A Review of Sustainable Moorland Management

Report to the Scientific Advisory Committee of Scottish Natural Heritage

October 2015

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Executive Summary

The Board of Scottish Natural Heritage (SNH) requested its Scientific Advisory Committee (SAC) in 2014 to form a sub-group to review sustainable moorland management in Scotland. The review was commissioned in response to a number of concerns expressed to, and by, Board members over the intensification of some moorland management practices. This report presents the findings of the review.

The report is divided into three parts, dealing with background issues (**Part 1**), findings based on an examination of the evidence base (**Part 2**), and emerging issues and recommendations for SNH to consider (**Part 3**). The report is presented primarily from the perspective of natural heritage and biodiversity issues across moorland, noting the three pillars of sustainability – environmental, social and economic.

The sub-group reviewed a large literature and drew heavily on written and oral submissions given in support of a two-day Evidence Hearing, and subsequent requests for further detailed contributions.

Key issues

Four key issues emerged which should be considered in conjunction with the recommendations.

1. Need for a shared vision. There is no shared vision or strategy for Scotland's moorland, beyond that enshrined in legislation and Government policies, and there is a sense of stasis in thinking and ambition over how to develop a programme of work to sustain Scotland's moorlands. We propose that Scotland's Moorland Forum should undertake work to address this – to develop a vision and proposals for realising this. The recently published 'Protected Areas for Nature Review (SNH, 2015f) and Scottish Government consultation on Land Reform (Scottish Government, 2014a) provide an important impetus for this.

2. Moorland deterioration. There is compelling evidence on some aspects of moorland deterioration, and we seek a development of the environmental audit approach to support our understanding of changes, the drivers, and what needs to be done to improve matters (this chimes with the approach espoused in the Scottish Biodiversity Strategy, SBS, *2020 Challenge for Scotland's Biodiversity,* Scottish Government 2013) and the ensuing *Route Map 2020* (Scottish Government, 2015f). The report produced by Moorland Working Group (2002) provided a good inventory of the evidence base, but it is now out of date. We are especially concerned about the decline in some moorland bird populations, notably some of the waders and raptors, but also about the steady loss of heath vegetation cover (connected with heavy grazing pressure and afforestation). For some moorland wildlife there is disagreement over moorland management impacts, partly as a consequence of a weak evidence base, and we have made specific reference to mountain hares in this regard. We heard about some excellent examples of moorland recovery and high standards of management. We were pleased to note the considerable progress being made in support of habitat restoration through Peatland Action (SNH, 2015c), funded by the Scottish Government, and stimulated by the IUCN Peatland Programme (IUCN, 2015).

The peatland work has brought into focus the need for more concentrated action around improving our understanding of 'ecosystem health', the processes underpinning this, and also the adoption of standards for good management to realise this. The advent of the ecosystem approach and

recognition of the importance of quantifying the 'stocks' and 'flows' of natural capital are welcome, though we remain concerned that the inherent value of moorland nature in its own right must be recognised and promoted. We note wide-ranging references to topics such as 're-wilding', 'land degradation' and 'wet deserts', and find these loose. We hope that further, more critical thinking on these topics will be framed in terms of landscape setting and ecological and geomorphological contexts.

3. Evidence gaps. There are some key evidence gaps, and these need to be addressed through further work. In particular, we would like to see continued effort across Government and its agencies to develop a moorland habitat map which can serve as a basis for strategic planning, analyses and scenario modelling. As part of this, we seek enhancements of the evidence base underpinning the Scottish Rural Development Programme (SRDP) in order that we can be clearer about beneficial impacts of funding, and what further areas (geographically, and in terms of natural heritage interests) require support. We commend the ambition of *The Land Use Strategy, LUS* (Scottish Government, 2014b). We advocate devising some novel experimental work to underpin our understanding of moorland ecosystem health. In support of this, we note the importance of investing more effort in mobilising and sharing data and information across agencies in order to economise on spend and effort in evidence gathering and analyses (building on SEWeb, 2015).

4. Standards of management and stewardship. We consider that if we are to see a step change in progressing our stewardship of moorland ecosystems we need to see: a) firm reliance on the scientific (in the widest sense) evidence base; b) adherence to common (and widely shared) standards for good management; and c) recognition of the inherently unproductive nature (in terms of agriculture) of moorland soils which require considerable financial and other inputs to be socio-economically viable. We note the defining role of moorland management in shaping the exceptional international importance of the environmental and cultural values of Scotland's moorland. We heard a diversity of views on the emphasis placed on different aspects of management, and noted that whilst some are heavily regulated (e.g. deer management and predator control) others are less so (e.g. muirburn, tracks and medicated grit provision for grouse moor management).

Recommendations

The ten recommendations for SNH to consider are put forward in conjunction with the above key points:

Recommendation 1*: SNH is asked to update its audit of changes and trends in moorland biodiversity and the influence of land use drivers, and to ensure that biodiversity objectives/outcomes are central to interventions to improve and demonstrate sustainable moorland management.*

Recommendation 2: *SNH is asked to strengthen its geodiversity portfolio in support of its delivery of the 2020 Challenge for Scotland's Biodiversity.*

Recommendation 3: *In consultation with other key stakeholders, SNH is asked to define and communicate its understanding of ecosystem health in relation to moorland, and the adoption of high standards for management practices.*

Recommendation 4: *SNH is asked to ensure that by 2019 the habitat map for Scotland, based on Annex 1 habitat types and the EUNIS habitat classification, is completed.*

Recommendation 5: *SNH is asked to work with the Scottish Government to develop the evidence base on the impact of SRDP spend on biodiversity (notably the relationship between agricultural grazing and High Nature Value outcomes).*

Recommendation 6: *Scotland's Moorland Forum, working with its members and wider stakeholders, is asked to produce a shared vision for Scotland's moorlands founded on environmental sustainability, and to devise a strategy for delivering this.*

Recommendation 7: *The Scottish Government, as it develops national and regional objectives within its Land Use Strategy, is asked to give further consideration to strategic planning and the regulatory framework underpinning moorlands, with due regard given to environmental, social and economic outcomes.*

Recommendation 8: *SNH is asked to work with Scotland's Moorland Forum to design and deliver large-scale and long-term experiments to support our understanding of moorland ecosystem health.*

Recommendation 9: *SNH is asked to complete its inventory of key data on the current management of moorland (e.g. Deer Management Group plans), with protocols governing availability and use by key stakeholders, and noting the need to adapt to climate change.*

Recommendation 10: *SNH is asked to continue its leadership, on behalf of the Scottish Government, in resolving conflicts over moorland land use, conservation and management.*

Part 1. Background

Context

Moorland, peatlands and rough grasslands form a mosaic of semi-natural habitats, little of which can be considered truly natural, having been substantially altered through sustained woodland clearance, grazing, fire and forestry (Moorland Working Group, 2002). Taken as a whole, the uplands cover almost two thirds of Scotland's land surface. Almost 15% of the land is heather-dominated moorland (Figure 1; Thompson *et al*., 1995a, Moorland Working Group 2002) – a cultural landscape. Most moorland is managed for sheep and cattle, deer and grouse shooting, forestry, renewable energy, water provision, recreation, nature conservation and a wide range of amenity interests. The landscape is largely open and dominated by dry and wet heath, blanket bog and rough grassland vegetation. The soils are predominantly acidic and heavily podsolised, and the climate is cool, wet and windy. Much of the active management involves muirburn, sheep and deer grazing, tree planting, and predator control to benefit game species. Historically, drainage was widespread, and over large tracts commercial forestry has replaced sheep walk and grouse moors (see Usher and Thompson, 1988, Robertson *et al*. 2001a, Moorland Working Group, 2002, Van der Wal *et al*., 2011 for details). More recently, wind farms have become prominent over substantial

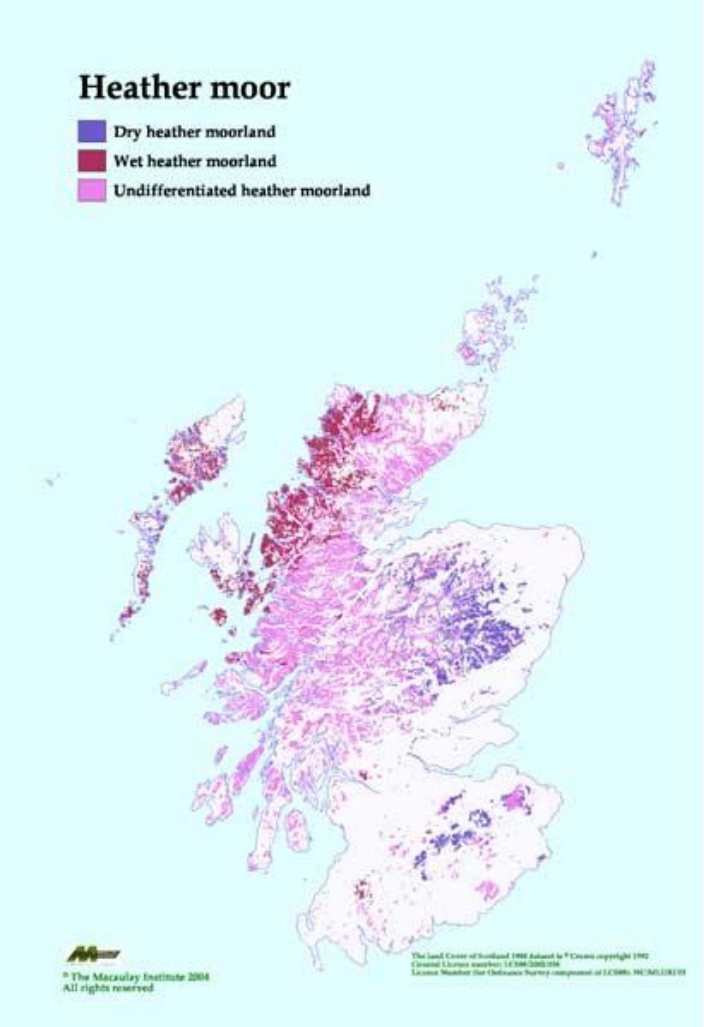

Figure 1. Extent of moorland in Scotland. From James Hutton Institute: http://www.macaulay.ac.uk/explorescotland/lcs_sc_hm2.html

moorland tracts, and there has been substantial investment in peatland restoration to rectify centuries of blanket bog drainage for agricultural purposes.

Several reviews provide comprehensive overviews of moorland ecology and management nationally (e.g. Usher and Thompson, 1988, Thompson *et al.,* 1995a,b, Moorland Working Group, 2002, Bonn *et al.,* 2009, Bain *et al.,* 2011, Marrs *et al.,* 2011, Van der Wal *et al.,* 2011, Averis *et al.,* 2014) and regionally (e.g. Galloway and the Borders: Ratcliffe, 2007; Cairngorms: Shaw & Thompson, 2007). These have been drawn on in preparing this report, along with materials gathered by Scotland's Moorland Forum (Moorland Forum, 2015), and Natural England's recently completed Phase 1 review of the evidence base on the management of the English uplands (Natural England, 2013).

This review is concerned with the evidence base in support of policies and practices pursuant of sustainable moorland management. The three pillars underpinning this are environmental, economic and social, and these are prominent to different degrees over upland Scotland. **The review largely confines itself to open moorland landscapes, and does not address land and wildlife management issues affecting the wider upland and woodland landscapes which in so many parts are interspersed with moorland.**

Why the need for a review?

Periodically questions are asked about the impacts of current land use and associated management practices on moorland, in terms of their impacts on soils, water, wildlife, economic interests and wider environmental, social and cultural services. Several publications have provided substantial overviews, notably Moorland Working Group (2002) and, more recently, Van der Wal *et al.* (2011), and Lindsay & Thorp (2011). The first of these provides a clear summary of trends in moorland habitats and wildlife.

