Upland mountain view - Fleetwith, Lake District © Paul Glendell/Natural England

Natural England review of Upland Evidence: Assurance Group report (NEER007)

1st Edition - May 2013

www.naturalengland.org.uk

NATURAL ENGLAND

Natural England Evidence Review NEER007

Assurance Group report

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Published on 30 May 2013

ISBN 978-1-78354-003-7

Citation

This report should be cited as:

GALBRAITH, C.A., GILL, M., PEPPER, S. & HILL, T.O. 2013. *Natural England review of upland evidence - Assurance Group report*. Natural England Evidence Review, Number 007.

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Acknowledgements

The members of the Assurance Group would like to thank Evelyn Jack and Dave Stone for their excellent support throughout the review and Carol Scales for help with logistics. Congratulations are due also to the members of the five topic review groups and support staff in Natural England for their work in completing a very thorough and systematic examination of the issues involved.

Thanks are due also to Scottish Natural Heritage who made meeting rooms available for some of the meetings of the Assurance Group.

Finally, but most importantly, we thanks the various stakeholders for their input to the review programme.

Cover photograph

Upland mountain view - Fleetwith, Lake District © Paul Glendell/Natural England.

Preface

This is a review by an Assurance Group consisting of three senior external advisers and the Natural England Chief Scientist. It summarises the key findings of the Uplands Evidence Review Programme, and presents an independent assessment of the quality of the process and its conclusions, for assurance purposes, along with recommendations for future research.

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1 Introduction

The English uplands are nationally and internationally important for the value of their landscapes, biodiversity, agriculture, archaeology, cultural and natural resources, and the recreational opportunities they provide for health and wellbeing. (Defra 2011).

Upland areas hold a unique mix of land-uses with many vibrant communities still dependent on using upland ecosystems for their livelihoods. Agriculture, forestry and a variety of other industries such as grouse shooting have, historically, been the main land-uses; however these activities have now to be undertaken alongside other demands of upland ecosystems. For example, there are increasing demands from tourism, which need to be managed alongside other requirements such as efficient water management and an increasing requirement for carbon sequestration. All these ecosystem services are to be delivered from an area that holds an internationally important assemblage of species and habitats, many of which are particularly fragile and sensitive to change. In addition, many of these habitats and species, such as *Sphagnum spp*. for example, are fundamental to the wellbeing of the ecosystem and to the maintenance of the ecosystem services considered in this review programme. This is a complex, interlinked picture, with multiple management demands on the same areas of land.

It is imperative to ensure that decisions about the future management of this fragile and important part of England's landscape are based on sound evidence and that where possible a level of consensus can be achieved about what this evidence actually means in practice.

Many of the landscapes, habitats and species found in the uplands are a product not simply of the present land-uses practised there but of many centuries of management and use of these areas, and of the surrounding environment. No system such as this is static, however, and change is happening in the uplands, as it is in other parts of England's environment, so management practices need to change and adapt over time to the prevailing conditions. Similarly, one of the key challenges in reviewing any evidence base is to ensure that the evidence, which will inevitably be drawn from previous times, can help inform current and future management challenges. Ensuring that evidence is fit for purpose is one of the key purposes of this review programme.

Natural England has a key statutory role, working alongside a range of stakeholders, to ensure the sustainable management of the uplands. As the pressures on these areas increase, its work is subject to increasing scrutiny, making it ever more important that advice and decisions from the organisation are based on the best available evidence, and that the related evidence gathering processes are seen to be transparent and robust. This review programme has therefore been undertaken to help ensure that Natural England uses the most robust evidence available when formulating advice and taking decisions related to its work in the uplands. The review programme adheres to the principles outlined in Natural England's Evidence Standard, namely that:

- Our evidence and its application are quality assured at an appropriate level.
- We are transparent and open about our evidence and communicate it effectively.
- We make evidence accessible to the public and our stakeholders and at the scales required.
- We maximise the benefits of working in partnerships.
- We use specialist skills, knowledge and expertise effectively.

Reference: Natural England Strategic Standard Evidence V0.7.

In addition, the review programme was undertaken in the context of the principles outlined in Natural England's Quality Management Standard, namely that:

- A tiered approach to quality assurance must be used.
- The level of quality assurance must be appropriate to the circumstances in which work is undertaken.
- Functions must have a clear process for recording quality assurance undertaken.

Reference: Natural England Operational Standard Quality Management V0.4.

2 The Review Programme aims and scope

Aims and scope

2.1 This review programme has considered a number of key issues relevant to the management of the uplands. The overall intention was:

- To assess the best available evidence (including robustness, quality, and whether it has been peer reviewed) around each of the topics.
- To consider whether there are any significant gaps in the available evidence which require further investigation or research?

2.2 Below is the list of the individual topics that were covered. These were selected because they were regarded as particularly important and had been contentious over recent times; being the areas where Natural England is most frequently challenged on the evidence used. The review programme encompasses the evidence on key aspects of biodiversity and ecosystem services in the uplands, and the effects of land management practices upon them.

2.3 Whilst the following topics have been covered in depth, it is important to note that there are other aspects of land management that are not covered here. It is for Natural England to decide whether reviews should be undertaken on other subject areas in future. Additionally, related subject areas such as social and economic factors, whilst an important part of the process of developing advice from Natural England, are not part of this review programme but will be considered in the development of advice and policy in future, alongside consideration of the conclusions reported here.

Topics covered

2.4 The following topics were identified by Natural England as the areas for review. An overarching question was identified in each case, along with a series of sub-questions to provide a clear focus on priority issues for the topic review.

Review 1 - The impact of tracks on the integrity and hydrological function of blanket peat

Overarching question:

What are the impacts of tracks on the integrity and hydrological function of blanket peat?

Review 2 - Restoration of degraded blanket bog

Overarching question:

What are the causes and impacts of degradation of blanket bogs and what interventions are required for degraded bogs to restore the functions and characteristics to those of undamaged bogs, and maintain these?

Review 3 - The effects of managed burning on upland peatland biodiversity, carbon and water

Overarching question:

What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity, carbon and water?

Review 4 - Upland Hay Meadows: what management regimes maintain the diversity of meadow flora and populations of breeding birds?

Overarching question:

What management regimes maintain the floristic diversity and populations of breeding birds within upland hay meadows?

Review 5 - Impact of moorland grazing and stocking rates

Overarching Question:

What are the effects of grazing regimes and stocking rates on the maintenance and or restoration of moorland biodiversity and on ecosystem service delivery?

The Review Groups

2.5 The review programme has been delivered though a structured approach using staff from Natural England and independent scientists in the Topic Review Groups as follows:

Evidence Review Group

2.6 An Evidence Review Group for each of the topic areas produced evidence summaries using the references identified through literature searches, suggested by stakeholders and others.

2.7 The Membership of each group was:

- Specialist Lead from Natural England for each topic;
- Natural England librarians;
- Deputy Chief Scientist; and
- Evidence Review Project Manager and support.

Topic Review Group

2.8 A Topic Review Group was formed for each of the topic areas under consideration. Each Topic Review Group reviewed the evidence summaries (and supporting evidence where necessary) presented by the specialist Evidence Review Group and drew conclusions on the quality and robustness of the evidence.

2.9 The Membership of each group was:

- Chair – Natural England Head of Profession: significant experience in the analysis and interpretation of evidence.
- 2 members – recognised independent experts in the specific topic that each group will be reviewing.

2.10 The membership of each of the Topic Review Groups is shown in Table 1 below.

Table 1 Membership of each of the Topic Review Groups

Topic Review Group	Members	
Tracks Review Group	Mr Mike Grace	Natural England Head of Profession & Chair
	Mr Simon Thorp	The Heather Trust
	Dr Alan Dykes	Kingston University
Blanket Bog Restoration Review Group	Dr Ruth Waters	Natural England Head of Profession & Chair
	Dr Jill Labadz	Nottingham Trent University
	Dr Simon Caporn	Manchester Metropolitan University
Burning Review Group	Dr Mike Morecroft	Natural England Head of Profession & Chair
	Dr Richard Lindsay	University of East London
	Professor Rob Marrs	University of Liverpool
	Dr Fred Worrall	University of Durham
Hay Meadow Management Review Group	Dr Peter Brotherton	Natural England Head of Profession & Chair
	Dr Carly Stevens	Lancaster University
	Professor David Gowing	Open University
Moorland Grazing Review Group	Dr Angela Moffat	Natural England Head of Profession & Chair
	Dr Mariecia Fraser	Aberystwyth University (IBERS)
	Professor Robin Pakeman	James Hutton Institute

Assurance Group

2.11 The Assurance Group has reviewed and quality assured the outputs from the Topic Review Groups and produced this final report, including the overall summary and conclusions from the review programme, together with recommendations on any gaps in evidence or future research needs. The Topic Review Groups identified particular research needs in their topic areas, so the Assurance Group has only considered overarching issues and concerns in relation to future research needs.

2.12 The Assurance Group comprised three external experts and the Natural England Chief Scientist. The membership of the Group was:

- Professor Colin A Galbraith (Chairman).
- Professor Maggie Gill OBE.
- Dr Simon Pepper OBE.
- Dr Tim Hill.

The Group was assisted by Evelyn Jack and Dave Stone; both from Natural England.

2.13 The specific role of the Assurance Group was:

"To review and quality assure the outputs from the Topic Review Groups and produce the final report which will include an overall summary and conclusions from the review programme, together with recommendations around any gaps in evidence or future research needs".

2.14 In practice this has involved the Assurance Group in:

- Ensuring scientific rigour across the 5 topic reviews.
- Reflecting observations to the Topic Review Groups (an iterative approach was developed between the Assurance Group and the Topic Review Groups).
- Drawing out key themes across the 5 topic reviews which may impact on management in the Uplands.
- Considering the topic review reports against the headlines of scope, content and presentation.
- Commenting on the overarching research needs.

2.15 The following section outlines how the assurance role was undertaken in practice at each stage of the review programme.

3 Assurance Assessment

3.1 This review programme has addressed some of the key areas of work for Natural England and has examined the evidence base for the five key areas listed in 'Topics covered' section above. The review programme has been a large and complex piece of work, undertaken by a range of staff from Natural England with their initial findings scrutinised by external senior scientists from across the range of relevant disciplines. The Assurance Group provided a further important challenge, or second opinion on the work. The Assurance Group considered all the stages of this review programme and formed a view on its key characteristics and of the processes involved. In doing so, it has followed the guidance given in the code of practice from Natural England in relation to quality management, namely that:

- **Evidence** used is of a quality and relevance appropriate to give advice or inform decisions.
- **Analysis** carried out is appropriate to the evidence available and the issue under consideration.
- **Conclusions** are drawn which clearly relate to the evidence and analysis.
- **Uncertainty** arising due to the nature of the evidence and analysis is clearly identified and explained.

Reference: Natural England Operational Standard – Quality Management V0.4.

3.2 In taking forward its work the Assurance Group has considered the following seven questions:

1) Was the scope and proposed coverage of each topic review adequately described?
2) Did the questions used to frame the topic review address the key issues involved?
3) Was the review programme undertaken openly and transparently and were stakeholders involved throughout?
4) Was the literature search comprehensive; seeking out relevant published evidence irrespective of source and geographical location?
5) Was the evaluation of each reference selected as a result of the evidence search undertaken objectively and thoroughly?
6) Were the evidence summaries included in the topic reviews clearly and obviously based on an objective assessment of the evidence presented?
7) Has an effective executive summary of the key findings been produced and has the overarching question for each topic review been answered as far as possible given the available evidence?

Assurance: The initial scope and coverage of the topic reviews

Assurance question: Was the scope and proposed coverage of each topic review adequately described?

3.3 The initial scope of each of the topic reviews was considered by the Assurance Group. Whilst the scope of each was comprehensive, the Assurance Group were aware that some of the topic reviews covered large areas of science relating to complex and detailed aspects of upland management. The Assurance Group advised, after having seen the scope and initial draft of each topic review that the titles of some were broader than the specific questions being asked in the review implied, or in some cases the title was broader than the subsequent evidence base allowed to be fully addressed. For example, the scope of the review relating to the impact of "Tracks" did not address landscape issues; and the evidence base on the impact of tracks on biodiversity was particularly limited, hence titles were modified to more accurately reflect the particular content of the topic review. The gaps in evidence identified in

this process are considered below in Section 5, as part of the executive summaries for each topic review.

Assurance statement: The Assurance Group considers that the scope and coverage of the topic reviews is adequately reflected in the published title and content of each review, but notes that important gaps in the evidence base for some topics have been identified as part of this process.

Assurance: The questions considered by the review programme

Assurance question: Did the questions used to frame the topic review address the key issues involved?

3.4 This review programme on the Uplands is the first in a series of such evidence reviews and the Assurance Group makes two suggestions on procedural change for subsequent review programmes in relation to the questions used to frame the topic reviews.

3.5 Firstly, given the timing of appointing the Assurance Group members, and the start of the programme, it was not possible to involve the Assurance Group in drafting the questions and sub-questions used. This resulted in discussion within the Assurance Group about the way some of the questions were structured and consequently how some of the key issues were addressed. Whilst this lack of involvement in scoping the questions was not a conscious decision, best practice would have been to involve the Assurance Group at this early stage. Whilst this was not perceived to be a major issue, hindsight suggests that any future review programmes might consider involving the Assurance Group in this early stage of the work, in order to add valuable context and insight to how the questions could be drafted.

3.6 Secondly, the Assurance Group suggest that the number of sub-questions, and especially the number of sub-, sub- questions considered in each topic review should be limited, so that the work concentrates on the larger scale, and arguably more important aspects of the work. In addition, it seemed unlikely, even given the comprehensive nature of the review programme, that the most detailed points would be effectively addressed. It would be useful in future review programmes for the Assurance Group to be involved in defining the scope of any subsidiary questions to be considered.

Assurance statement: The Assurance Group suggests that future review programmes involve the Assurance Group from the outset in considering the scope, wording and number of questions and sub-questions to be addressed. This involvement would be 'good practice' for future review programmes and would ensure that the Assurance Group were able to offer input and assurance across the whole process.

