

Socioeconomic and biodiversity impacts of driven grouse moors in Scotland.

Summary Report



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**The views expressed in this report are those of the researchers
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1 Background

In May 2017, the Cabinet Secretary for Environment, Climate Change and Land Reform announced commissioning of “research into the costs and benefits of large shooting estates to Scotland’s economy and biodiversity”¹. A related Programme for Government (2017-2018) commitment published in September 2017 also states that a research project will be commissioned to “examine the impact of large shooting estates on Scotland’s economy and biodiversity.”

The focus of the Cabinet Secretary’s announcement concerns ‘driven grouse shooting’ estates. This report addresses the commission.

1.1 Objective

The main objective of this work is to bring together the best-available and new evidence to consider the socio-economic and biodiversity impacts of driven grouse moors in Scotland.

From July to October 2018 analysis was undertaken by James Hutton Institute and Scotland’s Rural College (SRUC) to address this remit. Three detailed reports have been produced on the following topic areas:

Socio-economic and biodiversity impacts of driven grouse moors in Scotland: Part 1: Socio-economic impacts of driven grouse moors in Scotland - an evidence review of the impacts of driven grouse moors on estate employment, wages, capital assets, etc. as well as on the wider rural business base and on local communities. The socio-economics of a selection of alternative land management models is also considered.

Socio-economic and biodiversity impacts of driven grouse moors in Scotland: Part 2: Biodiversity impacts of driven grouse shooting in Scotland – an evidence review of impacts from a range of management activities associated with driven grouse moors, including: muirburn; grazing (sheep and deer); legal predator control; mountain hare management; and a review of ecosystem service delivery by driven grouse moors.

Socio-economic and biodiversity impacts of driven grouse moors in Scotland: Part 3: Use of GIS/remote sensing to identify areas of grouse moors, and to assess potential for alternative land uses – using GIS and remote sensing to estimate the extent, intensity and characteristics of grouse moors in Scotland, including opportunities and constraints for alternative uses.

The approaches taken to addressing these research areas are provided in each of the detailed reports, together with full reference citations.

This summary report provides key information from these detailed reports, in particular the main findings, knowledge gaps and options for future research.

¹ <https://news.gov.scot/news/golden-eagle-deaths>

2 Summary of key findings

The following are key messages from each of the detailed reports. These are then followed by a more detailed overview of the outcomes of each study (Sections 3 to 5).

2.1 Key findings - Socio-economic impacts

- There is a narrow base of socio-economic evidence that specifically focuses on the economic impacts of grouse shooting, with some additional evidence relating to the wider game shooting or estate sectors. The dated nature of much of this research means that the social and economic impacts of more recent intensification of driven grouse moor management, on some estates, are missing from the research evidence base. Therefore, industry-collated and reported data (that has not been collected using standardised approaches and that does not provide key data to contextualise the figures) is often cited in contemporary discourse regarding grouse moor management.
- Much of the commissioned research and industry-collated socio-economic evidence suffers from self-selection and self-reporting bias (i.e. participants take part if they wish and the accuracy of the data they provide is not verified by an external party). The lack of a definitive dataset that includes all estates engaged in grouse moor management (and intensity of grouse management activity) means that it is impossible to assess how representative research and industry data is of the whole sector.
- The narrow evidence base and inconsistency in data collection approaches mean that evidence on socio-economic impacts is open to criticism. However, despite the limitations, the existing evidence base does provide some context relating to the social and economic contributions of grouse moor management.
- Grouse moor management and shooting activities on estates do not sit in isolation. Rather, the range of estate activities (e.g. management for sheep, deer, walked-up grouse shooting, driven grouse shooting, wind energy generation, tourism, conservation, etc.) are not mutually exclusive. Different land management activities can be undertaken together on the same piece of ground, and some staff members on estates may be engaged in other activities than grouse moor management and grouse shooting.
- Grouse shooting and related activities can be important to some remote and fragile local economies. The review of evidence suggests that that around 2,500 FTE jobs (both direct and indirect) were reliant on the grouse moor sector in 2009 with £14.5 million spent on wages related to grouse moor management and support activities, with a total Gross Value Added contribution of £23 million to the Scottish economy. There appears to be no evidence on the informal wage market driven by gratuities (tips) from those undertaking grouse shooting.
- Grouse moor related expenditure varies significantly between estates, often depending on moorland scale and intensity of management activities. Recent data collected by the Scottish Moorland Groups suggests average annual wage spend of £210,000 on those estates reporting significant grouse moor activity, with expenditure on their suppliers (often rurally located) averaging £515,000 per year. As data does not exist for the wider rural business base (data is also scarce for agriculture in these areas) or the scale of the estates the data was gathered on, it is impossible to assess how important this expenditure is.
- Incomes from grouse shooting are highly variable, often dependent on the mix of private versus commercial shooting and/or driven versus walked-up shooting days. Evidence from land agents suggests that the capital value of estates can be enhanced through improving