In 2014, the SNH Board raised concerns regarding aspects of the intensification of some moorland management practices. Some of these related to landscape issues and others to the specifics of management practices (such as burning, grazing, track construction and raptor persecution). In response to this, SNH invited its Science Advisory Committee (SAC) to form a Review Group tasked with examining sustainable moorland management issues.

Terms of Reference

The following Terms of Reference for the Review Group were set by the SAC:-

The Group shall provide an overview of the main moorland management practices, in terms of what is known about their extent, practices and impacts on the natural heritage. To support this, the Group will:

1. assess what is known about the immediate and longer-term impacts of these practices on natural heritage issues (using existing reviews);
2. assess the links between evidence and policy needs with regard to the LUS, SBS, SNH's species licensing and Natura requirements, and major programmes of on-going work (e.g. IUCN Peatland programme);
3. reach a view on what are the most significant issues at national and regional levels to guide the prominence we give to relevant work areas;
4. identify gaps in knowledge; and

5. identify any risks associated with failing to identify and achieve sustainable management of moorland landscapes, habitats and wildlife.

Members of the Review Group

The Review Group comprised: Professor Alan Werritty FRSE (Chair, University of Dundee), Professor Robin Pakeman (James Hutton Institute), Dr Colin Shedden (British Association for Shooting and Conservation), Dr Adam Smith (Game and Wildlife Conservation Trust) and Professor Jeremy Wilson (Royal Society for the Protection of Birds). The Secretary was Karen Rentoul, supported by Professor Des Thompson FRSE (SNH).

Preparation of the report

There is substantial literature on moorlands in books, scientific papers, research and technical reports, management guides and website material. The Review Group drew on these, and on some of the more recent policy-related publications. The *Land Use Strategy* (LUS) (Scottish Government, 2011), the *2020 Challenge for Scotland's Biodiversity* (taking forward the earlier *Scottish Biodiversity Strategy: Biodiversity Scotland*, 2015), and the Land Reform Bill (Scottish Parliament, 2015b), all have major implications for moorland management. The *IUCN UK Peatland Programme* (Bain *et al.,* 2011) has also put the spotlight on peatland restoration and management. The challenge of managing deer sustainably is set out in *Scotland's Wild Deer. A National Approach* (*including 2015-2020 Priorities*: Scottish Government 2014d). In stressing the need for a wider landscape perspective, *Protected Areas for Nature: A Review* (SNH, 2015f) is highly germane to sustainable moorland management.

Stakeholders take contrasting views on what was meant by the review topic. **For the purposes of this report we define sustainable management of moorlands as "management which sustains the fullest range of moorland natural heritage features across Scotland, and which supports ecologically and economically healthy ecosystems"**.

Given the wide-ranging nature of issues that arise when assessing the sustainability of moorland management, Group members initially mapped land management practices on to associated land uses, and scored these to identify those practices that, at present, give rise to the most concern. These and other practices are explored in more detail in the main body of the report. Individual Group members then worked in detail on specific aspects of moorland management practices in order to draw out broad findings on impacts, gaps in the evidence base, and key questions.

The Review Group held a two-day Evidence Hearing on 17-18 December 2014 attended by 23 witnesses (see **Annex 1**). The was also attended by several observers from organisations working closely with SNH: Maida Ballarini (Forestry Commission Scotland), Dr Roger Owen (Scottish Environment Protection Agency), Simon Thorp (Heather Trust) and Hamish Trench (Cairngorms National Park), and Roger Burton and Dr Andrew Coupar (SNH). In advance of the Hearing, written submissions were invited from a range of key stakeholders; these are available in **Annex 2,** and in some cases are referred to in the report.

In preparing the report we initially referred to the scientific, technical and policy literature; then to materials provided by way of invited written submissions, further written contributions (**Annex 3**), and information presented during the Hearing (referred to as 'Pers. Comm.').

Structure of the report

Following the introductory background material framing the review, the report comprises three sections:

1. **Over-arching issues:**
   - *Climate change*
   - *Land tenure and management*
   - *Wildlife Estates Scotland*
   - *Governance and regulation*

2. **Report findings:**
   - *Current moorland management practices* (muirburn, grazing-sheep, grazing-deer, native woodlands establishment, peatland and wetland restoration, paths and tracks, vertebrate control and renewable energy)
   - *Land-use drivers for change* (grouse moor management, livestock management, commercial afforestation, woodland restoration and re-wilding, deer management, nature conservation, renewable energy developments, nitrogen deposition

3. **Emerging issues and recommendations:**
   - *Need for a shared vision and strategy for Scotland's moorland*
   - *Key issues underpinning a vision and strategy* (nature conservation, connecting geo-diversity and biodiversity, sustaining ecosystem health, re-wilding, a habitat map, adapting for climate change, meeting priorities using the SRDP)
   - *A way forward for Scotland's moorland ecosystem health*
   - *Novel experiments to understand moorland ecosystem health*
   - *Mobilising and sharing data*
   - *Evidence gaps*
   - *Risks of sustainable moorland management failure and intensification of moorland management*

Over-arching issues

Climate change

Climate change is emerging as one of the key drivers of change across Scotland's moorlands, with evidence for homogenisation of vegetation attributable to climate change (as well as heavy grazing and acidic deposition) already apparent over the past 50 years (Ross *et al.,* 2012). Throughout the 21st century, Scotland's future climate is predicted to have higher temperatures in summer and winter, increased winter rainfall but decreased summer rainfall, and more frequent and more extreme rainfall events (Defra, 2009; Werritty & Sugden, 2012). An increase in climatic extremes is likely leading to more floods and droughts, though it is unlikely that there will also be an increase in average wind speeds. Moorland areas are especially vulnerable to predicted climate change and could be adversely impacted in the following ways (Defra, 2012):

- as blanket bog and other habitats dry out, there will be a reduction in carbon storage and loss of biodiversity;

- the risk of wildfires will increase with adverse impacts on forestry, woodlands, peat soils and heaths;
- whilst increased forest productivity (especially Sitka spruce) will enhance timber production, this will be offset by an increase in pathogens especially threatening native species such as Scots pine;
- the climate space for some species will move northward and/or to higher elevations with potential losses of dominant and iconic moorland species;
- greater risks of some wildlife diseases transmitted by ticks and other insects, which will increase in abundance and extend their range;
- more flash floods in rivers will trigger locally accelerated erosion of river beds with adverse impacts on salmonid habitats and, potentially, aquatic birds;
- agricultural intensification of marginal areas will encroach on moorland; and
- more people will participate in outdoor recreation (e.g. walking, mountain biking) in response to higher temperatures.

As noted later, the threat of these impacts will require an adaptation strategy if moorlands are to support both healthy ecosystems and vibrant rural communities. But it is also important to note that moorlands have a major role in mitigating climate change. Scotland's peatlands contain c. 1,620 Mt of carbon (Chapman *et al*., 2009). Although locally a highly variable store, a mean peat depth of 2 m represents 3,000 to 9,000 years of carbon accumulation (Campbell *et al*., 2012). Growing evidence suggests that this store is being depleted due to pressures of land use and climate change (Bain *et al*., 2011). In order to meet Scotland's emission targets it is vital that these carbon losses are reduced and ideally halted or reversed, with *Peatland Action* (SNH, 2015c) focused on restoring peatlands. The sustainable management of moorlands is thus a key component in delivering the Scottish Government's policy of a low carbon Scotland (Scottish Government, 2014c)) and is a main recommendation in the Annual Progress Statement (Committee on Climate Change, 2015).

Land tenure and management

Land management is funded by land use revenues which are relatively small, in line with the inherently low productivity of upland environments, and usually supplemented by private means, EU Common Agricultural Policy subsidy payments (including SRDP) and other more restricted public and charitable funding streams (e.g. EU LIFE, Heritage Lottery Funds, grants). In terms of tenure, Scotland's moorland is managed largely by private estates, public bodies and NGOs (Who Owns Scotland, 2015). The top 20 land owners in Scotland comprise four government departments/agencies (including SNH, with the Forestry Commission Scotland owning most), three NGOs and community groups, and thirteen private estates. It follows that management by these bodies will largely drive landscape and wildlife composition.

To some degree regulation governs this management. On 2 December 2014 the Scottish Government announced a public consultation on the *'Future of Land Reform in Scotland'* (Scottish Government, 2014a). Earlier, the First Minister set out the Government's vision that "Scotland's land must be an asset that benefits the many, not the few. This vision promotes a strong relationship between the people of Scotland and the land of Scotland, where ownership and use of land delivers greater public benefits through a democratically accountable and transparent system of land rights that promotes fairness and social justice, environmental sustainability and economic prosperity. Under this, Land Reform aims to ensure the correct balance of land rights to achieve this vision. This can only be achieved through a package of measures, taken forward and understood

together". The consultation closed on 10th February 2015, and we note the significance of this for future moorland management.

During the conduct of our review we have been struck by what some have directly called the 'idiosyncratic' nature of moorland management planning and implementation. Beyond directed spend through the SRDP and some public grants, most moorland management is directed by individuals accountable to their owners/land holdings. This does present fundamental challenges if we are to see improvements in the conservation status of some features across protected areas, or wider desired improvements. Noting the diverse patterns of land ownership, we recognise the importance of encompassing the three pillars of environmental, social and economic sustainability in developing an ecosystem approach to sustaining moorlands. Framed by both public and private objectives, sustainable moorland management is as much about resourcing particular activities and behaviours as it is about delivering specified outcomes.

Wildlife Estates Scotland

Few schemes accredit standards of management to whole estate operations, though some are directed at agricultural, forestry, and other development or conservation purposes. Wildlife Estates Scotland (WES) (Wildlife Estates Scotland, 2015) is one of the few national schemes accrediting land management. Currently, 23 estates have been accredited (covering some 270,000 hectares of moorland and other habitats), with five more pending. Sponsored by Scottish Land & Estates, but with validation contributions from Government agencies and NGOs, this scheme offers a good model for wider dissemination (see Annex 3).

However, we do not have a clear evidence base reflecting the state of nature across moorland, and the extent to which this is influenced by management practices *per se* and wider land uses (e.g. Moorland Working Group, 2002). Much of our report focuses on the detail underlying this, but we note that without an evidential framework, we will continue to see what some might regard as *ad hoc* approaches to management planning.

In the evidence sessions and supporting papers there was a recurring theme of setting 'standards' as a key element in making judgements on sustainability. We found these to be patchy in coverage, lacking wide ownership (hence, needing to be co-produced) and without performance evaluation/assurance mechanisms. The revision of '*Principles of Moorland Management*' being undertaken by Scotland's Moorland Forum should set important benchmarks on these standards. Wildlife Estates Scotland is able to highlight where there may be gaps in robust and recognised standards, and provides assurance as to performance against these. This should, in turn, secure improvements in estate management planning and conduct (which importantly could provide links with regional or national plans and strategies).

Governance and regulation

There is no single piece of legislation, regulation or policy determining how Scotland's moorlands are managed, although many instruments are relevant. Instead, legislation tends to be either broad in scope, or associated with particular land uses or land management. Of particular relevance are the EC Birds and Habitats directives which widely influence conservation and management of the natural heritage (e.g. Scottish Government, 2013). The Nature Conservation (Scotland) Act 2004 requires every public body and office-holder to further the conservation of biodiversity, and by the end of

December 2014 reports had to be lodged with the Scottish Government reporting on how the Biodiversity Duty was being met.

The *2020 Challenge for Biodiversity* places heavy emphasis on the importance of sustaining and restoring ecosystem health, and surmises that the National Capital Asset Index (2012) shows moorland to have been the poorest performing ecosystem type since 2006 (Figure 2). The term 'natural capital' refers to the sum value of the stocks of nature, and the services flowing from these. Peatland, which is a component of moorland, has a particularly high natural capital value given its biodiversity and carbon sequestration values, and the many 'services' it fulfils when intact.