Assurance statement: The Assurance Group suggests also that future review programmes consider limiting the number of questions, and subsidiary questions to be addressed, with a view to keeping this to a minimum.

Assurance statement: Noting the Assurance statements above, the Assurance Group is satisfied that the questions used in these topic reviews, do adequately address the key issues examined.

Assurance: Involving stakeholders

Assurance question: Was the review programme undertaken openly and transparently and were stakeholders involved throughout?

3.7 This has been a comprehensive and transparent process which has been undertaken openly, with key stakeholders involved as an integral part of the process. This has included the opportunity for stakeholders to comment on the scope of each topic review in the early stages

of the work; to submit evidence to the review groups; to have sight of the topic reviews in draft via preview on the Natural England website, and to participate in a meeting with the key Natural England staff involved to allow discussion of the draft findings of each topic review and of the assurance process. Table 2 outlines the various stages in this engagement.

Table 2 Stakeholder engagement

Timing/Date	Purpose of engagement	Media
April – June 2012	Developing the Uplands	E-mail, Website, meetings
	Evidence Review scope but specifically the Questions	
June – October 2012	Call for Evidence	E-mail, Website
From October 2012 (4-6 week intervals)	Update on progress, next steps aligned with Upland Delivery Review programme	
	Delivery Review programme	E-mail, Letters, Website
March 2013	Draft Evidence Statements – preview of developing reviews	Stakeholder Event – York
May 2013	Publication	Natural England On-line Publication Catalogue

3.8 This involvement of stakeholders is an important aspect that bodes well for the future use of the outputs from the review programme especially as there will, inevitably, be a period of reassessment for some advice and guidance by Natural England in order to incorporate these new findings. This reassessment will take time and it will, of course, be necessary for the existing guidance and advice to be maintained in the meantime.

Assurance statement: The Assurance Group commends Natural England for the open and inclusive approach taken in the review programme, involving stakeholders in each stage of the process.

Assurance: Literature search and reference sift

Assurance question: Was the literature search comprehensive; seeking out relevant published evidence irrespective of source and geographical location?

3.9 The five topic reviews considered a total of 7441 published papers in the first phase of activity. These were sifted to a short list of 477 for detailed review and for use in formulating the evidence statements presented in the topic reviews. Whilst this is an impressive number of references, it is impossible to state whether every last reference of relevance has been selected at this time. It is, however, evident that this has been a rigorous and in depth search, linked to a clearly structured evaluation process.

3.10 The subject areas covered by the topic reviews are of considerable scientific interest and consequently the range of published studies continues to grow over time. Together with the increasing pace of change in the uplands, this means that it is necessary to take a cautious approach in using historic studies to help inform future actions; while accepting that they may still, in reality, provide the best available evidence.

3.11 The Assurance Group is satisfied that this appears to have been a rigorous part of the process, involving a well structured approach to the selection and evaluation of the

references. The review programme has examined a wide range of studies, in particular, from England, UK, and Europe, and from North America. This geographical spread is important, as it means that “best practice” in management and research has been gathered from all of these geographical areas, providing context for any future research, monitoring and management in the English uplands.

3.12 The search and sift revealed a variety of types of study as follows:

- Randomised controlled trial studies.
- Non-randomised controlled trial studies.
- Comparative (non-controlled) trial studies.
- Correlative (including monitoring) studies.
- Non analytical studies/reviews.
- Expert opinion/formal consensus.

3.13 For further information relating to each of the references selected see the Natural England website.

Assurance statement: The Assurance Group is content that the literature search and reference sift have been undertaken effectively. The Assurance Group welcomes the overall objectivity and transparency of this part of the process, and in particular notes that readers will be able to drill back from the review through to the summaries that the topic groups have written and view the evaluation of the references used in each case.

Assurance: Evaluation of each reference

Assurance question: Was the evaluation of each reference selected as a result of the evidence search undertaken objectively and thoroughly?

3.14 After selection as part of the literature search, each reference was reviewed by one member of staff from Natural England, or if the particular reference was deemed to be problematic by two members of staff. This system has provided a “second opinion” at this stage in the process, when this was thought to be necessary.

3.15 Each reference selected was reviewed and classified into a range of study types as outlined in Table 3 below. Importantly, this classification includes a variety of study types, ranging from meta-analysis to expert opinion, thus allowing a combination of these types to form part of the developing evidence base. Additionally, each reference was scored according to its overall “quality” in relation to the particular questions being asked in each case. It is important to stress the specificity of this scoring system, where the resultant score is relevant to the particular questions being asked in each case only. Significantly, a reference that may score positively in relation to one review question may be scored as minus in relation to another, hence care is needed in relation to any wider interpretation of these results. See Table 4 for the details of the scoring used. This system followed the PICO framework methodology (Stone 2013) and has proved to be robust; providing a clear basis for judgements about the overall scientific “type” and “quality” of the references being reviewed. Importantly, this methodology has in effect, been peer reviewed and refined during the present review programme and has been well received overall.

Table 3 Classification of study types

Rating	Definition
1	Meta-analyses, systematic reviews of randomised controlled studies (RCTs) or RCTs (including cluster RCTs).
2	Systematic reviews of, or individual, non-randomised controlled trials, case-control trials, cohort studies, controlled before-and-after (CBA) studies, interrupted time series (ITS) studies, correlation studies.
3	Non-analytical studies, for example, case reports, case series studies.
4	Expert opinion, formal consensus.

Table 4 Study quality categories (based on the relevance to the questions being asked)

Rating	Definition
++	All or most of the methodological criteria, as set out in the assessment forms, have been fulfilled. Where they have not been fulfilled the conclusions are thought very unlikely to alter (low risk of bias).
+	Some of the criteria have been fulfilled. Those criteria that have not been fulfilled, or not adequately described, are thought unlikely to alter the conclusions (risk of bias).
-	Few or no criteria have been fulfilled. The conclusions of the study are thought likely or very likely to alter (high risk of bias).

3.16 Given the definitions of the study quality categories in Table 4 above, three issues appear to require consideration, however, before the use of this system in any further reviews.

3.17 Firstly, using the terms “minus” or “negative” to describe some of the reference as a result of this scoring system seems particularly problematic, especially as this score relates only to the particular questions being asked and is a reflection of the degree to which it covers the question being addressed. Such terminology is clearly open to misinterpretation in terms of any wider value of particular references. It is suggested that a more neutral term is adopted in future.

3.18 Secondly, it is possible that the system used was overly harsh in scoring what are otherwise considered to be systematic and rigorous field-based studies as “minus”. The Assurance Group recognises that these assessment methods were developed initially for use by the medical profession and are commonly applied to the testing of new drugs and medical techniques. These experimental areas in medicine are, of course carefully designed, with effective replicates and controls, allowing tight statistical analyses; aspects that in many field-based ecological studies are simply not possible. The Assurance Group is aware of related work on the evaluation of such scoring systems; for example, work of the Centre for Evidence-Based Conservation **www.cebc.bangor.ac.uk**, which may be worth further exploration by Natural England in this regard.

3.19 Thirdly, the Assurance Group insisted that the topic reviews focussed principally on the use of positively scored references, thereby providing a robust evidence base. The methodology does, however, allow some use of minus scored references to contribute to evidence statements which are based mainly on other, “positive” references. This is important, as by definition negatively scored references are likely to provide a less than robust basis to inform advice or policy.

3.20 It would be useful therefore, for Natural England to reflect on these issues so that a standard approach can be developed that recognises the unavoidable limitations of the individual field-based studies being evaluated.

Assurance statement: The Assurance Group can provide assurance that the system of assessment and use of references was effective overall. It suggests, however, that the terms "negative or minus" are not used: that any scoring system is not so rigid as to exclude field based data and information which could otherwise reliably contribute to a broader evidence base, and that future review programmes focus on the use of references scored at least in the middle, and preferably at the higher end of the quality spectrum in order to provide the most robust evidence base possible.

Assurance: The evidence summaries

Assurance question: Were the evidence summaries included in the topic reviews clearly and obviously based on an objective assessment of the evidence presented?

3.21 Evidence summaries were drafted for each topic review, drawing on the various references evaluated, and are a key part of each topic review, providing the foundation for later discussions and conclusions. We note here that each evidence statement drafted as a result of the evidence search has been scrutinised firstly by the two independent members of each respective Topic Review Group, and secondly by the independent Assurance Group before inclusion as the basis for the topic sections presented in Section 5 below. This process therefore provides a second and third opinion on the original draft produced by staff in Natural England.

3.22 Importantly, this part of the assurance role involved an iterative process, with the Assurance Group challenging the draft evidence statements and conclusions from each of the Topic Review Groups in order to ensure that a rigorous and objective approach was being taken at all times. The resultant evidence statements and conclusions are therefore as robust as it is possible to draw from the evidence available.

3.23 Whilst these statements are the collective judgement of each Topic Review Group, a standard description of the strength of evidence as strong, moderate or weak was developed and adopted where possible across all of the reviews, thereby bringing a degree of standardisation in approach. A fourth term, "inconsistent" was used where the evidence made it impossible to draw clear conclusions.

3.24 The description of the terms strong, moderate, weak and inconsistent, is of course partly a subjective judgment, taking account of not only the number of supporting studies and their quality scores, based on the criteria in Table 4, but also a consideration of the aims and focus of each study used in the assessment. The strength of evidence was considered as follows:

- **Strong** - evidence from a number of studies, or one or two very high quality studies- all "pointing" in the same direction.
- **Moderate** - evidence from two or three studies, of which at least one must be a minimum of '2+'; all "pointing" in the same direction but some weaker studies may be inconclusive.
- **Weak** - one study or a small number of minus scored studies but all suggest the same conclusions.
- **Inconsistent** - a mix of studies that show both positive & negative conclusions making it impossible to draw a conclusion.

3.25 The Assurance Group took a particular interest in this stage of the process, tracking a number of the summaries back to the original evidence base presented in each topic review in order to check the accuracy of the draft summary statements, and consequently making a number of recommendations as part of the iteration with the Topic Review Groups. The Assurance

Group is satisfied that the resulting evidence summaries are supported by the evidence base in each topic review, accepting that there will, inevitably be a degree of interpretation in relation to the use of individual studies in support of any statement used.

3.26 It should be noted as part of this stage of the review programme, that establishing that a gap in the evidence base exists is a significant result in itself and provides a useful steer for future research. This review programme has confirmed the existence of some unknowns which were already known, and has revealed some previously unknown unknowns! The details of these are provided below in Section 5 as part of the Executive Summaries from each topic review.

Assurance statement: The Assurance Group can provide assurance that the evidence summaries are an objective statement, based on the evidence reviewed and that a common interpretation of the strength of evidence has been used, where possible, across the topic reviews.

Assurance: Executive summaries

Assurance question: Has an effective Executive summary of the key findings been produced and has the overarching question for each topic review been answered as far as possible given the available evidence?

3.27 Each topic review includes an Executive summary presenting the key findings and evidence gaps that have been revealed as a result of this work. The Executive summaries for each of the topic reviews are presented in Section 5 below. These summaries do answer the overarching question in each case, albeit that further work is inevitably required beyond this review to enhance the levels of certainty attached to some of the detail, especially given the scale and complexity of the issues involved. In addition, the Assurance Group stressed the need for a clear synthesis of the key issues and conclusions from each Topic Review Group and emphasised the need for the results to be presented in a way that facilitated the use of the topic reviews by those who prepare advice and guidance to managers and regulatory authorities.

Assurance statement: The Assurance Group notes that Executive summaries have been included in each topic review, with the key conclusions agreed in each case by the external members of each of the Topic Review Groups. These summaries answer the overarching question in each case; however, the Assurance Group highlights the need for further work beyond the completion of this review to add to the levels of certainty attached to these summaries and to provide a better level of synthesis to inform the future preparation of advice and guidance. These issues are outlined in Sections 4-7 below.

4 Assessing the results: Overarching issues

4.1 In considering the outputs from the five topic reviews it is clear that there are a number of overarching issues that will require further consideration if a holistic and inclusive approach to developing the evidence base is to be maintained in future. This section highlights these issues and discusses some of the common needs that have been noted across the topic reviews.

4.2 It is apparent that the evidence base reviewed is less than complete in some areas compared to others. This is not unexpected, and we note again that the standards applied in this review programme have been demanding in terms of the level of scrutiny that each study has had to pass in order to form part of the topic assessments. Whilst this level of scrutiny provides reassurance that the information used at this time is robust and credible, it is important also to realise that the development of the evidence base will not cease with the completion of this review programme. Similarly, advice and guidance will continue to be required to help inform many areas of upland management, even in areas where the evidence base is incomplete at the moment. In such circumstances we encourage the continuation of the provision of advice and guidance based as now, on the best available data and information. Additionally, research should be targeted at those aspects of management where the impacts are still unclear, so that lessons can be learned.

The Ecosystem Approach and Ecosystem Services

4.3 Managing the Uplands has involved a complex set of land-management practices and has produced a close relationship between agricultural interests and nature conservation. We note here that many of the references considered in this review programme demonstrate the close interdependence between both sets of interests. In recent years, however, traditional management of upland areas has had to address some new concepts and to begin to view the upland resource in new ways.

4.4 The Ecosystem Approach; the integrated management of land, water and living resources, that promotes conservation and sustainable use in an equitable way, has proved challenging for many involved in the management of the uplands. This concept, linked to the need to clarify the nature and extent of the Ecosystem Services obtained from the uplands, has brought new perspectives, not just to management but also to the related research and monitoring agenda.

4.5 As noted earlier, the Uplands are now understood to be important not only for traditional services such as the production of food, for example, sheep; fuel, for example, peat and timber, but also for other services including water management, carbon management and tourism. Whilst these new “service” areas are reflected in the references evaluated here, there are still gaps in our collective knowledge about how ecosystems function and as a consequence it will take some years for research to be able to provide a fully informed evidence base to underpin the related policy and management agenda. The recently published UK National Ecosystem Assessment Report (UK NEA, 2011) provides a useful starting point for detailed work to investigate the nature and extent of the services provided from upland areas in England.