the annual grouse bag (intensification) with each brace of grouse worth up to £5,000 in capital terms.

- There is limited evidence on the socio-economic impacts of alternative land uses on moorland areas, particularly of the emerging rewilding and conservation approaches being taken on some private estates. Some alternatives (e.g. farming, forestry, renewables) are heavily reliant on public payments to justify the activity economically, with others (e.g. rewilding, conservation) more reliant on the benevolence of owners or members. It is challenging to make comparisons between land uses as there are regulatory limitations (e.g. for wind farms, forestry and woodland management) and biophysical constraints (e.g. to farming, forestry and woodland management, wind energy, housing) on some alternatives meaning they are only viable or permitted across some of the current grouse moor area.

2.2 Key findings - Biodiversity impacts

- Hare control impacts are likely to be context dependent and influenced by the level of control, local and regional hare population status (for which we lack data), and complex effects mediated through food webs.
- Legal predator control impacts can be both negative and positive, resulting in changes in the combinations of species present on managed grouse moors. As for hares, impacts will be context-dependent and mediated through food-webs.
- Impacts of muirburn on biodiversity are diverse and can be positive and negative, depending on a range of conditions including fire intensity; we assert that one of the main reasons for conflicting findings is that there is often no data on intensity of fires associated with measured biodiversity responses.
- In general terms, muirburn can provide structural diversity to the moorland landscape, particularly on drier moorlands, which is often associated with higher above-ground biodiversity. There is almost no published data on below-ground biodiversity impacts, and there is highly conflicting evidence on muirburn impacts on peatland biodiversity.
- For grazing, impacts depend on grazing intensity, and the balance of different types of grazers (sheep or deer). We have limited knowledge of the long-term impacts of grazing and how it can help or hinder grouse moor biodiversity, or indeed management impacts.
- Heather moorland provides a range of ecosystem services. But studies to date have rarely focussed explicitly on the impacts of driven grouse shooting on service delivery, and have focused on a small set of services (such as water quality and carbon storage). There are likely to be many interactive effects on biodiversity and ecosystem services of management activities associated with driven grouse shooting.
- To address substantial information deficits new, controlled experimental studies are needed to examine management impacts on biodiversity. New studies are also needed that investigate delivery of a wider range ecosystem services, and that provide a better understanding of the role of co-production of services through interactions between people and the environment.

2.3 Key findings - GIS/remote sensing analyses

- We have been able to integrate existing spatial data sets to identify a population of holdings that are potentially involved in driven grouse shoots, and it is possible to have an indication of where regionally more intensive driven grouse activity is being undertaken.
- Driven grouse enterprises on holdings occur at a wide range of scales and circumstances, and as an apparently exclusive land-based activity or as part of a diversified holding. This

was interpreted by the authors as meaning the consequences of any policy, regulatory or management prescriptions are likely to be challenging to assess ex ante.

- There are marked local variations in management intensity, with several areas identifiable in which management intensity is substantially higher than is typical for their surroundings. If linked to information on undesirable consequences, spatial analysis could provide the start of a framework to guide monitoring or licensing of activity.
- Typically, the Land Capability for Agriculture of the holdings is low, particularly for the land with grouse butts. A change to an exclusive use of this land as unimproved pastures is feasible but unlikely given reductions elsewhere in stocking of hill land. Improvement to permanent pastures is likely prohibitively costly, unlikely to fit with proprietor's desires, and to conflict with designations.
- Land capability for forestry is also low, but it would be better to make specific analyses of afforestation options using the Forestry Commission's forest management alternatives where the mix of public and private benefits can be judged. The need to avoid net carbon losses occasioned by current or alternative management practices means the need to integrate more sophisticated assessments of soils.
- There are many options for how assessments made here could be improved. In the research team's opinion, the most valuable option would be to update the strip burning maps using more up-to-date imagery. There would also be significant value in better integrating the socio-economic perspectives with the GIS analysis.