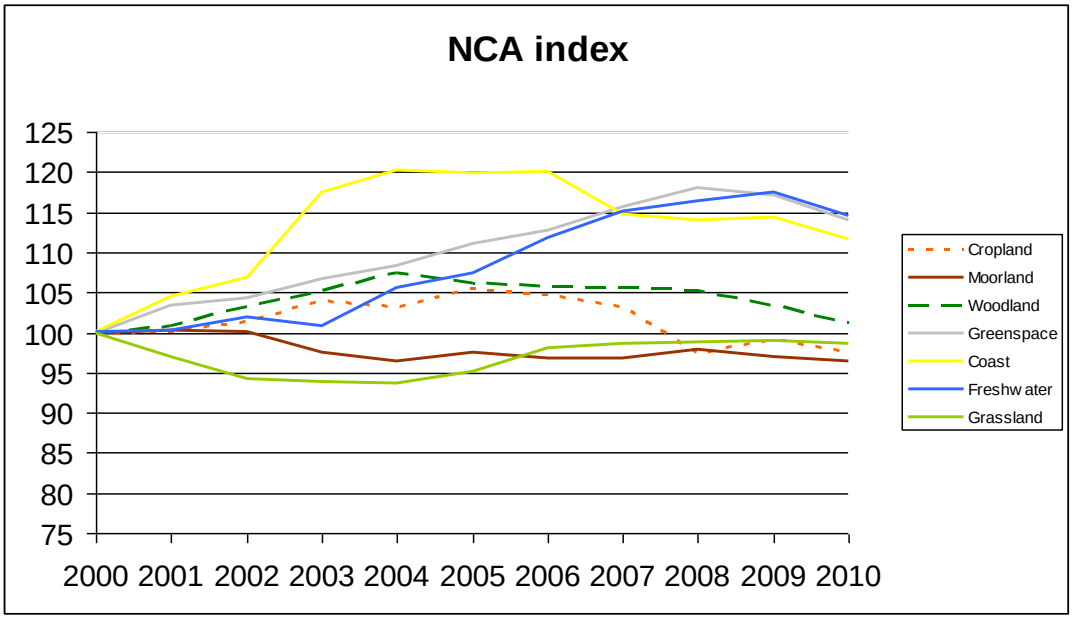

Figure 2. Natural Capital Asset Index. From: http://www.snh.gov.uk/docs/B814140.pdf

The other major aspect of the Nature Conservation Act relates to the designation and safeguarding of Site of Special Scientific Interest (SSSI). SSSIs are the primary designation for areas of land for nature conservation and also provide the underpinning protection for most Natura sites (under the EC Birds and Habitats Directives) and National Nature Reserves (e.g. Scottish Government, 2013). All unimproved semi-natural areas, which include most moorland, are also protected by *The Environmental Impact Assessment (Agriculture) (Scotland) Regulations 2006.*

Large areas of moorland are also provided with certain safeguards through being included within several of our 40 National Scenic Areas (The Planning etc. (Scotland) Act 2006, Town and Country Planning (Scotland) Act 1997, SNH, 2015a). Some moorland also receives policy protection as components of Areas of Wild Land (SNH, 2015b).

The *Land Use Strategy* (*Getting the best from our land - A land use strategy for Scotland)* was laid before the Scottish Parliament by the Scottish Ministers on 17 March 2011 in pursuance of Section 57 of the Climate Change (Scotland) Act 2009 (Scottish Government, 2011). In May 2014, the Scottish Government published its third progress statement and its refreshed Action Plan for planned activities up to 2016 (Scottish Government, 2014b). The *Land Use Strategy* provides a context for all decisions about land use, and the application of the principles to decision-making will, over time, deliver the Strategy's objectives. Thus Forestry and Woodland Strategies (F&WS),

development plans, River Basin Management Plans (RBMPs), National Park Plans etc. all contribute to the range of decision-making processes for delivery of the Strategy's objectives, and all have a bearing on moorland.

The CAP has a particular significance for moorland through its support for agricultural and environmental management and capital investment (Scottish Government, 2015a). The Basic Payments Scheme includes support for rough grazing within Less Favoured Areas (LFAs), much of which is moorland. This support is conditional upon achieving Good Agricultural and Environmental Condition (GAEC) including measures to retain soil organic matter. Another area of CAP influence comes through the SRDP (Scottish Government, 2015b) via the Forestry Grant Scheme, the Agri-Environment Climate Scheme, Scottish Upland Sheep Support Scheme and potentially the Environmental Co-operation Action Fund.

Part 2. Report Findings

Practices

Muirburn

Together with grazing and woodland clearance, fire has helped create moorland (Gimingham, 1995, Yallop *et al.,* 2009). Today, prescribed burning is used to improve spring grazing for sheep and deer, but is deployed mainly on driven grouse moors as rotational strip burning ('strip muirburn') of heather moorland to maintain a mosaic of young and old heather to provide forage and cover respectively for red grouse, (Miller, 1980). This management has played an important role in maintaining dwarf-shrub heaths and, arguably, has improved their resilience in the face of disease and pest species (e.g. heather beetle outbreaks). These heaths are of high international conservation importance (Ratcliffe & Thompson, 1988, Thompson *et al*., 1995a&b), and whilst the dominant component species are found as the understorey in natural woodlands, over much of Britain these heaths are essentially maintained by management. The heterogeneity of vegetation cover and structure that can be maintained by muirburn is capable of creating and maintaining high conservation value in plant, invertebrate and bird communities, although these communities lack fire-intolerant species and the biodiversity associated with native scrub and woodland.

Conservation outcomes from muirburn depend heavily on the interactions between burning rotation length, patch size, edaphic conditions, other anthropogenic pressures (grazing, drainage and atmospheric deposition), and the timescales over which these interactions are measured (Worrall *et al*., 2010, Grant *et al*., 2012, Glaves *et al*., 2013). Where such pressures occur together, they may be synergistically destructive, as in the Peak District (Yallop *et al*., 2009). Moreover, there is evidence that the amount of burning is increasing annually across Britain, with strong evidence of widespread overlap with deep peat soils, especially in northern England (Douglas *et al*., 2015).

The strongest case for long-term detrimental impact of muirburn comes from blanket bogs and wet heaths on deeper peat soils where there is growing evidence that burning is associated with degradation of peat-forming processes and habitat condition, with symptoms including lowered water tables, greater peat temperature extremes, nutrient impoverishment, increased acidity and dissolved and particulate organic carbon (DOC/POC), reduced macro-invertebrate diversity in moorland streams, and difficulties in *Sphagnum* re-establishment (Stewart *et al.,* 2004, Yallop & Clutterbuck, 2009, Clutterbuck & Yallop, 2010, Brown *et al.,* 2014). Increasingly, guidance suggests that sustainable moorland management should see burning cease on blanket bogs and areas of deep peat that might be regarded as recoverable bog (Glaves & Haycock, 2005, Yallop *et al.,* 2009, IUCN UK Committee, 2014).

It has been suggested that prescribed burning has additional socio-economic benefits by limiting the ecological impacts and economic costs of wildfire. For example, in the Peak District grouse moor management is associated with lower frequency of wildfire (McMorrow *et al.,* 2009). However, whilst large, intense fires can be destructive (Maltby *et al.,* 1990), many may have no greater impact than prescribed burns (Clay *et al*., 2010), and evidence suggests that over 50% of wildfires with known causes may themselves be caused by loss of control of prescribed burns (Legg *et al.,* 2006, Worrall *et al.,* 2010, National Trust for Scotland, Pers. Comm.). Overall, the relationship between the

use of prescribed fire and the frequency and extent of wildfires on moorland remains contested, and this is an area where the evidence base needs to be developed.

Grazing – sheep

More than any other management regime, sheep grazing determines the appearance and habitat composition of the uplands. Research has shown that this is a major driver for the vegetation present on moorland, and that the composition and structure of this vegetation controls the diversity and composition of other organisms (Martin *et al.,* 2013). However, most of this work is plot based and there is a lack of information about the impacts of large-scale changes in grazing regime across the uplands (e.g. Robertson *et al.,* 2001b).

Grazing has been responsible for the conversion of large areas from heather-dominated moorland to upland grassland, especially in the Borders, and has prevented extensive tree regeneration (Ratcliffe & Thompson, 1988; Moorland Working Group, 2002). Over the past two decades, however, there has been a decline in sheep numbers, and a further decline could impact on biodiversity, as well as the need for muirburn and ease of access (e.g. SAC, 2008, 2011). It is unlikely that the low level of support from the Less Favoured Area Support Scheme (LFASS) at c. £ 8 ha^{-1} will halt this trend. Arguably, too little grazing is potentially more detrimental to moorland biodiversity than too much (SRUC's Hill and Mountain Research Centre, Pers. Comm.). There is the potential that changes to the CAP would require an increase in stock numbers (to meet the minimum stocking density) which might lead to impacts in areas already with high numbers of deer. Deer numbers are not driven by the CAP, and may have increased in some parts in response to declines in sheep numbers (Waterhouse *et al*., 2008, Thompson, 2011; and see Pollock *et al.,* 2013). Future changes in stock numbers will be driven by the level of LFASS payments, but also by take-up of the 'Scottish Upland Sheep Support' scheme. This has been designed for "sheep producers who farm on Scotland's most challenging land" to help them "maintain the social and environmental benefits that sheep flocks bring to those areas". This is predicted to pay €100 per homebred ewe hogg (9-18 months old) that is kept on the farm or croft from 1 October in year of claim to 31 March the following year" (Scottish Government, 2015c). Along with market driven pressures, these different support mechanisms will probably influence stocking densities, but in what direction is unknown at present.

There is a clear understanding of how to assess grazing impacts (MacDonald *et al.,* 1998) and guidance on the level of utilisation that heather-dominated communities can support (Pakeman & Nolan, 2009). However, this cannot be used directly to set stocking rates because of weather and climate driven variation in productivity and the availability of alternative vegetation that may be grazed in preference (Armstrong *et al.,* 1997; SRUC's Hill and Mountain Research Centre Pers. Comm.). Adaptive management may be the key philosophy to be adopted (Martin *et al*., 2013), but this will necessarily be difficult in moorland systems that are slow to respond to change, and where livestock densities are linked to support payments.

For many years, it has been speculated that high stocking densities of sheep may have an adverse impact on soil water storage and the generation of runoff (O'Connell *et al*., 2004). The detailed relationship between sheep stocking density and flood risk has recently been examined in a multi-scale experimental and modelling study at Pontbren in North Wales (Wheater *et al.*, 2008). Between the 1970s and 1990s sheep numbers increased six fold and animal weights doubled. Since then farmers have planted shelter belts, moved to smaller, hardier breeds and reduced stocking levels.

Modelling studies show that reverting to 1990s patterns of land use, will give rise to frequent flood peaks increasing by 13%. By contrast, optimally located shelter belts could reduce peak flows by 29% and a full woodland cover by 50%. Although these findings relate to improved pasture on an under-drained heavy clay soil, direct observation in the Borders on moorland in the Bowmont Water catchment indicates that high sheep numbers and the resulting soil compaction can decrease infiltration and significantly increase runoff and potential downstream flood risk (M. Wilkinson, Pers. Comm.).

Grazing – deer

The impacts of grazing and browsing by deer on moorland (sometimes referred to as 'deer forest' over the deer range of north and west Scotland) are smaller than those of sheep (Albon *et al.,* 2007). There is, however, evidence that where deer are the main grazers, vegetation is heavily modified (e.g. Van der Waal *et al.,* 2011), and heather condition may be affected, and grasses under-grazed (DeGabriel *et al.,* 2011).