Scale

4.6 This review programme has shown that small scale studies have been the norm in the past; but the ecosystem approach, the complexity of demands, the general rate of change, climate

change and the need to develop an outcomes-based approach will require innovative approaches, especially in understanding ecosystem function and its relationship to ecosystem services at a large scale.

4.7 Looking ahead, the need to gain a clear picture of the management required to maintain healthy ecosystem functions as well as benefiting biodiversity and the overall economy of the Uplands, appears to us to be a key research priority if advice and policy is to be implemented at the landscape scale. Equally, the topic reviews have revealed that the detail of management matters where, for example; subtle changes in land-management may have significant implications for the biodiversity interest. Examples of the need for "fine- grained" management have been shown in each of the topic reviews, ranging from the detail of grazing regimes and the importance of "hefting", where sheep flocks have a particular home range, established over many generations in some cases; to the timing of grazing on hay meadows and the detailed pattern and timing of burning on many upland peatland areas.

4.8 The key issue is of course to continue to develop an effective evidence base that encompasses the large scale but that also provides significant information about the detailed management needs of key species and habitats in particular. The related challenge is for this evidence to be applied in the detail of large scale policy measures; for example the implementation of the Common Agriculture Policy, so as to sustain local variation and detail, whilst still adhering to overall EU rules and practices. There is considerable scope here for closely monitored demonstration studies seeking to develop best practice in land-management at the local level in particular.

4.9 As noted above, it is clear from the topic reviews that many of the references reveal the rate and scale of change in many parts of the Uplands. This has important implications for the development of the evidence base in future, with innovative techniques almost certainly being required. For example, where research in the past has focussed on particular species and aspects of habitat management, it seems that a more holistic, multidisciplinary approach will be required in future, along with analysis of new impacts and new management techniques to mitigate these impacts.

Adapting to climate change

4.10 The scope of this evidence review programme was not intended to cover issues related to possible future changes in the climate or to provide a detailed consideration of climate change models. It has been apparent across all the topic reviews, however, that much of the management of the Uplands, for example in terms of the timing and intensity of management events such as grazing or burning, has been dependent on limited climate variability over the years. Equally, a number of topic reviews, for example the moorland grazing review, have highlighted the effects of atypical weather events over recent times. More extreme weather events, including episodes of more intense or prolonged rainfall, are among the trends projected by Defra's UK Climate Projections (**http://ukclimateprojections.defra.gov.uk/**).

4.11 Recognising the relationship between land-management practices and maintaining the conservation interest of the Uplands, and especially given the fine grain and fragility of this relationship that has been revealed in the topic reviews, we suggest that attention needs to be given now to developing a more coherent evidence base on the impacts of a changing climate on the conservation interests of the Uplands, and their relationship with the communities and lifestyles of these areas. In addition, an increasingly variable climate and extreme weather events suggest that conservation of biodiversity would perhaps, in some cases, be best served by greater flexibility and variation in upland management practices, rather than the 'one size fits all' approach that can come about with tight agri-environment prescriptions. For example, this review programme has highlighted the different needs of different species, and that the annual variation in management, due to factors such as the weather, may have played an important part in supporting diversity. The richness of meadow biodiversity, for

example, is not necessarily promoted by rigid prescription of cutting or grazing dates, although that may favour some species.

4.12 There is now a clear challenge for all the agencies that are involved in managing such areas to develop a holistic and integrated approach to monitor and research the impact of climate change in the Uplands. In addition, the impact of climate change will, in all probability, require the reassessment of long-held traditional management practices and consideration of their sustainability as the climate changes. The importance of such traditions in terms of burning practices, grazing regimes and in hay meadow management are all relevant in this regard. Similarly, the construction of new tracks and the restoration of peatlands will need to be mindful of likely changes in the climate over time. Put simply, these changes will place new demands on our understanding of how these ecosystems work, and how they respond to management.

Atmospheric deposition of pollutants

4.13 The issue of chronic pollution has long been known to be a problem in the Uplands of England and in other similar areas across Europe, and has been monitored intensively over many years. The topic reviews have highlighted this as a key issue in the management of the Uplands in future. The topic reviews relating to burning on peatland and on the restoration of blanket bog, in particular, bring the issue of long-term atmospheric deposition of pollution into sharp focus, albeit that some areas containing *Sphagnum* (known to be pollution-sensitive) now seem to be showing some signs of recovery. Here again we would urge that the evidence base relating to this issue is further developed, not just to quantify the levels of pollution occurring but also to inform management actions to prevent further damage and where possible to reverse the damage seen so far.

4.14 Developing the evidence base becomes even more urgent given the recent focus on managing peatlands for “new” and important ecosystem services such as the provision of clean water and for the sequestration of carbon. We draw a comparison here between the demands for ecosystem services now being made of the Uplands, such as the provision of clean water and tourism for example, with the similar demands made of many of the country’s rivers some decades ago. What was achieved in cleaning up river ecosystems has been impressive over recent years, underpinned by an effective evidence base informing management actions to help reinstate a “healthy functioning ecosystem”. Based on the evidence presented in the topic reviews, the time seems ripe for a similar exercise in relation to the Uplands if the ecosystem is to be able to sustainably deliver the range of services being demanded at present and in the future.

A focus on outcomes

4.15 As the wider policy agenda focuses increasingly on “outcomes” rather than simply implementing a process, research and monitoring programmes will need to reflect this requirement and be oriented to enable advice on the desired outcomes to be based on a rigorous evidence base. This presents a considerable challenge for research providers across the board. The topic reviews have shown that there is already a considerable evidence base to support particular land-management outcomes, however, this will need to be supplemented in future as new outcomes are demanded, for example in relation to the management of peatlands to maintain their carbon stores or in relation to large scale water management.

4.16 In view of these changes, it may be less justifiable in future to separate the review of the ecological from the economic and social evidence base. This review programme has demonstrated that many of the studies undertaken in the Uplands over recent decades have focussed on particular aspects of upland ecology or management; considering impacts in isolation of other changes happening in these areas. This focus is entirely understandable, given resources and the particular interests of the researchers concerned, however we now

suggest that given the nature and scale of the evidence requirement that a multi disciplinary approach will be required in future to ensure that delivery of outcomes is effectively underpinned with credible evidence. In addition, part of this multidisciplinary approach should, where appropriate, include consideration of the economic and social aspects of particular management approaches. We note, for example, that the review of blanket bog restoration highlighted the need for judgements to be made about the economics of such restoration and the management options this might include.

4.17 It is important to note that the focus on outcomes reported in the topic reviews also presents a challenge to conservation research overall. Historically much research focussed on the potential and real damage caused to nature conservation in the Uplands from particular developments or from the progressive intensification of agriculture, for example. The challenge now, however, is to develop an evidence base that can inform, from an objective, scientific perspective, the question of what is desired – the "what do you want to achieve" question, rather than simply "what do you want to stop"! This review programme has shown that there are important gaps in the evidence base related to this shift in requirement but it has also shown that taking a positive approach, for example reinstating habitat or maintaining biodiversity, can be delivered effectively with time and effort. This would appear to be true for blanket bogs, for example, where the review concluded that restoration is possible, given time, sufficient resources and a positive approach to management, but this may be an issue still deserving further long term research.

4.18 Again, as noted in several of the topic reviews, the role of ecological networks and linkages between habitats in the Uplands requires further research and evaluation and seems to be an important concept in bringing about re-instatement of many of the habitats discussed here.

4.19 It is important to stress that, if the evidence base reviewed here is to be used to inform innovative management leading to planned outcomes in future, there has to be an active programme linking science to advice, policy and action. It is the view of the Assurance Group that this review programme has facilitated the taking of this next step.

5 Topic reviews – Executive summaries

5.1 The following section contains the Executive Summaries from each of the five topic reviews. Each gives a summary of the key findings and includes a section on the suggested future research that, in the view of the relevant Topic Review Group, is required to address the issues revealed by this review programme. It is important to note that these Executive summaries have also been critically assessed at the draft stage by the Assurance Group.

5.2 The reviews are presented in the following order:

Review 1 – The impacts of tracks on the integrity and hydrological function of blanket peat

Review 2 – Restoration of degraded blanket bog

Review 3 – The effects of managed burning on upland peatland biodiversity, carbon and water

Review 4 – Upland Hay Meadows: What management regimes maintain the diversity of meadow flora and population of breeding birds?

Review 5 – Impact of Moorland grazing & stocking rates

Note: The full citation for each topic review is included for reference.

Review 1 – The impacts of tracks on the integrity and hydrological function of blanket peat

GRACE, M., DYKES, A. P., THORP, S. P. R. & CROWLE, A.J.W. 2013. *Natural England review of upland evidence - The impacts of tracks on the integrity and hydrological function of blanket peat*. Natural England Evidence Review, Number 002.

Executive summary

Management of the English uplands is complex and achieving good environmental outcomes, while taking into account the needs of owners, stakeholders and other interests is a balancing act. An uplands evidence review has been undertaken in which a number of candidate topics have been considered. These topics were identified through stakeholder input, reflection on areas of advice subject to challenge and looking at what could make a difference on the ground. The five priority topics identified have formed the review programme and will help further the understanding of available evidence to support uplands management.

This topic review focused on a series of questions which were evaluated against scientific evidence. The topic review has also helped identify areas for future research; in the next phase, beyond the review programme, additional relevant information will be considered, for example social and economic factors, current working practices and geographic scale. The evidential conclusions drawn from these additional areas will help inform our future advice and practical management of the uplands on the ground.

Context

In recent years, in the English uplands, there has been an increase in the number of requests to construct tracks upon blanket bog for example to facilitate grouse management. In addition to this, there has also been an increase in the use of all-terrain vehicles in the uplands associated with upland management in general. Aside from the visual intrusion on the landscape there are concerns that the use of made and unmade tracks has effects on the processes and structure of blanket peat and are associated with major events such as landslips, as well as more subtle changes that disrupt the active formation of peat. Blanket bog is a globally rare habitat and much of its area receives protection under domestic and European legislation. In order to be able to ensure these sites receive the appropriate protection it is essential that we understand the impacts of track construction and vehicle use.

Purpose and focus of the review

This report covers one of five topics that form the Upland Evidence Review Programme being conducted by Natural England. All five topics have been addressed concurrently and this topic review forms part of the overall programme report.

The original over-arching question for this topic review was:

What are the impacts of tracks on the integrity and hydrological function of blanket peat?

Impacts on biodiversity were included within the scope of this topic review, but other than the loss of surface vegetation, no evidence was found that related to this issue so it is not considered further in this report.

This topic review report therefore addresses the available evidence to help understand the impacts of tracks and vehicle use on the structure and hydrology of blanket peat. Four sub-questions provided further focus for the topic review and these addressed **the structural integrity of peat, hydrological issues, vehicle usage** and **erosion issues**. The sub-questions were outlined in the draft scope of the Review Programme and refined following stakeholder feedback to address the key concerns.

This topic review is confined to a consideration of available information and this is used to identify some knowledge gaps. The topic review does not consider the effect of the state of our knowledge on Natural England's policy and advice; this will be a separate phase of work to follow the Upland Evidence Review Programme.

Process used in reviewing evidence

The initial search of the available evidence produced a list of 754 relevant papers and these were further filtered to identify 106 papers that were directly relevant to the review questions. In turn these were assessed against inclusion-exclusion criteria and evaluated closely. As a result of this process, 49 papers were accepted for quality assessment and data extraction with a further 5 being considered to be of relevance to the topic review although not providing quantifiable evidence.

A topic review group [the authors of this report] was established to agree the interpretation of evidence and from this; the group drew the conclusions that are found in each of the relevant sections. These conclusions were then used to determine a number of recommendations for further research.

Conclusions on the impacts of tracks and vehicle use upon the structure and hydrology of blanket peat

The topic review group has been careful to be led by the evidence and from our consideration of the evidence in which we had confidence we were able to reach a conclusion in respect of all of the sub-questions posed. The lack of evidence addressing the ecological impacts of tracks (aside from impacts upon vegetation) meant that we could not draw any conclusions in that respect.

In answering the over-arching topic review question, *what are the impacts of tracks upon the integrity and function of blanket peat*, it is that tracks have a number of impacts on the structure and hydrology of blanket peat. Constructed tracks affect structural integrity and can cause instability. The hydrology of peat is affected by construction, and drainage through ditches that can further affect stability. As might be expected the type of vehicle, loading and usage influences the impact of unmade tracks and there is evidence to suggest that in these cases erosion can become an ongoing problem.

More particularly, we have been able to reach the following conclusions:

- Tracks alter the structural integrity of blanket peat. Building upon peat compresses the peat and alters the drainage patterns on and around the peat, both within the peat body and over its surface. The level of compression and disruption depends upon the structure and wetness of the peat in question.
  Peat that is loaded (for example, by being built on) will consolidate, the permeability will reduce (affecting natural sub-surface drainage) and the level of surfaces and any structures will settle. Drier peat has a stronger surface layer than very wet or saturated peat, and therefore tracks on dry peat are less likely to cause damage. Drainage ditches can feed or focus water into areas of weak peat, thereby potentially creating instability. Similarly, the cutting of drainage ditches across slopes removes support for the slope

above and damages the structural integrity of the peat deposit. This may also lead to instability.