3 Socio-economic impacts

3.1 Background

This section is a summary of the review of the socio-economic impacts of driven grouse moors that was undertaken amidst the backdrop of Scottish Government commitments to “examine the impact of large shooting estates on Scotland’s economy and biodiversity.” The review collated evidence relating to the socio-economic impacts of driven grouse shooting in Scotland, with some additional material included relating to the impacts of wider shooting and game management at UK and Scottish levels. The review examined evidence on: employment impacts; the direct economic impacts (revenue and expenditure); indirect, induced and Gross Value Added impacts; well-being and wider community impacts; the costs of negative externalities from grouse moors; and, contributions from alternative land uses.

There is limited research and evidence on the socio-economic impacts of grouse moors and related activities and therefore this review conducted an extensive search for information including academic literature, commissioned research, media (papers, parliamentary evidence statements, videos, etc.), and parliamentary evidence. In addition, data gathered for specific commissioned research were revisited with a focus on driven grouse moors, and summary data from the most recent survey of grouse estates conducted by the industry representative group were assessed.

The role of driven grouse moors on local, often fragile communities can be significant through direct wage expenditure, supply chains and the hospitality sector. However, there is a narrow research base to draw-on and provide robust evidence with which to make policy decisions. There is very limited understanding of how grouse moor estates interact with the wider rural business base, the communities in which they are located, and the wider users of the Scottish countryside.

The evidence highlights how driven grouse moor management, and grouse shooting activities, are part of a myriad of wider sporting and general estate activities. Many media reports and widely quoted figures relating to the socio-economic impacts of grouse moors come from a very narrow base of industry-sponsored studies that have self-reporting biases and do not consider counterfactual scenarios (i.e. alternative land uses). As most of the research has been commissioned by representatives of the grouse or wider estate sector, the objectives of the research have been criticised, by some, as only focusing on demonstrating the positive aspects of grouse moor management.

3.2 Disaggregating from wider estate activities

Significant data collection challenges exist. In particular, many estates have challenges in disaggregating socio-economic data to enable a robust evaluation of the estate impacts. Specifically, these challenges relate to staff effort on different tasks and the split of ‘running’ and ‘investment’ costs between different cost centres. Part of the challenge in disaggregating data is that estate activities (e.g. sheep, deer, walked-up grouse, driven grouse, wind energy, tourism, conservation, etc.) are not mutually exclusive. Different land management activities can be undertaken together on the same piece of ground and some staff members on estates may be engaged in other activities unrelated to grouse moor management. There is evidence that, on average, gamekeepers on estates engaged in grouse shooting spend about half of their time on grouse-related activities, with other sporting activities (pheasants, partridge, deer, fishing), estate maintenance and pest control (including for farms), being other key activities. On estates where grouse provide a key income stream (particularly driven grouse), the gamekeeper time spent on grouse moor management activities tends to be higher.

3.3 Employment Impacts

Direct employment in the grouse sector includes gamekeepers, shoot managers and other estate staff, as well as seasonal and casual employees. Indirect employment relates to ‘downstream’ jobs

(e.g. supported by sales to game dealers) and the rest of supply chain jobs (e.g. related to food, travel, accommodation, etc.). Employment related to grouse shooting is often very important in local economies where grouse shooting is concentrated (with large seasonal spikes around the shooting season), despite being of less importance at regional and national levels.

Grouse moor specific direct and indirect employment (of which it appears the majority relates to driven grouse) is estimated to be in the range of 2,358-2,640 FTEs with an economic contribution of £14.5 million in 2009 (this includes direct and induced jobs that rely on grouse shooting).

3.4 Economic Impacts

Scotland's grouse moor sector was estimated to contribute £23.3 million GVA to Scotland's economy in 2009. Grouse moor management costs in Scotland vary significantly by estate size and the intensity of management, with average estate expenditure of about £120,000, costs of employing a gamekeeper of around £45,000 (including housing, vehicle, salary and equipment) and the cost of running a day of driven grouse at approximately £2,500 (including staff time, catering, pickers' and beaters' costs, and transport).