The 2013 review of deer management by the Rural Affairs, Climate Change and Environment Committee (RACCE) (Scottish Parliament, 2015) recognised that red deer numbers (predominantly across the uplands) had increased in recent decades, and could increase further due to factors such as declines in hill sheep (see also Holland *et al.,* 2011).

SNH's site condition monitoring (SCM) (SNH, 2010b) is one indicator that shows that many upland and woodland sites are in unfavourable condition due to excessive browsing and trampling by deer. The Native Woodland Survey of Scotland (NWSS) (FCS, 2014) showed that 33% of native woodlands showed herbivore impacts that could, if maintained, prevent future tree regeneration. Deer were the most common herbivore present. The RACCE report recognised that deer populations are impacting on the natural heritage of Scotland in a number of ways, and identified an evidence gap on such impacts outwith designated sites. The update of *Scotland's Wild Deer: A National Approach (including 2015-2020 priorities)* (Scottish Government 2014d) sets out the detail of work in hand by SNH to address these issues.

Native woodland establishment

While natural regeneration may be a preferred route to establishing upland woods, woodland planting is often used to expedite tree growth (FCS, 2015). Planting costs involve surface cultivation, weeding and protection of planted trees from browsing by guards, fences and culling.

The potential impact of such an activity and subsequent management patterns on open landscapes, particularly moorland, was acknowledged by the Woodland Expansion Advisory Group (Woodland Expansion Advisory Group, 2012).

Several concerns over the impact of native woodland establishment on open moorland were identified by Scotland's Moorland Forum (Moorland Forum, 2008). Planting trees on moorland leads to loss of moorland condition through habitat change, species change (affecting prey and predators), grazing and predation pressure and disease, changes to soils and runoff quantity and quality. Three significant consequences were suggested to us in our evidence gathering sessions. First, within the planted site moorland is lost to woodland. Second, immediately adjacent to the planted site moorland habitats and species are affected by woodland predators and distribution of domestic and wild grazers. Third, beyond the site, at landscape scales, moorland connectivity may be lost,

reducing successful dispersal and thus species resilience to change (also Woodland Expansion Advisory Group, 2012).

The sustainability of the moor affected by and adjacent to woodland planting is likely to be on a spectrum. At the sustainable end, small patches of low stem density, semi-natural woodland in unconnected cleugh sides seem unlikely to impede economic moorland management or affect moorland ecology, and such areas have high biodiversity value. Conversely, at the other end of the spectrum, the planting of large areas of moor will impact on an open moor's biodiversity and soils.

Of course, if the objective is to establish woodland in place of open moorland habitat there are many arguments to support this in terms of biodiversity and wider gains (e.g. Ratcliffe & Thompson, 1988, Gimingham, 1995, 2002, FCS, 2009, 2014, Marrs *et al.,* 2011).

Peatland and wetland restoration

Scotland's peatlands comprise a wide range of moorland habitats (notably blanket bogs and wet and dry heaths) which give rise to and sustain highly organic soils (SNH, 2014). Blanket bogs cover 23% of Scotland's land area, support 94 of the 219 terrestrial Special Areas of Conservation (SAC) extending over 221,000ha and store 1.6 billion tonnes of carbon (SNH, 2014). Well-managed peatlands are a key element in Scotland's low carbon policy (Scottish Government, 2013) and will help to deliver both the *Land Use Strategy* and the *2020 Challenge for Scotland's Biodiversity*. Given that 63% of blanket bogs are currently in "good condition", restoration of the remainder is an urgent priority to protect carbon stores and to promote healthy moorland ecosystems alongside vibrant rural communities.

In promoting the restoration of degraded peatlands and wetlands, Scotland's *National Peatland Plan* (SNH 2014) builds on recommendations in the *IUCN UK Peatlands Programme* (Bain *et al.,* 2011). In Phase 1 of the Plan for 2014/15, SNH has targeted 21 sites for opportunistic restoration where the work will be most effective (e.g. the Flow Country SPA/SAC working with RSPB). Against a total of 600,000 ha of restorable peatland, ambitious targets for restoration are being set (SNH, 2014, Scottish Government, 2015f). In prioritising restoration, the following criteria are being used: firstly, protected areas where the peatland is in an unfavourable and declining condition and secondly, sites registering significant downstream impacts in terms of improved water quality and/or potential flood risk reduction. Active habitat management of partially damaged peatlands (blocking drainage ditches, changing grazing regime and adjusting muirburn practices) should return these sites to a favourable peat-growing state. Where the damage is more severe, measures such as woodland removal, gully blocking and re-vegetating bare peat will be required (Bain *et al.,* 2011). Further detail on SNH's strategy for peatland restoration is given in *Peatland Action* (SNH, 2015c).

Paths and tracks

Paths and tracks are constructed across moorland to provide access for agriculture, forestry, recreation, sporting interests and the installation of renewable energy infrastructure. Whilst tracks are recognised as important for estate management and emergency access, their siting, design and construction remains contentious, particularly in the nationally important areas (National Parks, NSAs and Wild Land Areas) where there have been recent noticeable increases.

Turning first to paths and evidence during the Hearing, it was noteworthy that moorland was seen as having "relatively low landscape and recreational values" and not a "strong appeal for recreation"

(Bob Aitken Pers. Comm.). Many hill walkers evidently regard moorland as a "transition zone" which could explain why recreational conflict in terms of paths is limited in moorland areas. However, the proliferation of fencing (including electric fencing in some areas in Angus) was raised by the National Access Forum as an issue of concern. This was most problematic when fencing is placed across an existing path/track or across a clear ridgeline route without safe cross-points for walkers.

Just as there is little evidence of path-based recreation conflicting with other activities, there was little evidence of a conflict with biodiversity interests. Finney *et al*. (2005) found that when walkers in the north of England stayed on a path breeding golden plover were found up to 50 m from the path, but when walkers strayed from the path the birds stayed 200 m from the path. By contrast, in the Peak District, it was argued that hill walkers affected golden plover breeding success (Yalden & Yalden, 1989).

Turning now to tracks, in its detailed review of the impact of tracks on peatlands, Natural England concluded that the construction of tracks can "affect the structural integrity [of the peat] and can cause instability" (Grace *et al*., 2013), the risk of erosion being determined by the type of vehicle, loading and frequency of usage. But again the Review Group received no written evidence on these issues for Scotland's peatlands. There was also little evidence that such tracks affected biodiversity in Scotland, although similar effects as illustrated by the case studies described above for paths, are possible.

However, concern was expressed about the landscape impact of tracks (both new and existing) in moorland areas. "Visual scarring" was a term commonly used in the evidence sessions, reflecting claims that track construction has not always been done to the best standards. These concerns are long-standing, most recently expressed in the Scottish Environment Link's high profile campaign (Brown, 2013), although others have contested this (e.g. Scottish Land and Estates, 2014). Certainly National Parks, NSAs and the recently identified Wild Land Areas require particular effort to avoid or mitigate detrimental visual impacts from tracks on these nationally important areas. The recent proliferation of tracks has been attributed to an intensification of moorland management, both to facilitate grouse management and to install infrastructure for wind and hydro renewable energy.

The regulation and appropriate scrutiny of tracks has been much debated. Outwith National Scenic Areas, tracks for forestry or agricultural (but not sporting) purposes enjoy permitted development rights. The Town and Country Planning (General Permitted Development) (Scotland) Amendment (No. 2) Order 2014 now requires those considering the construction or alteration of a track with permitted development rights to make a prior notification to the relevant planning authority for approval. This should encourage the better siting and design of tracks. Advice on all aspects of constructed tracks is available from SNH (SNH, 2013).

Vertebrate control

Generalist vertebrate predators – especially crows, foxes, weasels and stoats – are routinely controlled by moorland managers, particularly on driven grouse moors (Hudson, 1992). Alongside habitat and disease management, experimental evidence shows that control of crows and foxes is effective in increasing post-breeding and spring red grouse densities as well as having similar beneficial effects for other ground-nesting birds, including lapwing, golden plover, curlew and hen harrier (Fletcher *et al*., 2010, Baines & Richardson, 2013, Langholm Moor Demonstration Project, 2014). By the same token, when grouse moor management is withdrawn from an area, numbers of

crows and foxes increase, whilst those of breeding waders and hen harriers decline (Baines *et al.,* 2008, Baines & Richardson, 2013). In contrast, there is little evidence that control of mustelids is effective in reducing their populations, and mustelid abundance remains a strong correlate of variation in red grouse survival where crows and foxes are controlled (Fletcher *et al.,* 2010, 2013).

Grouse moor management in some areas has been associated with the illegal killing of protected birds of prey. There is strong evidence that this limits the national range and abundance of hen harriers, golden eagles, red kites and peregrines (Etheridge *et al.,* 1997, Whitfield *et al*., 2003, 2006, Smart *et al*., 2010, Fielding *et al*., 2011, Amar *et al*., 2012). For example, although range and density of species such as hen harrier and golden eagle are almost unaffected by illegal killing over large areas of the Highlands and Islands of Scotland, the limitation has been severe in the south and east of Scotland and in northern England where, the hen harrier is now extremely rare as a breeding species (Redpath *et al*., 2010).

Hen harriers are known to be capable of limiting grouse densities below levels needed to sustain driven grouse shooting, especially on grassy moors where high meadow pipit and vole densities encourage higher settling densities of harriers (Redpath & Thirgood, 1997, Thirgood *et al.,* 2000, 2002), and in these situations hen harriers may also limit densities of meadow pipits and skylarks (Amar *et al*., 2008). The predation of grouse chicks by hen harriers can be alleviated very effectively through diversionary feeding of nesting hen harriers on grouse moors (Redpath *et al*., 2001, LMDP, 2015), but the technique has been little-adopted by grouse moor managers.

The conflict between the interests of driven grouse moor management and raptor conservation remains one of the most challenging in upland management, with proposals discussed including diversionary feeding, intra-guild predation by golden eagles, hen harrier 'brood management' and a move towards a less intensive grouse moor management (Redpath *et al*., 2010). Aside from the impacts of hen harriers, there is little published evidence of marked impacts of other raptors on grouse populations, or on those of other ground-nesting birds (Amar *et al*., 2008, Baines *et al.,* 2008, Fletcher *et al*., 2010, 2013, c.f. Thirgood et al., 1998).

The other vertebrate routinely controlled on moorland is the mountain hare, with *Ixodes ricinus* tick control and sport shooting on grouse moors the major cited reasons, as well as occasional control for protection of young forestry (Patton *et al*., 2010). Although mountain hares are widespread across arctic-alpine heaths, they are favoured by grouse moor habitat management, where they can be important hosts of ticks which, in turn, carry diseases which can kill grouse (Gilbert *et al*., 2001) Although, tick control measures can sometimes improve grouse chick production (Laurenson *et al*. 2003), there is no clear evidence that mountain hare culls serve to increase red grouse densities, and in any case both ticks and louping-ill virus persist when and where alternative tick hosts such as red deer are present at even low densities (Gilbert *et al.,* 2001, Harrison *et al.,* 2010). Given that culling can reduce mountain hare densities to extremely low levels locally (Laurenson *et al.,* 2003), and population trends are poorly known despite the species being listed under the Habitats Directive, the case for widespread and intensive culling of mountain hares in the interests of louping-ill control has not been made. In this regard, we note the call by SNH, GWCT and SL&E for voluntary restraint on large culls in December 2014, and urge vigilance to ensure the conservation status of mountain hares in the uplands is assured.

It is also clear that we need much improved monitoring methods and data to assess national trends in mountain hare populations. SNH-led work is being developed to address this. A combination of National Gamebag Census data, data from upland Breeding Birds Survey plots (where mammal observations are also collated) and unpublished, long-term time series data of mountain hare counts made known to SNH by Dr Adam Watson (Annex 3) provides the opportunity for a more systematic and comprehensive analysis of trends from data already to hand. These latter data derive from 63 moorland sites, mainly in upland Aberdeenshire, with data in some cases extending back to the 1940s. Initial examination of this remarkable data set provides a strong *prima facie* case for long-term population declines across moorland but not arctic-alpine habitats. We advise that SNH should complete a fuller analysis of these and other available data, and consider further conservation, management and research work on this species.

