of Current Grazing	*Season*	*Dates*	*Cattle / sheep*	
	Autumn		Cattle / sheep	
	Winter		Cattle / sheep	
	Spring		Cattle / sheep	
	Other		Cattle / sheep	
Additional information				
Has grazing pattern changed recently?	Yes/No			
	In past year	*How?*		
	In past 5 years	*How?*		
	In past 10 years	*How?*		
Does this relate to (spring / summer / autumn / winter)?				
How has grazing changed?	Yes / No (Nos/ha & timing)			
Additional information				
Livestock type	None			
	Sheep only			
	Cattle only			
	Mixed sheep and cattle in same year			
	Sheep some years, cattle others			
	Horses			
Specify breeds / rarity				

Current supplementary feeding	None / hay / haylage / silage (big bale) / silage clamp / straw / other	
	Salt lick	
	When	
	Where	
Additional information		
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?	
	When did you last lime?	
	How much?	None/< 1t/ha /1-2t/ha />2tha /specify other
Additional information		
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/ha / 10-15 t/ha / 16-20 t/ha / 21-25 t/ha
	Has this changed in past 10 years?	*If yes - See below*
Additional information		
Previous Fertiliser use? (under previous ESA scheme or other)	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		
Seed addition completed or planned?	Yes/No	
	How funded? HLS/ Haytime/ self-funded / combination (of which) / other (specify)	
	When?	
	What (seed / green hay / dried hay)?	
	Sources of seed?	
	Yellow Rattle?	
	Site preparation before adding seed? (scarify/ harrow/ none/ other)	
	Site preparation after seed addition?	
	Contractor used?	
Additional information		
7. OBSERVATIONS/ IMPRESSIONS OF CHANGE		
Have you noted any differences to swards 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

NATE 18 Quadrat Survey Form		Quadrat:_______.
Surveyor:	Date:	
Site name:	Site number:	Agreement no.:

Species name	Inner 1 x 1		Outer 2 x 2	Species name	Inner 1 x 1		Outer 2 x 2
	% Cover	Domin	DAFOR		% Cover	Domin	DAFOR
Anemone nemorosa				Myosotis discolor			
Achillea millefolium				Nardus stricta			
Achillea ptarmica				Phleum pratense			
Agrostis canina				Plantago lanceolata			
Agrostis capillaris				Plantago major			
Agrostis stolonifera				Poa annua			
Ajuga reptans				Poa pratensis			
Alchemilla glabra				Poa subcaerulea			
Alchemilla xanthochlora				Poa trivialis			
Alopecurus geniculatus				Potentilla erecta			
Alopecurus pratensis				Prunella vulgaris			
Anthoxanthum odoratum				Ranunculus acris			
Anthriscus sylvestris				Ranunculus bulbosus			
Arrhenatherum elatius				Ranunculus ficaria			
Avenula pratensis				Ranunculus repens			
Avenula pubescens				Rhinanthus minor			
Bellis perennis				Rumex acetosa			
Briza media				Rumex obtusifolius			
Bromus hordeaceus				Sagina procumbens			
Caltha palustris				Sanguisorba minor			
Campanula rotundifolia				Sanguisorba officinalis			
Cardamine flexuosa				Senecio jacobaea			
Cardamine pratensis				Stellaria alsine			
Carex caryophyllea				Stellaria graminea			
Carex flacca				Stellaria media			
Carex nigra				Succisa pratensis			
Carex ovalis				Taraxacum agg.			
Carex panicea				Trifolium dubium			
Centaurea nigra				Trifolium pratense			
Cerastium fontanum				Trifolium repens			
Cerastium glomeratum				Trisetum flavescens			
Cirsium arvense				Vaccinium myrtillus			
Cirsium palustre				Veronica arvensis			
Cirsium vulgare				Veronica chamaedrys			
Conopodium majus				Veronica serpyllifolia			
Cynosurus cristatus				Vicia sepium			
Dactylis glomerata				Viola riviniana			
Danthonia decumbens							
Deschampsia cespitosa							
Deschampsia flexuosa							
Equisetum arvense							
Equisetum palustre							
Euphrasia officinalis agg.							
Festuca pratensis							
Festuca rubra							
Filipendula ulmaria							
Galium saxatile							
Galium verum							
Geranium sylvaticum							
Heracleum sphondylium							
Hieracium pilosella							
Holcus lanatus				**Quadrat Photo Ref**			
Holcus mollis				Vegetation height (cm)			
Hypochaeris radicata				Bare Ground (%)			
Juncus acutiflorus				Litter (%)			
Juncus articulatus				Bryophytes (%)			
Juncus effusus				Grass (%)			
Juncus squarrosus				Forbs (%)			
Lathyrus pratensis				Sedge (%)			
Leontodon autumnalis				Rush (%)			
Leontodon hispidus				**Quadrat accuracy:**			
Linum catharticum				Relocated - with certainty (markers found)			☐
Lolium perenne				Relocated - with uncertainty i.e: orientation unclear			☐
Lotus corniculatus				Not relocated - good match between bearings /			☐
Luzula campestris				coordinates and target vegetation			
Molinia caerulea				Not relocated - poor match between bearings			☐
Montia fontana				/coordinates and target vegetation			

DOMIN scale: 10 (91-100%); 9 (76-91%); 8 (75-51%); 7 (34-50%); 6 (26-33%); 5 (11-25%); 4 (4-10%) 3 (<4% many individuals); 2 (<4% several individuals); 1 (<4% few individuals)

NATE18 SITE OVERVIEW

Penny Anderson Associates Ltd
CONSULTANT ECOLOGISTS

Surveyor(s):	**Date:**
Site number / name:	**Area:**
Option code: HK6 ☐ HK7 ☐ HK18 ☐	**Agreement number:**

Previous survey history: Indicative ☐ Validation ☐ New Site ☐

Topography:	Slope and aspect:	Elevation	Aspect

Differential GPS:

Note. The G09 feature will be the whole field for most HK07 sites - Make a note of this below. Some HK06 sites may have very different communities, of which the G09 will need to be mapped. MG3 and MG8 can be included in the same polygon. Make a note of proportions in data table.

☐ Whole field = G09 Feature?
☐ Map feature boundary (complete polygon) if only part of field UHM
☐ Existing Qs relocated & GPS coordinates for bottom L & top R corners obtained
☐ Existing Qs relocated approximately & GPSd
☐ New Qs aligned north, marked at NE & SW corners of 1x1m with GPS for markers

Photographs (general site view) (direction, location, fix on notable background feature e.g. barn)

Pen Portrait (+ve/-ve species at edge, overall species richness and diversity, other notable species (DAFOR) from W-walk, evidence of management e.g. grazing, negative indicators, feeding locations, etc):

Notes on Quadrats (re-found, GPSd, new established)

TO DO:

GPS feature boundary and existing & new quadrat locations
3 quadrats (1 x 1 m inner quadrat nested in corner of 2 x 2 m outer quadrat) + quadrat photos (mark direction)
RCA W-Walk dependent on site size (min 10 stops) recording features within 1m of each stop
Pen portrait (use insight gained on W-Walk)
Soil samples on W-Walk (20 x 7.5 cm cores, placed in a single bag and labelled using NE derived forms) (*01344 899031 to collect*)
1 Representative photo of site GPS location + mark direction on map
Farmer Management Questionnaire