Many grouse shooting estates invest considerably in infrastructure related to grouse shooting (e.g. grouse butts, shooting accommodation, staff housing, access tracks, lunch huts, etc.), particularly where the management objectives are to maximise grouse numbers, and / or grouse-related income.

Industry data suggested that, across 32 estates in key grouse shooting areas in 2015, £6 million was spent on staff wages. In 2016, 45 estates spent £23 million in upstream supply sectors (running costs and capital investment). This investment can be driven by owners' aims to increase the capital value of estates (with estimates of up to £5,000 capital value per brace of grouse), or the owners' desires to increase personal shooting opportunities for friends, family and business acquaintances.

3.5 Societal Impacts

There is evidence that the grouse shooting industry leads to some localised population retention (meaning schools and other services can be retained), and maintenance of cultural aspects and community identity. However, little has been reported on the social and cultural aspects of alternative land uses, and evidence reveals some disconnect between communities and grouse estates – which the establishment of Regional Moorland Groups² has sought to rectify.

There is a paucity of evidence that identifies the costs of the (often contested) negative externalities associated with grouse moors (e.g. raptor persecution, impacts of heather burning on soils and certain bird species, perceived negative landscape impacts). Negative impacts (perceived or actual) may limit visitor spending within an area from the estimated half million domestic visits, 2.7 million accommodation nights and £187 million spend on visits that included watching wildlife / bird watching in 2015.

3.6 Alternative Land Use Impacts

Alternative land use options on grouse moor areas may be constrained by biophysical factors (e.g. land capability, climate change) or regulatory factors (e.g. environmental designations, land use planning). There are a wide range of socio-economic impacts associated with alternatives, but they rely on exchequer support to varying degrees and have a range of landscape and environmental impacts (positive and negative) associated with them. Indicative figures of impacts of some alternatives are provided in Table 1 along with indicative figures for grouse moor management for

² These were established in 2015, following recommendations by Mc Morran et al (2015) about how to improve and enhance relationships between sporting estates and their local communities. See: <https://www.giftogrouse.com/community-groups/>

comparison. Care must be taken when interpreting these figures as each alternative cannot simply be introduced across all moorland areas due to environmental, landscape, biophysical, economic, and labour constraints. The extents of coverage of each area in Scotland are deliberately not provided here due to land use not being mutually exclusive, and the extent of each alternative's coverage on moorland area being difficult to estimate.

Table 1 Indicative comparisons of annual expenditure per hectare and hectare required per FTE job

Land Use	Spend per Hectare (Ha)	Hectares per full-time equivalent job (FTE)
Driven Grouse: ● <i>Angus Glens</i> ● <i>Monadhliath</i>	£120/Ha £51/Ha	875 Ha/FTE 1,038 Ha/FTE
NGOs ● <i>RSPB</i>	£181/Ha £144/Ha	277 Ha/FTE 173 Ha/FTE
Sheep Farming	£98/Ha	580 Ha/FTE
Largescale Wind	£2,240/Ha local investment costs £7,150/Ha Scottish investment costs £517/Ha community benefit	15 Ha/local FTE 5 Ha/UK FTE
Forestry	£346/Ha	422 Ha/FTE

3.7 Future research options

Suggestions for further research and data collection to help provide more robust evidence on the socio-economic impacts of driven grouse shooting, filling identified data gaps, were considered by the research team. In particular, we suggest that more systematic approaches to data collection are required, and also suggest that the majority of the information gaps would benefit from data collection and analysis over a longer time-period than the 'snapshot in time' approaches that studies, to-date, have used.