Renewables

Renewable energy developments have brought great change to many of our upland and moorland areas in the past 20 years. Wind farms are the most obvious change at the landscape scale, with over 200 developments in place to date which equates to 4921 MW with 3556 MW consented but not built and 3745 MW in planning (Scottish Renewables, 2015). Small scale hydro schemes, though mostly less visually intrusive, have similar impacts on the ground.

Although optimising energy production is clearly a key driver for any renewables development, numerous constraints influence the final configuration. These include habitat, soil and landscape considerations. Minimising the carbon footprint through use of the 'carbon calculator' is also important, and is a material consideration in relation to Section 36 applications (see: Scottish Government, 2015e).

The main impacts on moorland habitats are from direct land take for tracks, crane hard standings, turbine bases, control buildings and borrow pits and changes in drainage. There are also indirect impacts associated with these operations – most notably cable trenches and pipelines. These impacts result in habitat loss and habitat change through altered hydrology which in turn, can lead to changes in how a wide range of animal species use these areas. Additional impacts can arise through the improved access provided by these developments, enabling sporting and recreational activities in areas which were previously inaccessible and/or unattractive. There is no shortage of good guidance relating to wind farms (SNH, 2015d) and the construction of tracks, both general (SNH, 2013) and floating (SNH, 2010a). Where previously afforested areas are felled returning land to a moorland habitat – albeit with turbines – over time this could be beneficial in enhancing overall biodiversity.

Published studies on wind farm developments and bird collision mortality are scarce. Two led by RSPB across multiple developments have, first, compared moorland breeding bird densities on operating wind farms and in nearby control areas, whilst controlling for habitat variation (Pearce-Higgins *et al*., 2009) and, second, assessed change in populations during and after construction in comparison with control sites (Pearce-Higgins *et al*., 2012). The first of these studies found that seven of twelve species studies showed reduced densities within wind farm areas relative to controls, equating to estimated density reductions of 15-48% within the wind farm footprint and a 500 m buffer. The second found more evidence for declines during than after construction (e.g. for

red grouse and curlew), although some species such as stonechat and skylark may have benefitted from habitat change during construction.

To mitigate such impacts, most renewables developments prepare and implement a Habitat Management Plan. These clearly have to be very site-specific to address local priorities, but again generic guidance (SNH, 2015e) is available to provide a steer.

Land-use drivers for change

Grouse moor management

Grouse moor management is a package of activities which manipulates three parameters: habitat, predation pressure and disease transmission. Only where grouse shooting is a primary objective are all three manipulations consistently undertaken on a moor, the intensity and regularity of the activity varying within and between regions and sites over time (Hudson, 1992, Baines *et al.,* 2008), as a function of desired bag size. These activities are undertaken primarily to produce a harvestable surplus (bag) of grouse, but evidence indicates a range of other environmental costs and benefits associated with such management (e.g. Grant *et al.,* 2012). Those activities associated with burning and predator control are discussed in more detail in other sections of the report.

A national and international demand for recreational driven grouse shooting (Dunlop & Smith, 2012) has propelled this to become a dominant or shared objective on around 20-30% of Scotland's moorland over the past 100 years. This demand drives the investment in management (Sotherton *et al*., 2009) and there is no apparent decline in demand for grouse shooting (CKD Galbraith, 2014). Indeed, after decades of decline in investment in driven grouse shooting moors, there is evidence pointing to a recent upsurge in investment, with more moors showing signs of intensive management associated with this (e.g. Savills, 2014). However, it is important to note that there is no contemporary map of heather moorland showing areas managed for red grouse c.f. other land uses (see Douglas et al., 2015).

Grouse moor management is designed to maintain the viability of the harvested grouse population, whilst providing sufficiently large and consistent numbers of grouse to be shot. However, individual practices have consequences for other aspects of sustainable moorland management (Van der Wal *et al*., 2011). Examples of trade-offs include medication to control grouse parasites stabilising grouse productivity and supporting continued investment, but allowing grouse densities to reach levels where novel diseases are expressed (Baines *et al*., 2014b) and with possible wider environmental impacts of the medication (Oh *et al*., 2006). Track and fence construction/renovation may be prompted and influence recreational access opportunities. Muirburn conserves open moorland habitats (Robertson *et al.* 2001a) but restricts woodland expansion, and can damage peatlands (see Muirburn section). Raptor, passerine, deer and hare populations are also constrained, though some ground-nesting species other than red grouse benefit from the predator control typically associated with grouse moor management (Fletcher *et al.* 2010; Baines *et al.,* BOU conference presentation, 2014). The scale of these trade-offs varies across regions and in time and is greatest where high yields are sought through driven shooting. An extreme case is the near-extirpation of hen harriers from the grouse moors of England (Redpath *et al*., 2010). Work is under way to address these problems in Scotland, for example through the Langholm Moor Demonstration Project (LMDP 2015).

Livestock management

Livestock numbers in the uplands are driven by support payments, particularly through the Less Favoured Area Support Scheme (LFASS) and, from 2015, the 'Scottish Upland Sheep Support' scheme. Changes in support in the last decade have seen stocking rates decline. In turn, such declines necessarily have an impact on biodiversity, with a shift from species characteristic of more open areas to those preferring taller and more heather-dominated vegetation (Pearce-Higgins & Grant, 2006). There is a concern that the potential replacement of livestock grazing by deer is likely across the deer range.

Stocking rate data (available at both farm and parish levels) are collected at a coarse scale and it is therefore difficult to identify changes that are specific to moorland grazing as compared to changes on the inbye. In particular, there is little information as to the effect of stocking rate reductions on the biodiversity value of High Nature Value (HNV) farming, especially on the large areas of common grazings.

Payments under LFASS and the Scottish Upland Sheep Support scheme have been designed to support agricultural activity in the face of severe climatic and soil limitations for agriculture and are not targeted for environmental benefit. However, there is evidence that suggests that landowners would be willing to switch to payments based on the delivery of ecosystem goods and services (Scottish Land & Estates Pers. Comm.). Setting environmental objectives and paying for their delivery could positively engage land managers in managing moorlands for multiple benefits. It could also reduce bureaucracy and increase engagement as the payments would be for delivering benefits rather than for opportunity foregone.

Commercial afforestation

The area of Britain under forest has more than doubled since the Forestry Commission was created in 1919 to develop a strategic timber reserve (Ratcliffe, 2007). Most of this is upland conifer plantation encouraged by fiscal advantages alongside grant aid and low agricultural land values (Avery & Leslie, 1990, Phillips & Watson, 1995). Today, 17% of Scotland is wooded, with Government aspirations to increase this to 25% through multi-purpose woodland expansion in the second half of the 21st century (McIntosh, 2011).

Unlike agricultural grazing, and deer or grouse management, conifer planting in the uplands has been regarded by many as a fundamental change in land use resulting in a significant loss of moorland habitat (e.g. Sydes, 1988, Phillips & Watson, 1995, Ratcliffe, 2007, Van der Wal *et al*., 2011) with impacts on wildlife in adjoining areas through predation pressure. Even in cases where restoration to moorland is undertaken, as in the case of blanket bog restoration from conifer forestry in the Flow Country (Wilkie & Mayhew, 2003), this is a long-term undertaking with outcomes measurable only over decades (e.g. Wilson *et. al.*, 2014). Certainly, the biodiversity impacts of afforestation are marked. For example, Ratcliffe's (2007) review of impacts in south-west Scotland documents extensive loss of raised and blanket bog habitats and estimates the loss of at least 5,000 breeding pairs of curlew. These conifer plantations, even if of non-native species such as Sitka spruce or lodgepole pine and especially if of native Scots pine, do however bring biodiversity value of their own, especially if supported by sensitive management of plantation age structure and species mix, fencing, grazing pressure, forest rides and riparian areas. For example, recent

population changes of woodland grouse across Scotland have much to do with the response of these species to upland forest management (Pearce-Higgins *et al.,* 2007, Watson & Moss, 2008).

Although the direct impacts of moorland conversion to conifer plantation radically change moorland habitat and landscape, their indirect effects on adjacent moorlands are also important. These effects include: (i) habitat and hydrological effects of plantations on blanket bog (Shotbolt *et al.,* 1998); (ii) impacts of predation risk from forest-dwelling predators on ground-nesting bird assemblages (Pearce-Higgins *et al.,* 2009, Douglas *et al.,* 2014, Wilson *et al.,* 2014); (iii) elevated *Ixodes ricinus* tick densities – and hence potential disease risk – on blanket bog (Gilbert, 2013); and (iv) elevated acidity in streams flowing from forested catchments with knock-on effects on the ecology of riparian species such as dippers (Vickery, 1991). Given this range of impacts and that 60% of open land between 200 and 300 m asl, and 40% of land between 300 and 400 m asl, in the UK is within 1 km of conifer forestry (J.D. Wilson *,* BOU conference presentation; see Scridel, 2014), indirect effects of conifer forestry on moorland environmental interests need more careful consideration. This is especially the case when one considers the well-established international conservation importance of those moorlands (Thompson *et al*., 1995b). For example McIntosh's (2011) assessment of key challenges facing forestry in Scotland did not consider open-ground interests. Although the final report of the Woodland Expansion Advisory Group (WEAG, 2012) recognised the potential for conflict, there were no clear recommendations on how this should be resolved or managed.

Woodland restoration and re-wilding

Natural regeneration of woodland is the most obvious manifestation of the concept or ethos known as re-wilding, and is the preferred route to establishing upland woodlands (FCS, 2015). Though hard to define, re-wilding appears to commonly mean the reduction of human inputs into an ecosystem in order to restore 'natural' functions that are perceived as being suppressed. Re-wilding is often quoted as associated with the introduction of formerly extinct species, notably large carnivores.

Re-wilding is a broad label which is understood in various ways and is commonly expressed in terms which include large scale habitat 'restoration', 'encouraging natural processes' and 'minimum intervention'. Re-wilding projects or proposals also vary widely in nature, context and scale, ranging from relatively small site-based initiatives to grander aspirations to create large interconnected natural areas at national or continental scales, with reintroduction of keystone predators. Projects of the former type are already underway in western Europe, including the well-known Oostvardersplassen in the Netherlands and a partnership project (including Natural England and the Forestry Commission) to reduce the intensity of management in Ennerdale in the Lake District. The re-wilding label has also been applied to diverse projects in Scotland ranging from Carrifran and Glen Feshie to Alladale, and including the management of various upland estates owned by JMT, NTS and RSPB, such as Quinag, Mar Lodge and Abernethy respectively. Re-wilding could indeed be taken to encompass management approaches adopted by SNH at sites such as Beinn Eighe and Creag Meagaidh. A decrease in grazing pressure is a key objective in many such schemes, and in the Scottish uplands 'minimum intervention' is commonly taken to include reduction of deer densities, through fencing and/or intensive culling, and a reduction in the intensity of muirburn.

Interest in re-wilding has steadily grown across Europe over the last decade (e.g. Wuerthner *et al.,* 2015), gathering momentum from EU-level initiatives to safeguard near-natural forest areas in

Eastern Europe, and this agenda enjoys strong support from some NGOs. Conditions that allow expansion of existing woodland onto moorland typically require a reduction in activity that suppresses tree regeneration, usually burning or grazing. The scale of impacts may differ from those experienced through planted and managed woodland. Unlike planted woodlands, reducing grazing pressure is typically done without fencing through large scale stock removal and deer culling. There are some sectoral concerns over the effects of increased predation pressure, changes in browsing and grazing intensity on neighbouring land, loss of high nature value grazing, parasite distribution, risk of wildfire, degradation of views, and loss of a cultural landscape (Moorland Forum, 2008).