- Tracks alter the hydrological system of blanket peat at either surface or sub-surface level. The artificial drainage of peat results in the settlement of the peat, which disrupts the hydrology both within the sub-surface peat body and over its surface. Drainage channels are damaging as they result in drying of the peat and may lead to instability of the peat depending upon their position within the slope or by channelling water into areas of structural weakness.
  Constructed tracks result in the settlement of peat and the reduction of sub-surface flow through the peat because of the consolidation process. Compression of the peat through track construction may lead to accumulations of surface runoff water (ponding), which may lead to erosion and/or instability of the track and adjacent peat. Constructed tracks usually require ditches to be made to manage runoff, but these ditches are normally damaging because they result in drying and possibly instability of the peat. Drainage of peat results in deformation (in the form of settlement) of the peat.
- The type of vehicle, loading and usage influences the impact of unmade tracks upon the structural integrity and hydrology of the blanket peat. Vehicle use on unmade tracks is damaging to the surface vegetation. The level of damage depends upon the type of & weight of the vehicle, the number of journeys made and the type and wetness of the peat in question.
  The number of vehicle movements, the weight and the type of tyre or 'caterpillar' track used by the vehicle are relevant, with weak evidence to indicate that rubber 'caterpillar' tracks may reduce the level of impact. One study showed that vehicle use on unmade tracks damages vegetation in ways that may be irreversible. We found that the evidence is insufficient for any meaningful comparisons to be made relating to the impacts of vehicles moving across constructed tracks.
- The disruption of blanket peat by tracks (both constructed and unmade) at surface and sub-surface level results in erosion and this erosion is ongoing. The science does not allow the separation and quantification of this erosion. From the available evidence we have not been able to quantify levels of erosion derived from a constructed track as there is no research that has addressed this subject in isolation.

Research recommendations

Finally, the report sets out a number of concluding remarks and recommendations that are suggested by the evidence, which we hope will be of interest for the direction of future research and operational considerations. Including investigations of:

- The reduction of permeability that results from consolidation at surface and sub-surface levels under a 'floating' constructed track by means of long-term monitoring of a track (or tracks) following construction and with reference to pre-construction conditions.
- The biodiversity impacts arising from (a) altered downslope hydrological conditions and (b) the use of alkaline road gravel (limestone) on otherwise acidic peatland.
- Other relevant hydrological properties of the peat mass including features such as pipes and desiccation cracks, and how they may affect the overall response of the peat.
- The geotechnical properties of the peat mass, how they relate to the botanical composition of the peat and how they change under loading.
- Surficial hydrology, erosion and vegetation change at a variety of contrasting sites damaged by temporary constructed tracks.

Surface and subsurface peat properties and conditions following disturbance by vehicles driving across the peat and with reference to pre-construction conditions.

Review 2 – Restoration of degraded blanket bog

SHEPHERD, M. J., LABADZ, J., CAPORN, S. J., CROWLE, A., GOODISON, R., REBANE, M. & WATERS, R. 2013. *Natural England review of upland evidence - Restoration of Degraded Blanket Bog*. Natural England Evidence Review, Number 003.

Executive summary

Management of the English uplands is complex and achieving good environmental outcomes, while taking into account the needs of owners, stakeholders and other interests is a balancing act. An uplands evidence review has been undertaken in which a number of candidate topics have been considered. These topics were identified through stakeholder input, reflection on areas of advice subject to challenge and looking at what could make a difference on the ground. The five priority topics identified have formed the review programme and will help further the understanding of available evidence to support uplands management.

This topic review focused on a series of questions which were evaluated against scientific evidence. The topic review has also helped identify areas for future research; in the next phase, beyond the review programme, additional relevant information will be considered, for example social and economic factors, current working practices and geographic scale. The evidential conclusions drawn from these additional areas will help inform our future advice and practical management of the uplands on the ground.

Context

The Uplands of England are influenced by multiple users, each exerting a different range of pressures which can result in conflicting priorities. Natural England has a specific role in helping deliver the Uplands Policy Review; in particular through our research and evidence-based advice, our delivery of agri-environment schemes, and our partnership work with the hill farming and moorland management sector and rural communities to deliver a wide range of public goods and environmental benefits. To ensure that the best evidence underpins these strategies, Natural England has undertaken a review programme to gather and assess evidence on a range of key topics affecting the uplands. This topic review presents the evidence relating to the restoration of degraded blanket bogs.

The topic review process

The topic review has been carried out using a robust methodology to assess the balance of evidence concerning specific questions relating to blanket bog restoration. A total of 105 studies have been analysed and summarised for this topic review. This topic review uses the term blanket bog to refer to the habitat which forms blanket peat, and areas supporting predominantly blanket peat are termed blanket peatlands. Since blanket bog habitat can be lost through degradation, the scope of this topic review covers all blanket peatlands. Some evidence has been drawn from research on raised bog peatlands, which represent a closely analogous situation.

The individual questions addressed by this topic review can be summarised as:

- What are the features of an undamaged blanket bog?
- What plants form blanket peat?

- What managements or influences cause degradation to bogs, and how?
- To what extent do restoration management interventions restore bog functions and features?
- Specifically, what are the impacts of grip blocking and is it always necessary?
- Are any blanket peatlands inherently unrestorable?

Summary of conclusions

The wider implications of both degradation and restoration of blanket peatlands are considered in the context of the impacts of damage and restoration.

The review found that undamaged blanket bogs have high water tables which fluctuate in a layer overlying a permanently waterlogged layer of peat. They accumulate peat and are a carbon (C) sink, but emit methane. They have rapid stream responses to rainfall, slowed by any areas of *Sphagnum*, and have low export of dissolved organic carbon (DOC), but also contain some peat pipes.

Peat is formed due to waterlogging, therefore peat-forming plants are those adapted to wet environments. Several studies show that English and Welsh blanket peat is made up mainly of *Sphagnum* and *Eriophorum* remains, along with some remains of dwarf shrubs, but these do not form peat on their own. In some areas and layers there is a large component of unidentifiable grasses/graminoids that may represent *Molinia* remains.

Studies from Scotland show that ploughing and planting trees lowers water tables and causes subsidence of the peat. The topic review found evidence that ploughing and planting trees changes the ground flora, but may reduce methane, and there may be short term gains in carbon capture. Peat cutting can affect bog vegetation and peat left bare dries out on its surface, but not lower down in the peat mass. Cutting drains through blanket peat lowers the water table and discourages *Sphagnum*, while encouraging plants that like drier environments, especially downslope of the drain.

Individual studies report different impacts of drainage on catchment flow characteristics, but widespread surveys show that drainage is associated with more peat pipes. These surveys show that drainage can also accelerate erosion, especially on steep ground, although a recent meta-analysis suggests it is likely to reduce methane emissions. Experimental studies suggest that atmospheric deposition of pollutants may be damaging *Sphagnum*, but there is much evidence of recent *Sphagnum* recovery from across the country.

Land management practice such as drainage, grazing or burning often causes changes in semi-natural vegetation, and is often focused on increasing palatable species or encouraging vegetation dominated by ling (*Calluna vulgaris*). The evidence indicates that areas with more *Calluna* have more peat pipes and more dissolved organic carbon (DOC). Laboratory study suggests this vegetation has higher methane (CH_4) and carbon dioxide (CO_2) emissions than areas with *Sphagnum* or *Eriophorum*. There is some evidence that gullying and hagging, resulting from the development of small stream channels, also lowers the water table in some bogs. Further surveys show that this is most associated with high flat areas of bog, while linear gullies can also form in peat located on steeper slopes. Some palaeoecological studies suggest that gullies may represent channels formed over 200 years ago, and surveys and case studies indicate that they mostly erode slowly. However, other case studies in bare peat areas show more rapid erosion of up to 6 centimetres (cm) loss each year, losing peat into watercourses and by wind erosion.

Studies in Scotland and Ireland show that felling trees can encourage blanket bog vegetation to recover, especially if the plantation is young, or where disposal of waste wood on site by chipping is practised. Many studies demonstrate that bare eroding peat can be re-vegetated and stabilised using nurse grasses or heather. The success rate of this re-vegetation is helped by applications of lime, fertiliser, and stabilising treatments such as geojute. The evidence suggests this will help prevent loss of particulate organic carbon (POC), but will not prevent ongoing loss of peat as dissolved

organic carbon (DOC) or as carbon dioxide (CO_2). Much research from Canada and elsewhere proves that cut-over peatlands can be managed to restore *Sphagnum*, provided the right combinations of water table, chemistry, species, mulches and/or nurse species are used. The evidence suggests that establishment of *Sphagnum* in English blanket peats would seem possible, but has not yet been fully demonstrated. Several studies show that the dominance of *Molinia* can be reduced with intensive application of grazing, cutting and or herbicides. There is some evidence that gully blocking will trap eroding peat sediment which will become re-vegetated.

Most studies show that blocking grips raises water tables, increases abundance and diversity of invertebrates, and there is some evidence that it encourages wetland plants over relatively short timescales. However, studies also indicate that the catchment flow properties and DOC export of grip-blocked peatlands differ between studies, suggesting that they do not rapidly recover to resemble those of undamaged peatlands or that other factors such as topography or vegetation may be more influential. Meta-analysis shows that grip blocking will probably decrease CO_2 emissions but increase methane emissions. A laboratory study suggests that methane may be reduced through leaving grip pools open, not infilling or reprofiling grips and by encouraging *Sphagnum* vegetation, rather than *Calluna* or *Eriophorum*, across the rewetted moor. A survey indicated that not all grips need to be blocked: those on shallow slopes will re-vegetate naturally, and may infill (though may still have a drainage impact).

The topic review found no evidence that any of our blanket peatlands are unrestorable, although costs of restoration effort may not be repaid rapidly by improvements in function, and the timescales for full recovery to approximate undamaged function may be long.

Research recommendations

There are a number of key areas for further evidence gathering, either by conducting a wider review or completing additional research, which would help to inform how best to restore degraded blanket bogs. These topics include:

- natural ‘creep’ of peat masses;
- peat formation by *Molinia*;
- multivariate and community analysis of peat profiles;
- impacts of afforestation on blanket bog birds;
- longer term impact of forestry or deforestation on peatland carbon balance;
- impact of drainage on DOC export, and on CO_2 exchange;
- impacts of atmospheric pollutants on wider bog plant communities;
- impact on peatland function of *Molinia* or its control;
- hydrological impacts of transpiration by vascular plants in bogs;
- recovery of water tables following deforestation;
- management of humidity to encourage *Sphagnum* recovery on low water table areas;
- control of over dominance of bog vegetation by *Calluna* or *Eriophorum vaginatum*;
- hydrological impacts of gully blocking;
- impacts of grip blocking on CO_2 flux, and holistic and multivariate; and
- properly replicated whole-catchment studies of grip blocking.

Review 3 – The effects of managed burning on upland peatland biodiversity, carbon and water

GLAVES, D.J., MORECROFT, M., FITZGIBBON, C., LEPITT, P., OWEN, M. & PHILLIPS, S. 2013. *Natural England Review of Upland Evidence 2012 - The effects of managed burning on upland peatland biodiversity, carbon and water*. Natural England Evidence Review, Number 004.

Executive summary

Management of the English uplands is complex and achieving good environmental outcomes, while taking into account the needs of owners, stakeholders and other interests is a balancing act. An uplands evidence review has been undertaken in which a number of candidate topics have been considered. These topics were identified through stakeholder input, reflection on areas of advice subject to challenge and looking at what could make a difference on the ground. The five priority topics identified have formed the review programme and will help further the understanding of available evidence to support uplands management.

This topic review focused on a series of questions which were evaluated against scientific evidence. The topic review has also helped identify areas for future research; in the next phase, beyond the review programme, additional relevant information will be considered, for example social and economic factors, current working practices and geographic scale. The evidential conclusions drawn from these additional areas will help inform our future advice and practical management of the uplands on the ground.

Context

Peatlands are areas with a naturally accumulated layer of carbon-rich peat, formed from dead and decaying plant material under waterlogged conditions. The United Kingdom (UK) is of international importance for peatlands, holding between 9-15% of Europe's peatland area and about 13% of the world's blanket bog. Upland peatlands in England comprise two UK Biodiversity Action Plan (BAP) priority habitats: blanket bog and upland flushes, fens and swamps, together with the wet heath element of upland heathland, that generally occur on unenclosed land above the Defra Moorland Line.

Burning is widely used as a tool in the management of a range of moorland vegetation types including upland peatlands, principally:

- to create new growth for livestock grazing;
- to increase the diversity of the age and structural of heather[1] for game management; and more recently
- for conservation management.

[1] Scientific names of species mentioned in the Executive summary are given at first mention (and subsequent mentions for plants) in the main text of the report.

In England, upland peatland habitats are often degraded, with the characteristic, varied mire vegetation 'modified', in some cases to the point that it is dominated by a single species, particularly heather or purple moor-grass and, in places, hare's-tail cottongrass (Critchley 2011a, Defra 2011). This reflects a variety of past impacts including those of atmospheric pollution, overgrazing, drainage and burning, including wildfires (UK Biodiversity Group 1999, Natural England 2010, Defra 2011). More recently, concerns have been expressed by some about the possible effects of burning on aspects of biodiversity associated ecosystem services, especially carbon sequestration, and water quality and flow, although the effects are much debated (Yallop *et al.* 2009, IUCN 2011, Worrall *et al.* 2011, Holden *et al.* 2012).

Purpose

The purpose of this topic review is to review the available evidence on the effects of managed burning on upland peatland biodiversity, carbon sequestration and water quality and flow.

Scope

The topic review covers biodiversity maintenance and restoration objectives, including the effects of burning on modified, degraded upland peatland habitats and their restoration, and the effects on carbon sequestration, and water quality and flow, key ecosystem services. Biodiversity is the variety of life and has many different aspects, but in the present context we use it to refer to the habitats and characteristic associated species of flora and fauna of upland peatland habitats, in particular blanket bog, and associated upland habitats on peat soils, including flushes, fens and swamps, and wet heath. Characteristic flora and fauna are those species associated with less modified, functioning, high quality upland peatland habitats.

Restorability per se is not covered (although it is considered in the UER blanket bog restoration topic report, Shepherd *et al.* 2013).

This topic review sets out the evidence base; it does not make recommendations about how this evidence should be interpreted and applied to Natural England's working practice and advice. Consideration of other relevant information, such as practicality of implementation (on which social and economic considerations have a bearing), landscape and archaeology/historic environment, is an important part of the process of developing advice, but is not part of this uplands evidence review programme.

The search for evidence was confined to temperate and boreal peatlands (especially blanket bog, but including other bog/mire/fen/wet heath), biodiversity (flora and fauna), carbon sequestration, water (quality and flow), and (managed) burning. References relating to dry heath, mineral soils, forests, tropical/arctic/tundra areas and wildfire (unless related to the effect of management burning) were excluded with a few exceptions when they provided relevant evidence that was otherwise missing.