- Comprehensive study of economic and employment multipliers at local and regional scales to determine the extent and impact of connections between grouse shooting estates, surrounding businesses and communities (including the local and regional economic impacts of shooting participants) over time. *High priority*
- Comparison of the employment and wider economic impacts of grouse moor management at different shooting intensities to compare long-term impacts of the different types. *High priority*.
- Comparison of the relative socio-economic impacts of let grouse days and long-term grouse leasing with private (non-commercial) grouse shooting and estate-run commercial grouse shooting - both currently and in terms of future potential roles. *Medium priority*.
- Assessment of the impact of grouse moor management and wider sporting management on land values and the impact of trophy (capital) values on landowner and land manager approaches to moorland management. *Medium priority*.
- Evaluation of community perceptions of grouse shooting, including in relation to community well-being, demography, conflicts, etc. *High priority*.
- An evaluation of the socio-economic impacts of alternative land uses for moorland, in particular of rewilding approaches to land management – where there is a paucity of evidence of the social and economic impacts of this evolving land management approach. *Medium Priority*.
- Independent research to engage with gamekeepers on motivations, behaviours and support needs. There is limited evidence on why certain management methods are utilised in the management of game on sporting estates, or attitudes to biodiversity and conservation. This important group of land managers are understudied and developing a greater understanding of their drivers, concerns and motivations would likely be beneficial. *High priority*.

4 Biodiversity impacts

In order to assess the impacts of management activities strongly associated with driven grouse shooting on biodiversity, we undertook a literature review. This built on published evidence and recent reviews, updating these where possible with information from more recent studies. We focussed in particular on the impact of a number of management activities strongly associated with driven grouse shooting: hare management, predator control, muirburn and grazing. This set of management activities was agreed with the project Steering Group. We also undertook a 'light touch' overview of the impacts of these management activities on the ecosystem services and benefits provided by areas of land managed for driven grouse shooting.

4.1 Hare management

The conservation and population status of mountain hares remains unclear. While there is emerging evidence of severe localised declines in NE Scotland a clear and objective assessment is hindered by a reliance on incidental data from surveys that were not designed to monitor mountain hares.

Killing mountain hares will reduce the local population in the short-term, but the wider and long-term effects will depend on the proportion killed, the spatial scale and the duration over which they are killed combined with the regional population dynamics and how the population responds to large-scale and localised removal of hares. Because of several contributing factors, evidence suggests that sport shooting of mountain hares is likely to have a limited effect on overall and long-term mountain hare conservation status. However, we expect the impact of population control (reduction) to be different; it will depend on the level of control, the spatial and temporal extent and interaction with local and wider hare density and hare management.

Although the overall impact of hare population control on hare populations is more likely negative than positive, evidence to assess the mediating effects on these impacts of control levels, population densities, and phases of population growth is lacking. Mountain hare populations have the potential for high population growth rates and there is evidence of density-dependent compensation. At the same time evidence suggests that hare populations in Scotland show limited dispersal capacity and may therefore be prone to local extinction, though hare spatial ecology is not well understood.

Changes in mountain hare numbers could have potential cascading effects on predators, although the effects are not well researched. As many predators are generalists the impact might not be severe, but this is not known, and a reduction or loss of mountain hares may result in predators taking a higher proportion of alternative prey (including grouse).

Although hare browsing can suppress tree growth and woodland establishment (depending on hare densities and the availability of alternative browse species), we found little evidence to support population control of mountain hares to protect heather. There is also limited available information on the biodiversity impacts of browsing by mountain hares, the effects on sensitive vegetation, and the need for associated hare population control. There is also no substantive evidence of competition between grouse and hares for forage. Similarly, except under unusual circumstances, there is no compelling evidence for population control of hares as part of tick and/or LIV control to benefit grouse.

There are interactive effects of other management activities on mountain hare populations: legal predator control and muirburn can both benefit mountain hares. However, evidence is mostly correlational and the lack of experimental evidence makes it impossible to identify the relative importance of land use and other biotic and abiotic factors.

4.2 Legal predator control

Experimental studies from moorland managed for grouse shooting, suggest that the impacts of legal predator control varies between non-target bird species, and that predator control tends to increase breeding success more than population density. Correlational evidence also strongly suggests that predator control can have positive biodiversity effects by increasing breeding success and numbers of some species of ground nesting bird, particularly upland waders, that breed on moorland, but effects can be negative for other species. There is also evidence that predator control favours a slightly different bird community compared to other areas under different management, thereby promoting an overall greater number of species at a landscape scale.