In this shift from active management, we felt that a vision for moorland and wider upland landscapes was an essential prerequisite prior to developing lines of evidence on the sustainability of 're-wilding'. However, we note the growing enthusiasm for this form of management, and recognise the concerns that traditional 'open moorland' managers will have in response to this.

Deer management

Sustainable deer management is an important component of moorland and upland management, which also impacts upon other land uses such as grouse moor management, afforestation, nature conservation, livestock grazing and recreation. Total costs associated with deer management in Scotland in 2015 were estimated to be £105M, supporting 2,520 FTEs (PACEC, 2006). Not all of these costs relate to moorland.

Scotland's Wild Deer. A National Approach (including 2015-2020 Priorities) (Scottish Government, 2014d) sets out the challenge of managing deer sustainably. It notes: "In practice, most enterprises pursue both 'private' and 'public' objectives together in their management activities. Some of these objectives are potentially conflicting, but many will be complementary. Managing conflicting objectives is one of the key challenges that deer managers and SNH will need to address." This poses challenging questions on how to increase economic opportunities associated with deer, minimising economic costs attributable to wild deer, and increasing participation in the management and enjoyment of wild deer.

The RACCE review of deer management in 2013 recognised that deer are of significant value to the Scottish economy and that deer populations are impacting on the natural heritage, including moorland (RACCE, 2014, and see Scottish Parliament website with associated papers). The Committee recommended that all Deer Management Groups (DMGs) should work towards having deer management plans adopted by the end of 2016, and this is being progressed (RACCE, 2014).

The current voluntary approach, supported by the *Code of Sustainable Deer Management*, has been questioned by those seeking greater regulation of sporting activities, based upon moorland and peatland impacts as well as deer impacts on woodland (FCS, 2014). SNH advocated more clearly defined management outcomes, with effective target setting and monitoring mechanisms. These should be incorporated into management plans. Monitoring of the annual deer harvest could be improved, along with population trends at national and regional levels, to guide discussions on ecosystem health enhancement. A number of elements of current deer management were identified as having wider application in other areas of moorland management. These included *Wild Deer Best Practice* and Deer Management Groups (Scottish Government, 2014d) being a model or surrogate for moorland best practice and the establishment of 'Moorland Management Groups'.

Deer act as hosts to ticks (and louping ill virus) and deer control can reduce tick numbers (Gilbert *et al.,* 2012). This has acted as a driver to significantly reduce deer numbers in some areas managed for red grouse (such as the Angus Glens), although there is little evidence of actual benefits (Harrison *et al*. 2010 and see section above on vertebrate control). The use of acaracides on wild red deer was suggested as an alternative to culling, and as an aid in reducing louping ill in grouse, but there may be implications for the quality of venison from deer treated in this way.

Nature conservation

Nature conservation has been an increasingly important objective of upland and moorland land management since the middle of the 20th century. As early as the late 1950s, Nicholson (1957) listed six nature reserves in the uplands of mainland Scotland, and by the 1980s several key landscapes had either been protected as nature reserves or designated under the EC Birds and Habitats directives to protect examples of moorland and native woodland ecosystems from commercial conifer forestry, including Craig Meagaidh, Abernethy Forest and the Caithness and Sutherland Flows (Smout, 2000). Today, both the state and the NGO sector own and manage large areas of Scottish moorland primarily for nature conservation, with objectives ranging from the protection of individual species of conservation concern to management of natural capital, and the safeguarding of wild land. In addition, conservation designations under Scottish, UK and European legislation bring both regulatory requirements and (limited) financial incentives for moorland management in the interests of nature conservation over areas managed privately for agricultural or sport shooting objectives (Warren, 2002).

As a cultural landscape, much of the modern nature conservation interest and importance of moorland, especially dwarf-shrub heath, derives from its long history of native woodland removal, grazing and muirburn to create open, semi-natural habitats and landscapes (e.g. Ratlciffe & Thompson, 1988, Thompson *et al*., 1995a, Warren, 2002, Van der Wal *et al*., 2011). Set in this context, delivering successful nature conservation outcomes in moorland landscapes involves identifying regimes of 'range management' (Sydes & Miller, 1988) that sustainably deliver nature conservation outcomes. Typically, as in nature conservation in agricultural systems generally, regimes which avoid either abandonment of management or intensification in the interests of a single purpose, are most likely to succeed in delivering nature conservation outcomes. To take one example, the greatest threats to moorland bird conservation interest have come from either intensification or, conversely, abandonment of grazing, from the direct habitat loss and predation-mediated edge effects of commercial conifer plantation, and from some of the management practices associated with intensive, driven-grouse management, notably illegal killing of birds of prey (Pearce-Higgins *et al.,* 2009).

Overall, population decline remains the predominant trend amongst a wide suite of upland bird species across the UK, including in Scotland (Balmer *et al.,* 2013), and reversal of such losses would be an important indicator of an improvement towards sustainable moorland management. However, such losses are not confined to birds. The UK's first *State of Nature* report (Burns *et al*., 2013) indicates declines in the populations of almost two-thirds of 877 species assessed across plant, invertebrate and vertebrate taxa, and extinction threatening iconic species such as the wild cat. As well as the changes in agricultural, sporting and forestry land use and practice that have affected birds, these losses also reflect the pervasive impacts of atmospheric pollution and, to a lesser degree, climate change on the flora of moorland habitats (Van der Wal *et al*., 2011). For example, by

resurveying heath, mire and grassland plots first studied in the 1950s in the Highlands and Islands, Ross *et al.* (2012) found declines in both plant species richness and variation in heath and grassland, reducing the distinctions between some plant communities. There were losses of dwarf-shrub, forb and lichen cover in favour of generalist upland grasses, sedges and rushes. Acidification, climate change and grazing were considered the probable conjoint drivers of these changes, giving rise to the term 'homogenisation of upland vegetation'.

Reversal of these biodiversity losses, beyond that in the minority of moorland that is under primary conservation management, relies on integrating conservation objectives with the wider economic and cultural uses of moorland (Ward *et al.,* 1995, Van der Wal *et al*., 2011), namely grazing, forestry and sport shooting as well as, increasingly, recreation and renewable energy generation. Extent and condition of blanket bog and dwarf-shrub heath, richness and diversity of moorland vegetation, and the distribution and abundance of upland breeding birds, and mammals such as mountain hare and wild cat, might form a usefully diverse suite of indicators of success. The extent of public funds to deliver public goods lies at the heart of this integration, but the future is challenging as pressure on Common Agricultural Policy Pillar II funds places further constraints on an already limited flow of Rural Development funds for upland environments. However, there are some indications of change. There have been substantial increases in investment in peatland restoration driven by government climate change mitigation and adaptation policies (*Peatland Action*: SNH, 2015c), and this should yield substantial nature conservation gains (Cris *et al*., 2011). But for these gains to be fully realised, adequate monitoring must be in place to measure these outcomes.

A prospectus for nature conservation at the heart of future sustainable moorland management requires incentives and regulation favouring 'High Nature Value' agricultural, forestry and sport-shooting management which in turn supports well-targeted peatland, dwarf-shrub heath and native woodland restoration. The Scottish Government's *Land Use Strategy* could help deliver this, and some of our existing moorland nature reserves and designated sites – 'jewels in the biodiversity crown' of Scotland's uplands – already show what can be achieved. For example, sustainable native woodland, peatland and deer management at Coignafern, Beinn Eighe and Creag Meagaidh; peatland restoration following forest removal in the Flows; deer management sensitive to flooding and water supply needs at Glenfeshie and in the Trossachs National Forest, and partnership working to reconcile grouse management with bird conservation and habitat restoration on Langholm Moor, all provide exemplars of what sustainable moorland management might begin to look like.

We should not forget that the origins of the distinctive nature of moorland lie in centuries of losses of ecological productivity and richness (e.g. Mc Vean & Lockie, 1969, Smout, 2000). In this context, it was noted by several people at the Hearing that novel, large-scale experimentation was needed in support of developing the evidence base for sustainable moorland management. Intervention to test the long-term nature conservation consequences of restoring ecological productivity through land management changes (including re-wilding) designed to reverse historical acidification and nutrient losses might be one example. Perhaps Scotland's National Parks, with their primary statutory objectives to conserve and enhance the natural and cultural heritage in the context of sustainable economic and social development and use of natural resources, might be the places for such novel experimentation.

Renewable energy developments

Due to low human population density and high wind resource, upland landscapes, including moorlands, are now subject to widespread development of commercial wind farms in pursuit of ambitious Scottish Government targets for renewable energy generation (Scottish Government, 2011). Given the international conservation importance of moorland bird populations in the UK (Thompson *et al*., 1995b) and the susceptibility of birds to population reduction through collision, displacement and barrier effects (Langston, 2013), it is important to understand how construction of wind farms affects bird populations both at individual moorland sites and cumulatively. The published evidence base is poor, and needs to be extended. Empirical estimates of collision mortality remain almost non-existent in the Scottish uplands and instead development decisions rely on modelled predictions which are sensitive to parameter estimates (e.g. proportion of flights through the rotor-swept volume, and whether or not individual birds takes evasive action) that are in some cases educated guesses (Chamberlain *et al.,* 2006; Douglas *et al.,* 2012). As described above, published studies of the displacement effects of wind farm developments are also scarce.

Overall, there is emerging evidence that a few moorland breeding birds do appear to show marked local reductions in abundance as a consequence of wind farm construction. Of these, the effects on curlew are perhaps of greatest concern given this species rapid population decline. However, as with collision risk, some critical studies of displacement effects remain absent. First, we lack studies which have monitored moorland breeding bird populations through pre-construction, construction, and post-construction phases of development. Only one such study, of golden plover, is close to completion (RSPB, Pers. Comm.). Second, we lack studies of the response of birds to mitigation put in place around windfarms, especially in relation to types of management action undertaken as a result of funding coming from the windfarm. Third, we lack empirical studies of the cumulative impacts of wind farm development on moorland breeding birds as the industry expands across Scotland.

Nitrogen deposition

The impact of nitrogen deposition is complex requiring different management strategies across moorland habitats. Recent research has shown that, in general, nitrogen deposition reduces plant species richness in heathlands and leads to increased abundance of nitrophilous species (Southon *et al.,* 2013). Increased deposition also affects ecosystem functioning, reducing litter C:N ratios and affecting some plant enzyme activities. As deposition is highest in the south of Scotland, it is in these regions where impacts have been most severe (e.g. Van der Wal *et al.,* 2011*)*.

There is also a link between nitrogen deposition and grazing by large herbivores. Additional nitrogen inputs favour grasses over dwarf shrubs (Bobbink *et al.,* 2010) which can lead to the direct loss of lichens (Britton & Fisher, 2007) and favour sedges over mosses (Van Der Wal *et al.,* 2003). Such an increase in preferred vegetation for large herbivores can lead to positive feedback, as increased grazing and trampling benefit the grasses and sedges (Van Der Wal *et al.,* 2003).

The deposition of atmospheric nitrogen increases ecosystem carbon sequestration, particularly in forests, through increased productivity and decreased soil respiration (de Vries, 2009). Atmospheric nitrogen deposition also increases carbon sequestration in moorlands when grazing is removed (Smith *et al*. 2015). By contrast, in moorlands at higher elevations dominated by bog, tussock tundra and arctic heath, nitrogen deposition results in reduced carbon stocks through increased moss

decomposition – a response dependent on the local availability of phosphorus. It has been suggested that if moss productivity is enhanced by the application of small amounts of phosphorus (c. 5 kg ha^{-1}), the depletion in upland carbon stocks associated with N deposition could be reversed (S.J. Woodin and colleagues, Pers. Comm.). Experimental work testing this claim is now under way as part of a SNH-funded PhD study. If successful, judicious application of phosphorus across bog, tussock tundra and arctic heath habitats may locally increase the resilience of upland carbon stores – a major Scottish Government objective.