Questions addressed by the evidence review

The over-arching topic review question is:

What are the effects of managed burning on the maintenance and restoration of upland peatland biodiversity, carbon and water?

The following sub-questions provide a further focus for the review:

a) What are the effects of managed burning on the maintenance and restoration of the characteristic floristic composition, structure and function of upland peatland habitats?
b) What are the effects of managed burning on the maintenance and enhancement of the characteristic fauna of upland peatlands either directly or indirectly through changes in vegetation composition and structure?

c) What are the effects of managed burning of upland peatlands on carbon sequestration, either directly or indirectly through changes in vegetation composition and structure?
d) What are the effects of managed burning of upland peatlands on water quality (including colouration, release of metals and other pollutants and aquatic biodiversity) and water flow (including downstream flood risk), either directly or indirectly through changes in vegetation composition and structure?
e) How do differences in the severity, frequency, scale, location and other characteristics of burns (including 'cool burns') affect upland peatland biodiversity, carbon and water?
f) How does the interaction of managed burning and grazing affect upland peatland biodiversity, carbon and water?
g) Is there a relationship between managed burning of upland peatlands and 'wildfire' (risk, hazard, occurrence, severity and extent)?
h) What is the extent, frequency, practice and type of managed burning (including 'cool burning') on upland peatlands (including in relation to designated sites and water catchments)?

Due to the multiple factors being considered under most of the sub-questions, evidence relating to discrete elements within these sub-questions was assessed separately. Many references contributed evidence to multiple sub-questions.

Process

An initial literature search and a call for evidence from stakeholders produced a list of 895 references (excluding duplicates). Filtering on title and abstract reduced this list to 492 references that were likely to be relevant and these were obtained and assessed against inclusion-exclusion criteria. As a result of this process, 227 papers were accepted for quality assessment and summarising, with 170 references grouped in to 123 evaluated studies used in the topic review.

Summary of conclusions

The nature and strength of the evidence relating to the effects of managed burning was reviewed for each sub-question and from this, evidence statements and the following conclusions were developed. A total of 54 evidence statements were developed from the evidence derived from evaluated studies. Of these, the majority were classed as strong, 19 (35%), or moderate, 28 (52%), with only six (11%) classed as weak and one (2%) as inconsistent. There were clear differences in the volume and strength of evidence across the eight sub-questions with a greater volume and stronger evidence on the effects on flora, fauna, carbon and water, and on burning extent, but less on the effects of differences in severity, interactions with grazing and wildfire. Recommendations for future research and other evidence gathering to address gaps are made at the end of this summary.

a) What are the effects of managed burning on the maintenance and restoration of the characteristic floristic composition, structure and function of upland peatland habitats?

There is strong evidence that managed, rotational burning results in a change in the species composition of blanket bog and upland wet heath vegetation, at least for a period of time. This included strong evidence that:

- Burning of blanket bog and wet heath typically leads to an initial period of graminoid dominance, in particular of hare's-tail cottongrass, purple moor-grass or deergrass, typically lasting 10-20 years, and with an initial decline in dwarf-shrub cover and in some cases diversity.
- Heather and some other dwarf shrubs tend to decline during the initial graminoid-dominant phase, but typically then increase, especially on drier sites, and may become dominant. This may take 15-20 years or longer on less-modified, wetter blanket bog and may not occur, for example, with too frequent or severe burning and/or heavy grazing.

- Bryophytes as a group tend to decline initially after burning of blanket bog. *Sphagnum* bog-mosses as a group have shown mixed responses, in some cases increasing in the early post-burn stages, sometimes declining or being killed and sometimes then increasing or recolonising after varying periods.
- Burning is associated with the creation of bare ground at least at a fine-scale.

There is moderate evidence that:

- Burning leads to an increase in cloudberry.
- The composition of blanket bog vegetation can continue to show change more than 80 years after the last burn.
- Burns can lead to the creation of relatively flat, unpatterned bog surfaces. This may be followed by the re-establishment of hummock-hollow topography following gradual recovery or recolonisation of *Sphagnum* bog-mosses.

There is relatively little evidence on the effects of differences in burning rotations on peatlands, with only one long-term experimental study (at Moor House National Nature Reserve in the North Pennines) that has covered multiple rotations of differing lengths (10 and 20 years). This provides moderate evidence that differences in frequency of burning affect the vegetation composition and structure of blanket bog. At this site, more frequent burning has promoted dominance of hare's-tail cottongrass, with heather achieving higher cover under the longer rotation.

Changes in vegetation composition and structure may affect the functioning of the peatland ecosystem and hence have effects on associated ecosystem services which are reviewed in subsequent sub-questions. When interpreted in relation to the characteristic floristic composition, structure and function of upland peatland habitats, overall these vegetation responses to burning, in particular the tendency to dominance of graminoids and/or heather may reduce the chance of maintaining active, functioning peatland. Similarly, where restoration is an objective for modified, degraded upland peatland habitats, burning may perpetuate dominance of graminoids or heather.

b) What are the effects of managed burning on the maintenance and enhancement of the characteristic fauna of upland peatlands either directly or indirectly through changes in vegetation composition and structure?

There is strong evidence that burning indirectly influences the invertebrate community composition of upland peatland habitats, typically benefiting open-ground species such as ground beetles and surface-active spiders. Many of the studies indicate an increase in overall species-richness or diversity and suggest that this occurs through increases in structural diversity at a relatively fine scale and the presence of open patches or short swards amongst taller unburnt vegetation resulting from patchwork burning. Thus, conditions are provided for open ground species and for species that favour taller vegetation such as some web-spinning spiders. Many of the studies were carried out on modified upland peatlands and hence not all of the invertebrate species and assemblages are necessarily characteristic peatland species associated with less modified, functioning, and high quality upland peatland habitats.

There is moderate evidence, that too frequent burning is likely to render peatland sites less suitable or unsuitable for the large heath butterfly (a UK BAP species), but that occasional burning may be beneficial perhaps in favouring the larval foodplant, hare's-tail cottongrass, and in reversing succession on at least some drier sites.

There is moderate evidence (reviewed under sub-question d) that burning is correlated with changes in the diversity and composition of aquatic invertebrate assemblages in watercourses draining upland peatland catchments. These changes reflect declines in certain groups, especially mayflies and stoneflies, and increases in flies.

There is strong evidence of correlations between moorland habitat types, their vegetation composition and structure, and densities of some moorland breeding birds, particularly waders. In

few studies has this been related directly to peatlands rather than moorland in general or specifically to burning practice. We can however say that there is strong evidence that:

- Certain species are associated with particular moorland vegetation characteristics. Red grouse and stonechat are associated with increasing heather cover; snipe and curlew with heterogeneity in vegetation structure; golden plover and skylark with short vegetation; waders with wet conditions; whinchat with dense vegetation; stonechat with tall vegetation; and meadow pipit with grass-heather mixes.
- There are correlations between burning and/or predator control intensity and densities of some moorland breeding birds. Higher densities of red grouse, golden plover and curlew with increased burning/predator control were each shown in two studies; and higher densities of lapwing, redshank and ring ouzel each in single studies. Two studies showed lower densities of meadow pipit and single studies showed lower densities of skylark, wheatear and twite with increasing intensity of burning/predator control.
- The dates of first egg-laying of some moorland bird species and the legal burning season (which closes on 15 April in the uplands in England) overlap in the first half of April. In all but one case, it was the minority of first nest attempts (with nine species having more than 10% of first egg-laying attempts before 15 April). This indicates a potential vulnerability for those species that nest on the ground or in vegetation that is likely to be burnt (six species) rather than actual losses. There is also moderate evidence of earlier nesting over time for eight species, which may in the future increase the proportion of first nest attempts by mid-April.

Only one study looked in detail at changes in numbers of breeding birds (for five waders) in relation to burning. This showed moderate evidence of greater declines in golden plover under more intensive (rather than less intensive) burning management and that curlew and lapwing declined more on 'heather-dominated' plots than on 'bog' plots.

One study showed moderate evidence of an increase in breeding success and numbers of lapwing, golden plover, curlew and red grouse and breeding success of meadow pipit in response to legal predator control, indicating that such control contributes to the increases shown by some species on grouse moors in other studies probably in addition to any burning effects.

There is weak evidence of a correlation between burning and/or predator control intensity and overall diversity of moorland breeding birds.

c) What are the effects of managed burning of upland peatlands on carbon sequestration, either directly or indirectly through changes in vegetation composition and structure?

There is strong evidence that managed burning affects various components of the carbon cycle of upland peatlands. This includes strong evidence that:

- Moorland burning results in increased water colouration and/or dissolved organic carbon (DOC) in peatland watercourses.

There is moderate evidence that:

- Burning reduces peat accumulation and reduces above and below ground carbon storage compared to no burning.
- Managed burning can result in erosion and reduction in the level of the soil surface.
- There are increases in gross CO_2 fluxes of respiration and photosynthesis.
- There are carbon loses through fuel consumption during burning and in conversion to char.

Only relatively recently have attempts been made to estimate complete carbon budgets that consider the overall impacts of burning. So far, these have produced inconsistent evidence, with predictions of both positive and negative overall effects of burning, although the estimates provide strong evidence that burning affects the processes controlling carbon budgets of upland peatlands.

d) What are the effects of managed burning of upland peatlands on water quality (including colouration, release of metals and other pollutants and aquatic biodiversity) and water flow (including downstream flood risk), either directly or indirectly through changes in vegetation composition and structure?

As noted above (c), there is strong evidence that moorland burning results in increased water colouration and/or dissolved organic carbon (DOC) in peatland watercourses. Related to this there is:

- Strong evidence that the area of recent burning on deep peat is correlated with an increase in water colouration and/or DOC at the catchment-scale in watercourses draining peatland catchments.
- Moderate evidence that the area of heather-dominated vegetation on deep peat is correlated with an increase in water colouration and/or DOC, in soil water in one case and in watercourses draining peatland catchments in another.
- Moderate evidence from laboratory studies that burning is associated with an increase in water colouration and increased pH (which are likely to be related as pH controls solubility of DOC).

However, the relatively small number of recent small plot- or stand-scale studies of water colouration and/or DOC in relation to burning have shown inconsistent evidence. It has been suggested that this may reflect differences in time since burning (as effects have been shown to be greatest soon after burning) and sampling too deep in the peat (as effects have been shown to occur only in the upper layer).

In relation to soil and water chemistry, there is weak evidence of differences in concentrations of chemical entities after a burn, for example, with aluminium, iron and sodium increasing and calcium, chlorine, bromine and pH declining.

There is weak evidence from small-scale plot/stand studies: of shallower water tables initially after burning; and of increased frequency of surface runoff after recent burning. However, no evidence was identified specifically relating to the effect of burning on watercourse flow or the risk of downstream flood events. If there are any effects, they are likely to be highly site specific.

As noted under sub-question (b), there is moderate evidence that burning is correlated with changes in the diversity and composition of aquatic invertebrate assemblages in watercourses draining upland peatland catchments. These changes reflect declines in certain groups, especially mayflies and stoneflies, and increases in flies.

e) How do differences in the severity, frequency, scale, location and other characteristics of burns (including 'cool burns') affect upland peatland biodiversity, carbon and water?

Few studies were identified that related differences in the severity and other characteristics of burns directly to differences in effects on the four aspects of upland peatlands reviewed under the main sub-questions (a-d). However, there is:

- Strong evidence that moisture content, vegetation type and phenology, recent weather and human factors are important factors in the ignition of fires.
- Moderate evidence that fuel load and structure are critical factors in fire behaviour, particularly in 'fireline' intensity (heat output per unit length of fire front) and rate of spread, although residence time and depth of penetration of lethal temperatures into the soil are perhaps more important in determining severity of impact, but are much less well understood.

Little evidence was identified on the types of burning practice taking place in the English uplands in general and specifically on deep peat, including on the extent to which 'cool burning' is practised. However, there is moderate, recent evidence (reviewed under sub-question h) that burns into the bryophyte and lichen layer occur in a proportion of cases on blanket bog and wet heath.

There is evidence that, in addition to initial fire severity, pre-fire vegetation composition is an important factor influencing post-fire recovery. Related to this, there is moderate evidence (reviewed under sub-question a) that differences in the frequency of burning (ie rotation or return period) affect vegetation composition and structure on blanket bog. More frequent burning tends to promote dominance of single competitive species, particularly graminoids, especially hare's-trail cottongrass and purple moor-grass, and in drier situations, heather.

Some of the catchment-scale studies (reviewed under sub-question d) are relevant to burn frequency as they suggest that water colouration and/or DOC are related to the area of recent burning which is determined by rotation length; the shorter the rotation, the greater the proportion that has recently been burnt. Thus, there is strong evidence that increased frequency of burning results in an increase in water colouration and/or DOC.

No evidence was found that specifically identified differences in effects related to differences in the size or location of burns on upland peatlands, although more generally there is some evidence that larger fires tend to be more variable in terms of intensity and severity. They also reduce diversity at a fine scale in terms of vegetation composition and structure compared to a mosaic of different-aged burns, although this relates particularly to heather and heaths.

f) How does the interaction of managed burning and grazing affect upland peatland biodiversity, carbon and water?

From the relatively small number of evaluated studies that included grazing treatments, there were few significant interactions between burning and grazing, although there are many studies that demonstrate significant effects of these two major moorland management practices separately (see also the UER topic report on the impacts of moorland grazing and stocking rates, Martin *et al.* 2013). It is however possible that interactions may occur at a relatively large, for example, moorland grazing unit, scale and are not easy to pick up in smaller plots. For example, new growth, particularly of graminoids, following burning generally attracts stock. Thus, burning is specifically used for stock management to provide more even grazing. The extent, including the size and distribution of burn patches, as well as total area burnt, can influence the distribution and level of grazing by stock. However, there is:

- Moderate evidence from the only long-term burning and grazing experiment (at Moor House) of some interactions with grazing in the initial period following burning: in particular a greater increase in the extent of bare ground and an increase in grazing on, and reduction in cover of, cloudberry, compared to ungrazed treatments.
- Moderate evidence that burning results in increased grazing of purple moor-grass by sheep and deer, but that this may be short-lived.
- Weak evidence that burning on short rotations and/or heavy grazing after burning can lead to maintenance of the dense graminoid phase in wet heath (rather than its replacement by heather), but that high grazing intensity and low burning frequency pushes the balance in favour of heath rush and mat-grass.

g) Is there a relationship between managed burning of upland peatlands and 'wildfire' (risk, hazard, severity, extent and damage etc)?