Part 3. Emerging issues and recommendations

Need for a shared vision and strategy for Scotland's moorland

In his Foreword to *The British Uplands: the dynamics of change,* Professor Charles Gimingham (2002) commented: "Sadly, for too long there has been little in the way of a broad vision for the uplands. True, there have been insights into particular aspects of land use such as forestry, livestock improvement, management for sport, tourism or nature conservation – but these have been only limited insights based on sectoral interests, with no inspiring vision. What has been the result? I would argue that we have had exploitation of the resource, depopulation and loss of rural communities, ecological degradation, declining productivity, reduced incomes, and reduced biodiversity". This statement is still apposite today.

In conducting this review the panel agreed with witnesses and written comments referring to a lack of a vision or strategy for moorlands. Some have stated it is difficult to advise on sustainable moorland management when there is no shared, national vision on what is desired. Bob McIntosh (Pers. Comm.) remarked that "The *Land Use Strategy* provides a national vision, with the aim of regional strategies giving expression to that, implemented through local work". We endorse this view, but note also the desirability of having such a cascade from 'national' to 'local' for Scotland's moorlands.

A number of initiatives have targeted specific moorland management practices – most recently the well-received consultation on a *National Peatland Plan for Scotland* (SNH, 2014) that provides vision statements with a commentary on management practices. Similarly, there is a strategic plan for the national forest estate (FCS, 2009). Further high level commentary is provided on the Moorland Forum website with its guidance on *Principles of Moorland Management* (Moorland Forum, 2015) and a review of the evidence on changes: *Scotland's Moorland: The nature of change* (Moorland Working Group, 2002). SNH's own contribution as to what this vision might involve includes its conservation objectives for heaths and other upland habitat set out in 2001 nationally and regionally, but these are sharply focused on wildlife, as are some others (e.g. Thompson & Horsfield, 1997, Thompson *et al.,* 1995b). A year later in *Natural Heritage Futures* (SNH, 2002) detailed assessments for a wide range of habitat formations were developed, including vision statements. Most recently, the *Protected Areas for Nature: A Review* (SNH, 2015f) recommends a more holistic approach with local landscape settings afforded a much greater role in the management of protected areas. All these initiatives are laudable, but there is no contemporary overall vision or strategy for Scotland's moorlands. The development of a vision and strategy for moorland management needs to be grounded in a holistic approach at a landscape scale.

Below we identify the key issues (and supporting recommendations) that conclude our report.

Key issues underpinning a vision and strategy

We deal with these under a number of section headings flowing from Part 2.

1. Nature Conservation

Nature conservation success and reversal of current moorland biodiversity losses are at the heart of future sustainable moorland management. This requires incentives and regulation to favour 'High Nature Value' agricultural, forestry and sport-shooting management which in turn supports well-

targeted peatland, dwarf-shrub heath and native woodland restoration. The Scottish Government's *Land Use Strategy* can help to deliver this and some of our existing moorland nature reserves and designated sites, as 'jewels in the biodiversity crown' of Scotland's uplands, already show what can be achieved. Interventions to test the long-term nature conservation consequences of restoring ecological productivity through land management changes (including re-wilding) would be an innovative response to help achieve nature conservation objectives. In addition, current information on the natural heritage status of moorland is of variable quality and the interactions between key drivers are poorly understood. We are especially concerned about the recently documented decline in upland birds (SNH, 2015g), and advise that Moorland Working Group (2002) report should be updated.

Recommendation*: SNH is asked to update its audit of changes and trends in moorland biodiversity and the influence of land use drivers, and to ensure that biodiversity objectives/outcomes are central to interventions to improve and demonstrate sustainable moorland management.*

2. Connecting geodiversity and biodiversity

Sustainable moorland management based on the ecosystem approach implies a seamless strategy embracing the non-living parts alongside the living parts of the natural world. The former, collectively termed geodiversity, provides the platform from which many of the key ecosystem services that support moorland biodiversity are derived – soil formation, biogeochemical and water cycling alongside the provision of minerals and nutrients. Also vital in sustaining biodiversity are the mosaic of landforms and dynamic geomorphic processes that underpin habitat formation and maintenance (Thompson *et al*., 2001). Since maintaining these processes is a key element in conserving biodiversity, geodiversity forms part of the stock of natural capital and underpins the 'ecosystem approach' in managing the natural heritage. The role of geodiversity in maintaining the natural heritage takes a number of forms (Gordon & Barron, 2011):

- making space for natural processes by providing a mosaic of environments with options for habitats/species to be maintained, adapted, relocated or restored. Ensuring a mosaic of environments is also important in protecting ecological networks and connectivity;
- promoting working 'with' rather than 'against' nature, accepting that natural change (e.g. landslides and peatslides) is inevitable; and
- learning from palaeoenvironmental archives in moorland peat deposits and loch sediments which provide longer records of trends and rates of change (Dearing *et al*., 2010). Given climate change, this can help inform realistic biodiversity targets.

In addition, geodiversity provides added value in terms of landscape, amenity and natural beauty – important elements in the valuing of moorlands and conservation of the natural heritage (Gordon, 2012). By underpinning both regulatory and cultural ecosystem services, geodiversity has a vital role in placing a value on moorland landscapes.

Given the above, management strategies sensitive to local geodiversity are vital to ecosystem health, giving due regard to the mosaic of landforms, soils and associated processes. This implies effective partnership between those concerned with promoting biodiversity and those with protecting the geodiversity heritage. We note that geodiversity significantly lags behind biodiversity in its recognition by policy makers and make the following Recommendation.

Recommendation: *SNH is asked to strengthen its geodiversity portfolio to support its delivery of the 2020 Challenge for Scotland's Biodiversity.*

3. Sustaining ecosystem health

Today's moorland landscapes are largely cultural landscapes, held in a state of arrested ecological succession, and shaped by management through deforestation, muirburn, livestock and deer grazing, predator control, and tree planting with a range of amenity provisions for leisure and recreation. Our definition of sustainable moorland management focuses on ecosystems that are healthy both in terms of their ecology and economy. But in placing nature conservation at the heart of future sustainable moorland management, due regard must also be played to the economic and social viability of the local communities that derive a living from Scotland's moorlands.

We note that the *2020 Challenge for Scotland's Biod*iversity espouses the principle of achieving ecosystem health through adopting the ecosystem approach to management. Clearly, in some areas high standards of 'good' practice are being adopted, but in other areas they are not. We want to see the development and sharing of good practices, currently being promoted by Scotland's Moorland Forum.

4. Re-wilding

The ecosystem services provided by re-wilding are poorly quantified. The case for re-wilding in upland Scotland is often made most strongly on the basis of reversing the 'wet desert' (Darling, 1955) or an emotional attachment to wild places (Shepherd, 2011). The ecological status of wild land under present climatic conditions is, however, much more complex than this generalisation implies, ranging from relatively natural to clearly anthropogenic, with various shades and local variations in between – and this position is further complicated by long-term climatic variation. The potential natural vegetation of some wild land areas may therefore differ little from the current position, and would only develop in line with ecological timescales, with any associated ecological benefits being uncertain and long-term. The cultural ecosystem service gains, for example in relation to tourism and outdoor recreation, may also be fairly modest because Scotland's wild land areas already provide many of these benefits in their present form. However, there is clearly a lot of interest in 're-wilding' and we would like to see more work to develop our understanding of potential impacts on ecosystem health.

Recommendation: *In consultation with other key stakeholders, SNH is asked to define and communicate its understanding of ecosystem health in relation to moorland, and the adoption of high standards for management practices.*

5. A habitat map for Scotland

A key resource in promoting healthy moorland ecosystems is a standardised habitat map. Scotland's uplands extend to 5 M ha of which some 21% has been mapped according to the National Vegetation Classification (NVC). The remaining 3.9 M ha has been mapped to other classifications, with considerable reliance still on Land Cover of Scotland 1988. SNH has a statutory duty under the Habitat Regulations to undertake surveillance and the assessment of the conservation status of Habitats Directive Annex 1 habitats occurring in Scotland. A standardised habitat map is fundamental to this, incorporating Annex I habitat types from the Habitats Directive within the broader-scale mapping of EUNIS (European Nature Information System) habitats.

This EUNIS-Annex I habitat map will, *inter alia* serve the following purposes:

- natural capital accounting, including quantification of extent for the 15% target to restore degraded ecosystems;
- condition assessment of widespread habitats for biodiversity assessment and Article 17 reporting, for which we have limited knowledge beyond protected areas;
- habitat network analysis;
- determining resilience, ecosystem health and ecosystem service provision from habitat condition (Medcalf *et al*., 2012, 2014);
- assisting land management decisions in support of the *Land Use Strategy*, especially by Deer Management Groups;
- spatial targeting, implementation and evaluation of SRDP; and
- informing the design of large scale field experiments and other scientific studies.

It is clear from the above that a standardised moorland map for Scotland is needed. We note that the *2020 Challenge for Scotland's Biodiversity* ends with a commitment to publish a habitat map by 2019. Based mainly on the re-classification of legacy data, SNH has recently fulfilled part of this through the publication of a EUNIS map, and is working on the Annex I detail. Furthermore, we have specified the uplands as the priority in Scotland for the JNCC assessment of the capability of Earth Observation for habitat condition and change assessment (http://jncc.defra.gov.uk/page-5563).

Recommendation: *SNH is asked to ensure that by 2019 the habitat map for Scotland, based on Annex 1 habitat types and the EUNIS habitat classification, is completed.*

6. Adapting to climate change

A key characteristic of healthy ecosystems is resilience to climate change. As noted in *Climate Change and Nature in Scotland* (SNH, 2009) there are a variety of strategies for addressing the adverse impacts on climate change on moorland ecosystems. These include:

- reducing the pressure on moorlands from processes which exacerbate climate change impacts (e.g. pollution; grazing; spread of invasive non-native species and pathogens);
- creating new spaces for natural processes (involving landforms, water and soil) and species interactions coupled with reducing fragmentation and increasing available habitat;
- modifying management practices where grazing, burning or draining has reduced habitat diversity or the size of species populations;
- promoting management practices which increase habitat diversity thereby enhancing resilience to climate change;
- using adaptive management for conserving the natural heritage whilst also obtaining an economic return from moorlands; and
- where the loss of habitat or species is inevitable, planning to manage this change with the possibility of translocating species of conservation concern.

All of these strategies are consistent with the goal of promoting healthy moorland ecosystems and the *2020 Challenge for Scotland's Biodiversity* . We further note that delivery of these strategies is a key element in SNH's contribution to Scotland's Climate Change Adaptation Programme.

7. Meeting priorities using the Scottish Rural Development Programme

Agricultural support payments within Scotland are the lowest in Europe on an area basis (Scottish Government, 2015d). SRDP support for moorland management is rolled up into a single 'Moorland Management' option, which can be integrated with stock disposal, away wintering of stock and upland cattle grazing. The two former activities, however, do not address current concerns about undergrazing, but perhaps reflect past concerns about overgrazing under different agricultural support mechanisms (e.g. headage payments). Moorland Management also allows for the integration of a range of capital items, including bracken control, heather restoration, muirburn and heather cutting, and deer management, as well as surveys of deer populations and impacts.

Recommendation: *SNH is asked to work with the Scottish Government to develop the evidence base on the impact of SRDP spend on biodiversity (notably the relationship between agricultural grazing and High Nature Value outcomes).*

A Way Forward for Scotland's moorlands – vision and strategy

We do not have a shared holistic approach to managing Scotland's moorlands (Skerratt *et al*., 2014). The advent of the ecosystem approach and the quantification of natural capital 'stocks' and 'flows' espoused in the *2020 Challenge for Scotland's Biodiversity* provides a basis for developing such an approach. We see Scotland's Moorland Forum as the organisation potentially best-suited to framing such a moorland vision and developing a strategy for its delivery. The recent SNH-led public consultation on *A National Peatland Plan* (SNH, 2014) is an important model for such work.

Given that the concept of the sustainable management of moorlands is contested – not all stakeholders will even agree with our working definition of sustainable moorland management – a key issue is to bring all sectors (public, private business, NGOs, research) together to decide on a shared vision for moorland encompassing evidence-led governance and management approaches. Delivering on the vision will, in turn, require a collectively owned strategy. This implies a new way of working in which land managers and others can jointly frame the key questions and agree on how to gather evidence to address them.

Such a co-production of knowledge allows for the structured gathering and testing of local 'vernacular' information alongside knowledge developed more formally using the scientific method. Where it can be clearly demonstrated that the former robustly informs the latter, both enhanced scientific understanding and more widespread acceptance of the management implications emerges. Research on the derivation of such jointly-owned knowledge production indicates that it is both time-consuming and demanding (as demonstrated by the UK Research Councils' Rural Environment Land Use project on upland flood risk management, Rural Environments and Land Use, 2010, Whatmore, 2009, Lane & Odoni, 2010) but, if successful, such an approach can yield far more effective environmental management. An example of seeking to apply such an approach is Scotland's Moorland Forum 'Understanding Predation' work package, currently in progress (http://www.jottercms.com/showpage.php?id=12411).

Recommendation: *Scotland's Moorland Forum, working with its members and wider stakeholders, is asked to produce a shared vision for Scotland's moorlands founded on environmental sustainability and critical ecological thinking and to devise a strategy for delivering this.*

Such an initiative would also enable the interests of moorland stakeholders to be more readily reflected in delivering the Scottish Government's much wider *Land Use Strategy*. However, we advise that fully embedding sustainable moorland management within the *Land Use Strategy* should await discussions on the weighting to be afforded environmental, social and economic aspects, and agreement on national and regional objectives.

Recommendation: *The Scottish Government, as it develops national and regional objectives within its Land Use Strategy, is asked to give further consideration to strategic planning for moorlands, with due weighting to environmental, social and economic outcomes.*

In terms of a strategy for delivering a vision for Scotland's moorlands, we initially propose novel experimentation designed to fill significant evidence gaps in our understanding of ecosystem health.

Novel experiments to understand moorland ecosystem health

As noted above, at the heart of sustainable management of moorlands is the maintenance and restoration of ecological productivity. This should support High Nature Value agricultural and sport-shooting management alongside peatland and native woodland restoration. The evidence base on how to restore ecological productivity via changes in current land management practices is weak and fragmented. Demonstration projects (e.g. the Langholm Moor Demonstration Project) and research papers (e.g. Whittingham, 2011; Madden *et al.,* 2015) imply that controls on grazing and burning regimes, and predator numbers, can result in greater biodiversity whilst not undermining the livelihoods of rural communities reliant on sport-shooting and High Nature Value agriculture. But these studies are localised, small-scale and open to question if extrapolated to the rest of moorland Scotland. As a result we have been unable to develop a road map towards sustainable moorland management. We propose that this evidence gap be addressed by undertaking large-scale, long-term experiments designed and owned by key stakeholders. The experiments could assess the impact of selected land management measures (e.g. burning, grazing and predator control) on ecosystem health.

Recommendation: *SNH is asked to work with Scotland's Moorland Forum to design and deliver large-scale, long-term experiments to support our understanding of moorland ecosystem health.*

Mobilising and sharing data

Evidence gathering for this review generated a daunting list of important evidence gaps. Amongst the most frequently identified were: the response and resilience of moorland ecosystems to climate change; the sustainability of sporting management and its associated management practices; the socio-economic and cultural valuation of moorland ecosystems and landscapes; the environmental impacts of expansion of wind farms and forestry, and their associated infrastructure; and the definition and mapping of the moorland resource and its condition. For a full list see Evidence gaps section below.

Filling these evidence gaps will require significant investment in further research most notably via long-term, field-based experiments. But in the meantime much could be achieved if existing datasets held by diverse public and private bodies were to be made available to projects designed to promote the delivery of sustainable moorland management. Examples include:

- details of the location and extent of SRDP and forestry grant management options put in place on moorland or on adjacent farmland or forestry that have implications for moorland;

- environmental monitoring data from wind farms before, during and after construction (species, habitats, and carbon and sediment fluxes). The absence of such data severely limits our ability to understand the cumulative impacts of these developments on moorland ecosystems;
- local moorland management data including muirburn, livestock, game-bag and vertebrate control data; and
- data describing trial interventions on nature reserves and their outcomes.

SNH already holds significant relevant data (for example deer management, count and cull returns, habitat condition, as set out in *Scotland's Wild Deer. A National Approach (including 2015-2020 priorities)* (Scottish Government 2014d).

Recommendation: *SNH is asked to complete its inventory of key data on the current management of moorland with protocols governing its availability and use by key stakeholders, and noting the need to adapt to climate change.*

Evidence gaps

In compiling this report we have identified evidence gaps. Below we identify the most wide-ranging and challenging in delivering sustainable moorland management:

- state of ecosystem health across moorland, and how far this is influenced by management practices and wider land uses;
- response and resilience of moorland ecosystems to climate change;
- shared metrics on socio-economic and environmental sustainability of sporting management, hill farming and expansion of wind farms and forestry, and their associated infrastructure (including hill tracks) and management practices;
- optimal scale for management actions – landscape scale action is often more appropriate than at the landholding scale;
- socio-economic and cultural valuation of moorland ecosystems and landscapes;
- valuation of ecosystem services to allow multiple benefits to be assessed; and
- ecosystem outcomes of peatland restoration and moorland re-wilding.

Other, more narrowly focused evidence gaps that have emerged during the review are:

- trade-off between rotational burning and reduction of wildfire risk;
- improved monitoring and data to assess national trends of mountain hare populations;
- impact of short term policy cycles on long term ecosystem health;
- impacts of management on taxa other than vascular plants and birds;
- role of surface roughness on blanket bog water runoff;
- field-calibrated carbon budgets for wind farms located on peatlands; and
- longitudinal studies of bird population responses to wind farm developments, on and off site.

We commend the approach taken by SNH to address some of the evidence gaps noted above. Whilst SNH has shown important leadership in work to resolve raptor-grouse moor conflicts, and the development of advice on deer management and renewable energy developments, other agencies

have expertise that SNH can draw on. For example, FCS and SEPA have developed important guidance on woodland expansion and implementing the Water Framework Directive.

But other aspects of landscape and wildlife stewardship generate concerns. Accordingly, we support the ongoing development of evidence gathering and conflict resolving mechanisms to address these issues, notably with regard to mountain hare control, predator management, hill track developments and sharing of evidence.

Recommendation: *SNH is asked to continue its leadership, on behalf of the Scottish Government, in resolving conflicts over moorland land use, conservation and management.*

Risks of sustainable moorland management failure and intensification of moorland management

We acknowledge the significant contributions made by the private, NGO and public sectors towards delivering sustainable moorland management. Failure to deliver sustainable management of Scotland's moorland habitats and wildlife will jeopardise delivery of the following national strategies and compliance with the associated statutory instruments and international obligations, notably:

- *2020 Challenge for Scotland's Biodiversity* and compliance with EC directives and global biodiversity targets;
- aspirations of the SNH *Protected areas for nature – review report* (SNH, 2015f);
- adaptation and mitigation targets for greenhouse gas emissions as specified by the Scottish Climate Change Adaptation Programme 2014; and
- Scottish Government's *Land Use Strategy*.

Special attention needs to be given to the setting of good standards for sustainable moorland management. This is an important component of the revision of *Principles of Moorland Management* being undertaken by Scotland's Moorland Forum, and should set important benchmarks on these standards. Failure to meet these standards will jeopardise the attainment of sustainable moorland management.

More generally, failure to meet high standards of moorland management will result in reduced ecosystem health and further threats to the condition of protected areas. This would also risk rural livelihoods and cultural associations, such as the high value placed on moorland by the visiting public, and land managers.

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Annex 1. Attendees at the Hearing on 17-18 December 2014.

Name	Organisation
Dr Ron Macdonald	Scottish Natural Heritage
Dr Chris Miles	Scottish Natural Heritage
Ms Lesley Cranna	Scottish Natural Heritage
Mr Robbie Kernahan	Scottish Natural Heritage
Professor Joe Holden	Leeds University
Professor Chris Spray	Dundee University
Professor John Gordon	University of St. Andrews
Professor Bill Slee	James Hutton Institute
Professor Mark Reed	Birmingham City University
Dr Bob Aitken	Research Consultant (formally Loch Lomond and Trossachs National Park)
Mr John Thomson	National Access Forum
Mr Patrick Krause	Scottish Crofting Federation
Professor Steve Redpath	Aberdeen University
Professor Davy McCracken	SRUC
Mr Simon Thorp	Scotland's Moorland Forum
Dr David Baines	GWCT
Mr Richard Cooke	Association of Deer Management Groups
Mr Robert Bainsfair	ENVIRON
Mr Richard Luxmoore	NTS
Dr Bob McIntosh	Scottish Government, Environment and Forestry
Ms Maggie Keegan	SWT
Mr Andrew Midgley	Scottish Land and Estates
Mr Duncan Orr-Ewing	RSPB Scotland

Annex 2. Submitted written evidence provided in advance of the Hearing

In a separate document with evidence from:

- Scottish Land and Estates
- Professor Bill Slee
- SRUCs Hill & Mountain Research Centre
- RSPB Scotland
- Scottish Natural Heritage
- IUCN UK Peatland Programme
- Mr John Thomson
- Professor Mark Reed
- Mr Richard Cooke
- Dr Chris Miles
- National Trust for Scotland

Annex 3. Other submitted written contributions

In a separate document with evidence from:

- Wildlife Estates Scotland
- Dr Adam Watson FRSE

Annex 4. Abbreviations

ASL	Above Sea Level
BOU	British Ornithologists' Union
CAP	Common Agricultural Policy
DMG	Deer Management Group
DOC	Dissolved Organic Carbon
EC	European Commission
EU LIFE	European Financial Instrument for the Environment
EUNIS	European Nature Information System
F&WS	Forestry and Woodland Strategies
FCS	Forestry Commission Scotland
FTE	Full Time Equivalent
GEAC	Good Agricultural and Environmental Condition
GWCT	Game and Wildlife Conservation Trust
HNV	High Nature Value
IUCN	International Union for Conservation of Nature
JMT	John Muir Trust
JNCC	Joint Nature Conservation Committee
LFA	Less Favoured Areas
LFASS	Less Favoured Area Support Scheme
LMDP	Langholm Moor Demonstration Project
LUS	Land Use Strategy
MW	Mega Watt
NCA	Natural Capital Asset
NGO	Non-Governmental Organization
NSA	National Scenic Area
NTS	National Trust for Scotland
NVC	National Vegetation Classification
NWSS	Native Woodland Survey of Scotland

PACEC	Public and Corporate Economic Consultants
POC	Particulate Organic Carbon
RACCE	Rural Affairs, Climate Change and Environment Committee
RBMP	River Basin Management Plan
RSPB	Royal Society for the Protection of Birds
SAC	Scientific Advisory Committee
SAC	Scottish Agricultural College now SRUC
SAC	Special Area of Conservation
SBS	Scottish Biodiversity Strategy
SCM	Site Condition Monitoring
SL&E	Scottish Land and Estates
SNH	Scottish Natural Heritage
SPA	Special Protection Area
SRDP	Scottish Rural Development Programme
SRUC	Scotland's Rural College
SSSI	Site of Special Scientific Interest
WEAG	Woodland Expansion Advisory Group
WES	Wildlife Estates Scotland