Although little evidence was found of a direct relationship between managed burning and the occurrence, severity and extent of wildfire, there is moderate evidence that fuel load and structure are critical factors in fire behaviour. Burning reduces fuel load and may therefore have benefits for fire risk management, alongside other measures such as cutting and/or the creation of a network of

firebreaks and control zones. There may be an increased need for fire risk management in future, if certain climate change scenarios become a reality.

There is moderate evidence that 'heather moorland' in the Peak District, which is mostly managed by rotational burning, is less prone to the occurrence of wildfires than other moorland habitats. Although they still occur relatively frequently. This reflects the large extent of heather moorland and lower than predicted occurrence in relation to area.

h) What are the extent, frequency, practice and type of managed burning (including 'cool burning') on upland peatlands (including in relation to designated sites and water catchments)?

There is strong evidence from a recent national mapping exercise that rotational management burning occurs on about a quarter of the total moorland deep peat resource in England, mostly in the Pennines, Bowland and Northumberland. Over the remainder of the resource, burning on deep peat is now infrequent or does not normally take place, although it did occur on some of this land in the past.

There is moderate evidence that there has been an increase in the extent (and frequency) of managed burning on moorland in England, including specifically on degraded 'dry' blanket bog in the North Peak ESA. There is also moderate evidence of a recent increase in the number of gamekeeper's employed and potential number of shooting days per year (both 29% between 2001 & 2009) on grouse moors in the north of England, although this relates to all heather-dominated moorland rather than specifically peatlands.

There is moderate evidence that there is considerable variation in the frequency of burning on upland peatlands:

- Nationally, the average burn 'return period' (for heather-dominated proportion in brackets) was 64 year (26.5 year). However, this includes the majority of upland peatland that is subject to little or no rotational burning.
- In areas where rotational burning occurs on deep peat, the proportion burnt per year and hence the average return period is higher than the national average: 21.2 year (11.7 year) in the North York Moors, 39.3 year (15 year) in the North Pennines and 73.1 year (25 year) in the Peak District (and 25% in another earlier study of heather-dominated 'dry bog' in the North Peak ESA).
- In most of these areas the proportion burnt per year on upland peatland and dry heath are similar. And
- The proportion burnt per year in the national dataset was similar on Sites of Special Scientific Interest (SSSI) and on (the smaller area of) non-designated upland peatland.

No evidence was identified on the coincidence of burning and water catchments.

There is little evidence on the types of burning practice taking place in the English uplands in general and specifically on deep peat, including on the extent to which 'cool burning' is practiced. There is, however, moderate evidence that burns into the bryophyte and lichen layer and in to sensitive areas occur in a proportion of cases on blanket bog and wet heath (in 11-17% of all, including unburned, samples in two national surveys).

Research recommendations

Assessment of the available evidence indicates that the following areas would benefit from further research:

- The extension of experimental and other monitoring studies of the effects of burning on vegetation and ecosystem services to a wider range of sites across the English upland

peatland resource, ideally including additional medium/long-term studies covering multiple rotations across the full length of typical blanket bog burn rotations (for example, 15-25 year) (which are currently restricted to the Hard Hill experiment at Moor House). Ideally these should consider type of burning (for example, 'cool' and other burns). Such studies should also include the wider range of upland peatland habitats including wet heath, flushes, fens (including valley mires) and swamps, and consider the interaction of burning and grazing across the range of typical stocking rates and regimes that occur in moorland grazing units that include peatland habitats.

- Research on post-burn recovery times in upland peatlands including palaeo-archival studies on vegetation recovery after fire. Research on the effects of burning on the range of characteristic upland peatland species, especially individual *Sphagnum* bog-moss species, including post-burn recovery.
- Improved, more detailed and consistent description of the characteristics of study sites, for example, in terms of habitat, degree of modification, vegetation composition (including *Sphagnum* species) and structure, surface topography and condition, not just in vegetation but in wider studies, for example, on carbon and water. In addition, also recording information about the type and ideally intensity and/or severity of burns in related research projects.
- Improved and more consistent interpretation of existing and new vegetation data from an ecological and nature conservation/biodiversity perspective, for example, including consideration of aspects of autecology, functional types and associations, disturbance, habitats and vegetation community types, habitat condition, associated species, structure (including micro topography) and function.
- Research on restoration management, including the potential use of one-off burning and alternative treatments to reduce graminoid and heather dominance where this is an objective.
- Research on the effects of burning on key characteristic blanket bog species of fauna particularly invertebrates, reptiles and birds (including food availability, for example, craneflies as an important food item for waders).
- Further examination of data on bird nesting dates and breeding success in relation to burning (for example, from Nest Record Cards, vulnerability/risk from burning (especially short-eared owl and stonechat) and pre-nesting activity timing).
- Further studies addressing the relative lack of information on gaseous exchange of peatlands in relation to burning and on char production during burning and its significance.
- Extension of studies on aquatic invertebrates more widely across the English uplands. Interpretation of changes in community composition in terms of water quality and biodiversity, possibly including as food availability for predators (for example, fish and birds such as dipper).
- Studies of the effects of differences in the intensity/severity of fires and characteristics of burn patches such size, shape, location (for example, in relation to slope, watercourses etc), distribution etc
- National collation of data on the occurrence and characteristics of wildfires, including the relationship with managed burning and further study of the occurrence of wildfire in relation to managed burning on upland peatlands, perhaps by extending the modelling work done in the Peak District.
- Repeat of remote sensing surveys to map changes in the extent and frequency of burning on upland peatlands, particularly blanket bog, nationally and in the main areas where burning occurs in the north of England.
- Definitive, agreed mapping of grouse moors, together with data on burning management, for correlation studies, particularly with breeding bird survey data, and the relationship to other land uses including water catchments and designated sites.
- Improved recording of the occurrence and severity/effects of burning and wildfires in site surveys of upland peatland habitats, for example in Natural England's condition

assessment/'integrated site assessment'. National collation and analysis of data from Natural England's condition/integrated monitoring surveys particularly in relation to burning-related attributes. A repeat of the national sample survey of more detailed condition assessment of upland habitats in the Priority Habitat Inventories (last completed in 2008-10), perhaps on a rolling programme with a proportion of new sites added to the existing sites.

Review 4 – Upland Hay Meadows: What management regimes maintain the diversity of meadow flora and populations of breeding birds?

PINCHES, C.E., GOWING, D.J.G., STEVENS, C.J., FAGAN, K. & BROTHERTON, P.N.M. 2013. *Natural England review of upland evidence - Upland Hay Meadows: what management regimes maintain the diversity of meadow flora and populations of breeding birds?* Natural England Evidence Review, Number 005.

Executive summary

Management of the English uplands is complex and achieving good environmental outcomes, while taking into account the needs of owners, stakeholders and other interests is a balancing act. An uplands evidence review has been undertaken in which a number of candidate topics have been considered. These topics were identified through stakeholder input, reflection on areas of advice subject to challenge and looking at what could make a difference on the ground. The five priority topics identified have formed the review programme and will help further the understanding of available evidence to support uplands management.

This topic review focused on a series of questions which were evaluated against scientific evidence. The topic review has also helped identify areas for future research; in the next phase, beyond the review programme, additional relevant information will be considered, for example social and economic factors, current working practices and geographic scale. The evidential conclusions drawn from these additional areas will help inform our future advice and practical management of the uplands on the ground.

Context

Species rich upland hay meadows (UHM) are a rare and diminishing grassland type in England. These meadows support a high diversity of plants and provide valuable habitat for breeding waders and passerines. Despite considerable conservation efforts to protect and maintain them, principally through agri-environment scheme agreements, available evidence indicates that many meadows have continued to decline in quality. This has resulted in concern amongst farmers and ecologists that certain elements of meadow management, promoted under Higher Level Stewardship, may be incompatible with both maintenance of their biodiversity interest and provision of a viable hay crop for winter forage. There is particular concern and disagreement about the following aspects of meadow management:

- the amount, timing and frequency of nutrient and lime applications;
- the intensity of spring-grazing and date at which meadows are ‘shut-up’ for hay; and
- control measures for rushes, which are reported to have increased in frequency within hay meadows.

Purpose

The purpose of the topic review is to report available evidence on these aspects of meadow management and their impact on floristic diversity and populations of breeding birds, which represent the main conservation interests of this grassland type.

Scope

This topic review considers aspects of the management of upland hay meadows and the maintenance of their floristic and breeding bird interest within the context of UK farm regimes. These meadows are important mostly for their variety of plants and providing breeding habitat for a number of species of waders and passerines hence the review's focus on these interests.

This topic review focuses only on the direct effects of grassland management on breeding birds, namely nest destruction by either trampling, hay cutting or other field operations, for example spreading of farmyard manure.

This topic review does not consider evidence on the impact of meadow management on invertebrates, mammals, or species of birds which use the meadows for feeding alone. It does not consider the indirect impacts of grassland management interventions on birds as these have been comprehensively reviewed elsewhere.

This topic review does not consider the effect of the state of our knowledge on Natural England's policy and advice.

The search for evidence was confined to upland hay meadows and closely related neutral grassland from the UK and from analogous meadows across sub-montane and montane areas of western and central Europe.

Wider considerations

The influences of other in-field management interventions, of stocking restrictions and management on open moorland, and wider landscape scale processes on upland hay meadows biodiversity are considered in the introduction in paragraph 1.21 and Section 6 but did not fall within the formal scope of this review so evidence on these was not formally evaluated. However, it will be important that the impact of these factors is accounted for when revised management guidance is drawn up following this review.

Questions addressed by the topic review

The over-arching question for the topic review is:

What management regimes maintain the floristic diversity and populations of breeding birds within upland hay meadows?

Three sub-questions provide further focus, namely:

a) What types, rates of application and timing/periodicity of nutrient and lime applications maintain the floristic diversity and breeding bird populations of upland hay meadows?
b) What management methods or approaches control rushes (*Juncus* spp.) in upland hay meadows and maintain the floristic diversity of the meadows?
c) What spring-grazing levels, timing of shut-up/closure for hay and cutting dates maintain the floristic diversity and breeding bird populations of upland hay meadows?

Due to the multiple factors being considered under sub-questions (a) and (c) evidence relating to discrete elements within these sub-questions was assessed separately.

Process

An initial literature search and a call for evidence from stakeholders produced a list of 1667 relevant papers. Filtering reduced this list to 130 papers that were likely to be relevant and these were assessed against inclusion-exclusion criteria. As a result of this process 49 papers were accepted for quality assessment and data extraction (Annex 1) with 53 additional references being considered to be of relevance to the review although not providing quantifiable evidence.

Summary of conclusions

We assessed the nature and strength of the evidence for each sub-question and from this developed evidence statements and drew conclusions. See Annex 3 for the full list of evidence statements.

What management regimes maintain the floristic diversity and populations of breeding birds within upland hay meadows?

Overall the evidence evaluated provides support for a recognisable traditional hay meadow management regime, but with:

- more meadow-specific tailoring of nutrient input regimes according to soil-nutrient status, past history and management objectives;
- less uniformity of hay cutting dates at the landscape scale than has been the case in the last 20 years, to mimic the longer window for hay cutting that existed in the past when botanical diversity was higher;
- ideally, more flexibility to respond to spring weather conditions in any one year, for example by early shut-up of meadows in warm springs, though further work is required to inform this.

a) What types, rates of application and timing/periodicity of nutrient and lime applications maintain the floristic diversity and breeding bird populations of upland hay meadows?

There is strong evidence showing that nutrient applications of c. 18 kg N ha^{-1} yr^{-1} or greater led to significant reductions in floristic diversity in upland hay meadows and meadows on related neutral grassland types. The limited available evidence specific to Farm Yard Manure (FYM) inputs indicates that rates of 12 tonnes ha^{-1} $year^{-1}$ (equivalent to 9 kg N ha^{-1}, 10 kg P ha^{-1} and 69 kg K ha^{-1} annually) may maintain current diversity on *Anthroxanthum oderatum – Geranium sylvaticum* (hereafter referred to as MG3 following the National Vegetation Classification) meadows which have a history of inputs at this rate, but that botanical enhancements (increases in the cover of positive indicator species) occurred at the lower rate of 6 tonnes FYM ha^{-1} $year^{-1}$.

However, there is strong evidence to suggest that botanical responses to nutrient applications are driven by which ever macro-nutrient is growth-limiting in the grassland and potentially by historic nutrient inputs. As a consequence the additional application of nutrient for any given meadow should be informed by its soil nutrient status, grass utilisation, past fertility management and conservation objectives.

The evidence suggests that the amount of nutrients applied (rate) is the single most important factor influencing botanical response, with the evidence for any additional differential impacts of form (FYM versus inorganic fertilizers) being very limited and equivocal. Similarly the little evidence which does exist for MG3 and related grassland types suggests there is no significant effect of either different timings and or frequencies of nutrient inputs on floristic diversity. Occasional liming to maintain a pH of around 6 appears consistent with maintaining vegetation quality on MG3 hay meadow with a past history of lime application.

In contrast evidence for breeding birds suggests that there are benefits associated with FYM application through increasing prey abundance and availability, and with avoidance of any

agricultural operations (including nutrient inputs) in spring when lapwing are breeding. Whilst no studies examined the impact of application frequency on breeding waders, as a general principle less frequent applications might be predicted to be beneficial in reducing overall disturbance to nests and fledglings.

b) What management methods or approaches control rushes (*Juncus* spp.) in upland hay meadows and maintain the floristic diversity of the meadows?

There was little available evidence on rush control on species-rich grasslands and no evidence relating to their control within upland hay meadows.

Available evidence suggests that mowing rushes flush with the ground at least twice during the summer can reduce their vigour, and where only one cut is possible a late summer cut is most effective. Herbicide by weed wiping application can also be effective, although not without damage to other vegetation. Care should be taken to avoid poaching and creation of bare ground, which abundant rush seed will quickly exploit.

c) What spring-grazing levels, timing of shut-up/closure for hay and cutting dates maintain the floristic diversity and breeding bird populations of upland hay meadows?

Quantitative evidence on the impact of different spring grazing intensities and durations is limited to one study, which suggests that grazing to an average sward height of 5-6 cm rather than 3-4 cm and that shutting up meadows before the 15th May will maintain floristic diversity. This study also points to an important interaction between spring temperature (T-sum) and sward development in any given year and date at which meadows are shut-up, with significant effects on botanical composition particularly likely in warm wet years. The scope to use T-sum to inform the date at which meadows are best “shut-up” should be further explored.

Whilst there is good evidence proving a relationship between trampling by livestock and losses of nests in ground-nesting birds, which increase with grazing intensity and duration, most of the studies evaluated are correlative. None specify a sustainable stocking rate for breeding birds, although one study presents a “standardised trampling value” per type of livestock and per bird species from their data (survival rate per animal per hectare per day) which can be used to determine likely losses over a given grazing period.

There is a clear dichotomy in the preferred grazing intensities of the breeding birds of upland hay meadows between lapwing which prefer a moderate level of grazing to retain a short sward into late spring and the lighter grazed, and more heterogeneous vegetation preferred by other breeding birds (snipe, redshank, curlew, whinchat and skylark).

Studies comparing hay cutting dates indicate that consistently cutting on the 21st July maintains MG3 grassland in the short term (over 4 years). However, the window of time in which hay cutting takes place is significantly shorter than in the period before mechanisation, with most meadows cut by early August instead of cutting extending into September. Periodic late cutting may be helpful in mimicking this past management and allowing return of later seeding species. However, no direct or quantifiable evidence exists to support this assertion.

Evidence from a large number of studies shows that cutting of meadows prior to the peak fledging date of the bird studies reduced nest success. For yellow wagtails, which nest later than the breeding waders which use meadows, evidence suggests that delaying cutting until after 8th July enhances breeding success in the short term. Accumulated spring temperature (T-sum) has been shown to influence nesting and fledging in any one year and subject to further research could be used to inform the timing of hay cut under variable spring temperatures to enable better protection for breeding birds.

Research recommendations

Assessment of the available evidence indicates that the following areas would benefit from further research:

- Examination of the impacts of N application ≤20 kg N ha^{-1} yr^{-1} on floristic diversity (with directly equivalent FYM treatments) across a range of MG3 meadows with different nutrient management histories.
- Exploration of the role of P in influencing floristic diversity on MG3 meadows.
- Investigation of the impact of different seasonality and periodicity of nutrient input on MG3 meadows and its impact on both botanical composition and breeding birds.
- Identification of the reasons for increases in rush species within upland hay meadows.
- Trialling of sustainable, non-damaging rush control measures (including the use of lime) on MG3 meadows.
- The feasibility of determining and applying a threshold T-sum, to inform the time at which meadows are shut-up for any given year. This should be investigated across a range of MG3 sites and impacts on botanical composition and breeding birds assessed.
- Determination of the importance of regeneration by seed in maintenance of populations of long-lived perennials within MG3 meadows.
- Investigation of the historical management of hay meadows and their changing climatic and environmental context.

Review 5 – Impact of Moorland grazing & Stocking rates

MARTIN, D., FRASER, M.D., PAKEMAN, R.J. & MOFFAT, A.M. 2013. *Natural England Review of Upland Evidence 2012 - Impact of moorland grazing and stocking rates.* Natural England Evidence Review, Number 006.

Executive summary

Management of the English uplands is complex and achieving good environmental outcomes, while taking into account the needs of owners, stakeholders and other interests is a balancing act. An uplands evidence review has been undertaken in which a number of candidate topics have been considered. These topics were identified through stakeholder input, reflection on areas of advice subject to challenge and looking at what could make a difference on the ground. The five priority topics identified have formed the review programme and will help further the understanding of available evidence to support uplands management.

This topic review focused on a series of questions which were evaluated against scientific evidence. The topic review has also helped identify areas for future research; in the next phase, beyond the review programme, additional relevant information will be considered, for example social and economic factors, current working practices and geographic scale. The evidential conclusions drawn from these additional areas will help inform our future advice and practical management of the uplands on the ground.

Context

The majority of upland semi-natural vegetation is subject to grazing or forage production. Moorland areas are primarily grazed by pure-bred native sheep breeds, which as well as producing lambs for fattening also provides ewes for cross-breeding on upland in-bye land. This in turn provides breeding stock for lowland farms. Thus the moorland sheep flocks underpin the ‘stratified’ UK sheep industry.

The high nature conservation value of unenclosed upland areas in the UK is recognised through the identification of many of the habitats as Priority habitats in the UK Biodiversity Action Plan (BAP) and inclusion on the list of habitats under the EU Habitats Directive (EU, 1992) Annex 1. Large parts of the English uplands are designated as Special Areas of Conservation (SAC) under the Habitats Directive in recognition of theses habitats, and are Sites of Special Scientific Interest (SSSIs) under domestic legislation.

However, in recent decades overgrazing has impacted on upland landscapes and biodiversity. A major element of agri-environment and other land management schemes is establishing grazing regimes that allow recovery and sustainable management of habitats and which support ecosystem service delivery. Through such schemes the area of SSSI on which overgrazing was a key reason for unfavourable condition has been reduced from 230,000 ha in 2003 to less than 2,500 ha at present.

The Foot and Mouth Disease outbreak of 2001, followed by changes to livestock subsidy payments and a greater emphasis on habitat restoration under agri-environment schemes, has resulted in declines in breeding ewe numbers and beef cattle in upland areas. There are a number of other trends in the structure and practice of upland sheep farms in particular, which are likely to have varying impacts on moorland habitats and ecosystem services.

There remains concern and disagreement about the effects of grazing on the upland landscape and biodiversity, in particular about stocking rates, different livestock types, and the timing and spatial pattern of grazing regimes.

Purpose

The purpose of this report is to comprehensively review the effects of different grazing regimes and stocking rates, including:

- timing of grazing;
- the use of different types of livestock;
- the impacts of livestock management practices and interaction with other land management tools such as burning; and
- the abandonment or absence of grazing on moorland biodiversity and ecosystem service delivery.

Scope

The scope of the review covers the effects of grazing on biodiversity and ecosystem services. The range of outcomes for which research is available varies but generally covers:

- habitat type or mosaics;
- particular plant species or species groups;
- moorland birds;
- invertebrates;
- soils – stability, carbon storage; and
- hydrology.

The review does not consider the effect of the state of our knowledge on Natural England's policy and advice. It does not consider wider social and economic evidence that may influence advice.

Questions addressed by the topic review

The over-arching topic review question is:

What are the effects of grazing regimes and stocking rates on the maintenance and or restoration of moorland biodiversity and on ecosystem service delivery?

The following sub-questions provide a further focus for the review:

a) What is the effect of grazing on moorland biodiversity and other ecosystem services, including timing, frequency and regularity of grazing as well as livestock numbers, and what are the differential effects on integrated moorland ecosystem services?
b) What methods of stocking rate calculation, or setting grazing regimes, consistently provide regimes that maintain or restore moorland biodiversity, and what are the key parameters that calculations should include?
c) What changes have taken place under recent reductions and seasonal changes in sheep grazing, and what is the significance of these changes?
d) Over what timescales can grazing-related change in plant structure and diversity be observed or expected?
e) How is 'under-grazing' defined? What are the effects of low intensity regimes, set to restore small areas of priority habitat within a moorland mosaic, on other parts of the moorland including non-target habitats such as acid grassland?

f) What factors influence the spatial pattern of grazing? How effective are tools such as shepherding and burning in influencing grazing distribution, and how do they interact with stocking rates to achieve improvements in habitat condition and ecosystem services?
g) Do different types of livestock (species and breed), and combinations of livestock, affect moorland habitats differentially?
h) What are the effects of absence or removal of grazing on moorland biodiversity and other ecosystem services?

Process

An initial literature search and call for evidence from stakeholders resulted in 1,192 papers. These were screened by title and abstract for relevance. In total 316 were assessed to be relevant and the full papers were retrieved and checked against the inclusion-exclusion criteria. This resulted in 106 papers being accepted for quality assessment and data extraction (see Section 14). Some additional papers, although not providing quantifiable evidence, were considered relevant as they provided important contextual and background information (see Section 15).

The evidence relating to each sub-question was reviewed and conclusions drawn reflecting the strength of the evidence. In total 116 individual conclusions were derived. There is a high degree of inter-relationship between these sub-questions and recurring themes were drawn out to present a rounded set of conclusions.

Summary of conclusions

A number of key points emerged from the evidence identified under one or more sub-topic, each supported by a number of evidence statements. These key points are presented below, linked to some discussion of aspects of the sub-topics in the context of agri-environment schemes and other work.

The quality of evidence was however found to be variable, with only 21% of the individual conclusions that underpin the above points based on evidence judged as 'strong'. There is a relative lack of good quality studies on which to base management decisions.

Effects of stocking rate

- There is an association between sheep stocking rates at the landscape scale, and the extent and condition of dwarf-shrub communities.
- Where heather is present its condition, in terms of structure and canopy cover/frequency, can improve through reduced grazing pressure.
- The effects of stocking rates based on estimates of vegetation productivity will vary between sites and years.
- Sheep may provide a degree of *Molinia* control where dead material is reduced through cutting or burning.
- Grazing preferences of livestock vary seasonally.
- Grazing levels affects the structure of moorland food webs.
- Atmospheric nitrogen (N) deposition is likely to influence the effects of grazing.

The current practice within agri-environment schemes in England of setting limits in stocking rates, usually with lower maxima in winter, can have some effect of improving the condition of the heather dominated communities. Removal of a smaller proportion of the annual biomass production of the plant allows height to increase and the canopy to develop in area. There is some evidence that low productivity blanket bog and montane habitats have improved in condition where stocking rates have been reduced to annual averages of around 0.05 LU ha^{-1} yr^{-1} or less, often including off-wintering, and similar rates have allowed some recovery of previously suppressed montane plants in some of England's rarest and most fragile upland habitats. The effective stocking rate will vary spatially

across a mixed grazing unit, so rates that allow recovery of particular habitats may be lower or higher than the overall rate.

However, the evidence suggests that expansion in the area of dwarf-shrub communities is usually limited or slow, as grazing pressure may be concentrated on the margins of dwarf shrubs at the interface with acid grassland communities, and opportunities for establishment from seed in closed grassland swards are limited. Where grazing pressure is low overall, competition from tall grasses often restricts the spread of heathland plants.

Within Higher Level Stewardship there is a degree of tailoring of a stocking limit to the grazing unit, by taking account of the relative proportion of different vegetation types. The output is an overall indicative maximum stocking rate for the unit, which may be adjusted seasonally or monthly. This is still a relatively crude approach, and does not take account of geographic and climatic variation, and other factors that will influence the variation in productivity between sites, such as soils and topography.

The plot-scale controlled grazing studies also show that the level of utilisation and stocking rate that maintains heather cover varies, depending on factors such as the relative proportion of heather-to grass in plots. Other climatic and environmental factors will influence heather growth, and therefore the impacts of a given stocking rate at different sites. There is evidence that the productivity of a particular vegetation type will vary between sites, and between years at the same site (for example, by the different numbers of grazing days required to maintain target utilisation rates or sward heights in different years), suggesting that the impact of a given set stocking rate based on standard figures will differ between sites and years.

However, evidence does point to stocking rates that could form the basis of initial, generic guidance, or a check of whether an observed or calculated stocking rate for a site is likely to have positive results. Understanding of the actual response of the range of vegetation types on a grazing unit requires monitoring, designed to collect information on the utilisation of key components of the vegetation and the distribution of grazing impacts. This needs to be done in a way that informs the review and adjustment of grazing regimes to ensure site objectives are met (ie adaptive management).

Effects of recent changes in livestock numbers on moorland

- Expansion of dwarf shrub habitat can be slow or lacking under ESA stocking rates.
- Change in vegetation community type and broad character through grazing reduction or removal may take several decades.
- Low productivity or climatically stressed habitats may respond relatively quickly to changes in grazing pressure.

Whilst the detrimental effects of increased sheep grazing on moorland over the second half of the 20th century have been well documented there is limited evidence to indicate large-scale changes in moorland vegetation communities arising from recent reductions in grazing. However evidence is presented in this review of improvements in habitat condition and positive responses in important plant populations over relatively short timescales. Concerns are expressed by the farming community of the effects of under-grazing, for example, of the spread of bracken. This was not supported by the national Countryside Survey (Countryside Survey, 2009), which detected an increase of 15% in the area of dwarf shrub heath between 1998 and 2007. Whilst not statistically significant and reflecting some changes in analysis methods, the greatest increase was detected in the upland zone, mainly at the expense of acid grassland. Other than this, the area of mountain, moor and heath habitats showed very little change.

Within the dwarf shrub heath broad habitat the main change detected in the upland zone was an increase in the ratio of grasses to forbs, following a decrease in this ratio over 1990-1998. Species that decreased in frequency tend to be shorter grasses and sedges, with increases in taller grasses

and rushes. The dwarf shrub cowberry (*Vaccinium vitis-idaea*) was however among the species with the greatest increase in frequency over this time. There was a significant increase in measures of competitive species in the bog and upland acid grassland broad habitats between 1998 and 2007, and a decrease in stress-tolerant species. Overall cover of bracken and common gorse decreased significantly, and western gorse and hawthorn increased.

The evidence suggests that between 1998 and 2007 there was little indication of large-scale changes in the character of moorland that might result from reductions in grazing pressure. However, there is an indication from the Countryside Survey species results that taller, more competitive plants are increasing in frequency, which may be related to grazing reductions, and is consistent with many of the findings from grazing reduction and exclusion studies reviewed here.

Spatial factors

- The overall impact of a given stocking rate is influenced by the size and distribution of patches of preferred grazing.
- Grazing livestock do not range evenly over a moorland grazing unit.
- Livestock influence vegetation change by mechanisms in addition to grazing defoliation.

In reality, as evidenced here, livestock do not range evenly over an area of moorland and the distribution of sheep in particular is likely to be heavily influenced by the location of preferred

vegetation. In addition, many hill sheep management systems utilize sheep home-ranging behaviour, in maintaining “hefts” or distinct flock grazing areas. The strength and pattern of home-ranging may vary between sheep breeds.

Management hefts are likely to be influenced to some extent by the location of the farm and moorland access points, rather than solely the distribution of vegetation types, although there will be an interaction due to the grazing preferences displayed by sheep. The hefting system, or homeranging behaviour, may have a role in spreading grazing around on shared grazings such as common land.

A likely barrier to the achievement of ecosystem service outcomes, and possibly for biodiversity objectives in particular, is this variability in grazing pressure across a diverse grazing unit. The grazing patterns that result from sheep ranging behaviour and grazing preferences, management practices and topography are unlikely to match the conservation grazing requirements of different habitats and species. A reduction in sheep numbers, resulting either from conservation schemes or changes to farm enterprise structure, will not necessarily deliver these varying grazing requirements fully. A challenge for conservation advisers and land mangers is to better match livestock grazing patterns to the requirements of different habitats.

There is strong evidence that heather utilisation by livestock in general, and sheep in particular, is influenced by the choice of grazing and resting areas within the home range. Impact on heather and other dwarf shrubs is greatest in a narrow zone around grass patches, and the size and distribution of grass patches, along with the proportion of preferred grass species in patches, greatly influences the overall impact of grazing and its effects.

On many English types of moorland there is often a grass-dominated zone on the margins of expanses of dwarf-shrub dominated vegetation, particularly where management of heather for grouse is practiced. Whilst the zone of high heather utilisation may be relatively small in terms of the overall area of heather it is likely to result in contraction of the heather area over time, at a faster rate when livestock numbers are high. There is evidence that sheep are more likely to graze on young regenerating heather than older heather, which may reduce the concentration of grazing pressure in the grass to heather transitions.

The evidence for sheep to select grass patches of a particular size class is inconsistent, with evidence from one study and suggestions from others that sheep preferentially graze larger patches,

and evidence from two related studies that sheep select small patches. This may reflect different learning and experience of the grazing animals, and highlights the need to understand the characteristics of livestock in setting grazing regimes.

The role of cattle

- Grazing pressure and livestock type influences the balance of preferred to less preferred graminoid species.
- Grazing selectivity and choice varies between livestock species and there may be greater inter-breed variation in sheep than cattle.
- Summer cattle grazing is almost as effective as grazing exclusion in facilitating heather establishment from seed.

There is evidence from heather restoration studies that interventions that cause disturbance and create bare ground can aid the establishment of heather. Whilst it is impractical to implement this on a large scale, there may be a role for cattle grazing on moorland in providing localised disturbance, which could aid dwarf-shrub establishment if sheep grazing pressure is low or absent. Cattle have also been shown to graze less selectively than sheep, and may graze grass species such as *Nardus stricta*, usually avoided by sheep. In the medium term this might increase the proportion of preferred grasses in the sward and improve the quality of semi-natural grassland for light/moderate sheep and mixed grazing.

Cattle grazing needs careful management, however, as it can have detrimental impacts on vegetation through trampling and dunging, including damage to woody stems of heather. Evidence indicates that cattle will tend to spend most of their time on more fertile vegetation and around water supplies, and are unlikely to range evenly over a grazing unit. This may serve to reduce grazing on areas that sheep would be more likely to graze, where cattle are the sole grazers, or it may mean that target vegetation is not grazed to the degree that is required. Cattle grazing patterns can encourage sward heterogeneity, with potential to influence the abundance and diversity of different taxa.

Evidence suggests that diets selected by different breed types of cattle are similar, and that breed influence on diet is much less than between breeds of sheep. This may in theory increase the options of farmers in grazing semi-natural areas, utilising more commercially oriented breeds. It is likely however that the condition and productivity of such animals will be compromised where semi-natural moorland vegetation is a significant part of their diet, and that native hardy breeds are better suited to these environments.

Grazing removal and low intensity regimes

- Low intensity mixed grazing regimes can have biodiversity benefits.
- Moderate grazing can maintain plant species-diversity.
- Periods of summer grazing reduction or removal can benefit populations of key plant species.
- Relatively light grazing by sheep can affect the vegetation composition and condition of blanket bog.

There is evidence that periods of sheep removal can benefit not only heather establishment and improvement in condition, but can allow some recovery of heavily suppressed species which have few flowering opportunities, even under light sheep grazing. It is likely that prolonged grazing exclusion could be detrimental in all but the very lowest productivity or most climatically suppressed habitats, as competitive species increase and gaps for colonisation by less competitive species are lost. Targeted short or medium-term grazing exclusion could however be used in managing rare or restricted habitats and populations.

Similarly, relaxation or removal of grazing has been shown to allow recovery or increases in population of invertebrates and some moorland or upland birds, notably black grouse, but as swards become dense the effects are reversed as mobility and access to prey is compromised. There is evidence that tall grass that might be considered a sign of under-grazing can be important for moth diversity, and have increased insect abundance overall. However, studies also show that some moth species of conservation importance are associated with more heavily grazed situations, and skylarks are associated with short vegetation. Other species require tussocky vegetation, or contrasting structure at the foraging or territory scale.

There is some evidence that lightly grazed or ungrazed moorland vegetation is associated with greater soil microbial diversity, but reduced biomass compared to moderately grazed areas. Lack of grazing has been shown to increase carbon storage in above ground vegetation and the litter layer and root zone, but reduce the rate of assimilation of carbon dioxide (CO_2) compared to grazed situations.

It would seem that there is a role for targeted grazing exclusion or removal for allowing habitat or population recovery or providing habitat mosaics for different species. For restoration and recovery clear site-specific targets need to be set, that inform criteria for how and when grazing can be reintroduced.

Under-grazing

The review did not identify any studies that specifically attempted to quantify when moorland might be considered under-grazed. This is not entirely unexpected as the concept of under-grazing is largely a value judgement and dependant on the objectives set for a site or feature. There are however pointers from a number of studies to various scenarios that might be considered under-grazed in terms of the objectives set. A common understanding of what constitutes under-grazing for different outcomes, including livestock management, is required and how this might look in different habitats.

Grazing impacts on soils, water and carbon

- There is a link between grazing and soil erosion and loss.
- The impact of grazing on carbon sequestration and storage within moorland is variable, as it effects the relative contribution of different mechanisms.
- Grazing may have little effect on water quality, at least at relatively low stocking rates.

A significant grazing impact on ecosystem services has been the creation of bare ground and the soil erosion that may follow. This affects the moorland resource, its productivity and the potential for habitat restoration, but also results in siltation of watercourses and reservoirs. Further evidence is provided in the soil erosion studies reviewed here, of the need to limit grazing pressure, and suggests that stocking rates similar to those likely to improve habitat condition can also aid recolonisation of erosion scars. However, since erosion is often initiated on steep ground and where preferred grasses are found, the effective grazing pressure on these areas may be higher than the average for the grazing unit, and requires monitoring and consideration of the spatial distribution of grazing pressure.

Evidence was found that grazing reduced carbon storage in above ground vegetation and the upper soil horizons compared to ungrazed plots. There was no evidence of a consistent effect of grazing on carbon sequestration in deeper soil horizons in moorland peat and organic mineral soils. There was no evidence that grazing affected carbon accumulation in peat, but grazing may positively influence peat forming conditions through promoting a shallower water table.

There is no published evidence of grazing effects on water quality.

Grazing does appear to influence soil microbial communities, in term of biomass and the relative contribution of bacteria and fungi, which in turn affects soil processes such as the rate and efficiency

of nutrient cycling. Grazing removal results in reduced microbial biomass and nutrient (carbon and nitrogen) cycling, due possibly to reduced dung inputs and changes in the character of plant litter. There is evidence that microbial biomass and associated nutrient cycling may be optimal at moderate grazing levels. There is also evidence of a greater proportion of fungi in the soil biota of less intensively grazed and ungrazed sites.

The evidence suggests that “moderate” and “variable” (both spatially and temporally) levels of grazing are the most appropriate for delivery of many ecosystem services (including those related to soil carbon and biodiversity), though not necessarily those related to animal production.

Research recommendations and gaps

- A better understanding of the grazing and ranging behaviour of the common hill sheep breeds in England is needed, as the few studies that exist are based on Scottish blackface sheep. Possible changes arising from changes in the stratified sheep industry, including the trend for cross-breeds in particular, need to be evaluated in terms of what they may mean for grazing levels and patterns on moorland.
- There is a need to develop a more meaningful Livestock Unit (LU) system which takes into account not only the animals‟ nutritional requirements but the grazing choices that are made by different species, breed types and classes of stock when fulfilling these.
- There is a need to explore how information on the spatial distribution of vegetation types in a grazing unit should be used more effectively in setting stocking levels. This could include the examination of the potential role of hefting, as hefting will affect how animals will interact with the pattern of vegetation and its utilisation.
- Further research is required into techniques that can be used to influence the spatial distribution and feeding choices of sheep and cattle, including the provision of water and the use of supplementary feeding. Cutting or burning areas of less preferred vegetation and standing dead material can improve the attractiveness of underutilised areas, and the role of these techniques could be explored further.
- There is a need to develop a common understanding of what constitutes true under-grazing for different outcomes, and how this might look in different habitats.
- The interaction of grazing and heather beetle damage should be evaluated.
- There is a need for better evidence on grazing impacts and achievements – including assessments of the distribution of grazing pressure as well as the response of habitats or species. Methods need to be improved to ensure that ecologically meaningful measurements are made, but that these can be done quickly and efficiently.
- More evidence is needed on carbon budgets in different grazing/soil combinations. As management moves towards considering ecological services in the round, then understanding the trade-offs between different services, such as carbon sequestration and livestock production will be necessary.
- More evidence is needed on the impact of grazing on water quality in different soils.

6 Future research

6.1 It is apparent from the topic reviews that a series of research questions which could help to fill gaps in knowledge and thus enable the answering of more outcome driven questions have been identified as a part of this review programme. A particular gap in delivery identified by the topic reviews is the lack of long-term research and monitoring in the uplands. This is important, as such research and monitoring can add valuable context to observations of short–term changes or events; thereby revealing the longer-term trends that are occurring and adding a level of maturity and depth to any evidence base.

6.2 Additionally, it is clear that in future the development of the evidence base on the state of the environment in the uplands could, as discussed with stakeholders, include the use of innovative techniques such as the enhanced use of remote sensing, developing a multidisciplinary approach to the investigation of particular issues, and the use of citizen science. The latter is becoming an important tool in the collection of survey and monitoring data on a range of species and habitats in other areas, and has the added benefit of developing a greater knowledge base in the volunteers involved in any work.

6.3 The Assurance Group recognises that given the present wider financial situation that it is even more important to target research on the priority questions requiring answers, in this case with respect to Natural England's remit; however, the research requirement described in the topic reviews provides an agenda for a wide range of government and non-government bodies alike. The implementation of this programme of work should therefore not be viewed as being restricted to Natural England alone but developed as a collective effort overall.

7 Concluding remarks

7.1 This review programme has proved to be a valuable, if complex, exercise for Natural England and for the wide range of other stakeholders involved in the management of the English Uplands. We are conscious of the scale of resource that has been deployed to ensure that the review programme has been comprehensive, and recognise that an undertaking of this scale has to be focussed on key priority areas and be closely managed to ensure overall value for money. That said, we suggest that Natural England should keep under consideration the need for an update of the topics considered in this Upland Evidence Review programme, especially after any significant policy changes; or changes in management practices, if the rate of change being observed in the upland environment increases significantly or after some of the key research gaps have been filled.

7.2 Importantly, the resource implications of this exercise have been more onerous than expected, hence consideration could be given to undertaking any future review programme of this scale in partnership with the range of other bodies across the UK that have related responsibilities for the management of upland ecosystems and for the services they provide. The policy implications may vary, but the science is almost universally valid across the UK.

7.3 The next steps following this review programme will include reflecting on the published evidence statements to identify where current guidance may need to be amended.

7.4 The Guidance Refresh project team within Natural England will focus on the guidance relating to the 5 Upland Evidence Review topics. This work is expected to complete in December 2013, and will provide stakeholders with further opportunities to remain involved.

8 References

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Stone, D.A. 2013. *Natural England Evidence Reviews: guidance on the development process and methods (1st Edition 2013)*. Natural England Evidence Review, Number 001.

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Appendix 1 Assurance Group meetings

Table A Assurance Group meeting schedule

Date	Venue	Duration
20 November 2012	Teleconference	11:30 – 13:00
11 January 2013	Teleconference	14:00 – 17:00
29 January 2013	Edinburgh	11:00 – 15:00
12 February 2013	Teleconference	14:00 – 17:00
22 February 2013	Teleconference	10:00 – 13:00
27 February 2013	Edinburgh	09:00 – 13:00
18 March 2013	Edinburgh	11:00 – 15:00
22 March 2013	Teleconference	11:30 – 12:45
8 April 2013	Edinburgh	11:00 – 14:00
3 May 2013	Teleconference	15.00 – 16.30
17 May	Teleconference	15.00 – 16.00

Other related meetings were:

- Stakeholder Event 26 March 2013, York.
- Natural England Science Advisory Committee (NESAC) 8 May 2013, London.

Natural England is here to secure a healthy natural environment for people to enjoy, where wildlife is protected and England's traditional landscapes are safeguarded for future generations.

Catalogue Code: NEER

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