Predator control will, by definition, reduce local populations of controlled species, sometimes dramatically. However, the link between legal predator control and population change at the wider geographic scale is unknown and the effect of systematic and sustained predator control on the species that are controlled is not well understood. Predators carry out a range of ecological functions, and again the impact of reduced abundance of predator species, some of which are also important scavengers, is unknown. The carcass remains of killed animals provide a source of energy and nutrients for a wide range of organisms with cascading trophic effects that influence soil chemistry, vegetation, invertebrate and vertebrate communities. The removal of key stone predators can also influence the distribution and abundance of smaller predators (meso-predators) leading to the so called meso-predator release (greater numbers of smaller predatory species) with positive and negative biodiversity effects. However, and again in the context of predator control on grouse moors in Scotland, there is a distinct lack of knowledge about how removal of one, or a range of, predators affects other predators and wider food web. Overall the effects of predator control on wider biodiversity are poorly understood.

4.3 Muirburn

In the UK, there is currently a particularly strong association between muirburn and habitat management for red grouse, but it is also used in some moorland areas for management of deer and livestock grazing. On moorland areas managed for driven grouse (the focus of this review), rotational muirburn is carried out to create small patches of heather of different ages to produce a mosaic of patches of ground containing young, more nutritious heather stems for grouse to eat and patches of taller heather for cover. There is both guidance and regulation relating to muirburn (Muirburn Code 2017, SRDP and more).

Biodiversity impacts. There has been a great deal of research on muirburn impacts on above-ground biodiversity, with a wide diversity of often contradictory findings. Data availability on above-ground biodiversity impacts varies considerably across species groups - most available data relate to plants and birds, less for other vertebrates (apart from livestock, deer and mountain hares) and very few studies on invertebrates. One of the aims of muirburn as a management tool is to retain moorland vegetation-dominance and prevent regeneration of woodland and scrub - as such, it is well established that regular muirburn has a detrimental effect on tree and scrub species.

There is strong evidence that the major determinant of any reported increases in moorland biodiversity (including plants, birds and invertebrates) is the mosaic of different ages of burn giving a mix of habitat structures, particularly in dry-heath areas, as well as post-fire 'good seedbeds' for germination. There is no consistent evidence for increases or decreases in biotic homogeneity following regular muirburn. Undoubtedly, muirburn can in some cases cause detrimental effects on biodiversity (and other components of the system) - fire intensity seems to be critical in determining severity of impact, but most studies have not recorded this - the high degree of uncertainty and controversy concerning muirburn impacts is probably directly related to this paucity of connected information from fire intensity through to measured impacts - this is a major knowledge gap. There is strong evidence that a key issue in terms of impacts of muirburn is whether the fire has burned

into the moss/litter layer/soil/peat - in that order, it greatly increases the likelihood of detrimental impacts, not just on biodiversity.

Muirburn impacts on biodiversity can also differ according to the type of moorland. Strongest (but still inconclusive and contradictory) evidence for a greater likelihood of long-term *detrimental* impacts comes from blanket bog/wet heath areas, but recent publications from a 60-year experimental study dispute this assumption. Impacts of fire frequency on biodiversity are also an area of disagreement, with some modelling work but relatively little field-data. We propose that some of these contradictory findings probably also relate to (usually undocumented) differences in fire severity across the different studies. It has been widely assumed, for example, that regular muirburn is detrimental to peat-forming species such as *Sphagnum* but several studies have found the opposite. In addition, not all *Sphagnum* species are considered indicative of a bog in good health (some species are important peat-formers, others are not) so this also needs to be considered when assessing individual *Sphagnum* species responses to muirburn. There have also been surprisingly few studies on whether fire frequencies have changed over time in areas managed for muirburn, and how this relates to changes in biodiversity - this is another knowledge gap hampering understanding about longer-term muirburn impacts.

We found no direct studies on impacts of muirburn on below-ground biodiversity, apart from seed bank studies. Below-ground diversity plays a key role in regulating a whole suite of ecosystem functions (see later section), so the lack of information on muirburn impacts is a major knowledge gap. Fire intensity is again likely to be a key issue: impacts on soil structure/properties (and carbon in particular) have been shown to be more severe (sometimes catastrophic) under more intense, longer duration fires igniting dry soil/peat. Fires penetrating the moss/litter soil are likely to destroy much of the seed bank, which could result in a very different post-fire plant species composition (comprising vegetative regrowth and germination from seeds arriving in the seed rain as opposed to germinating from the soil seedbank). If the fire does not penetrate the moss/litter layer then we would expect below-ground biodiversity impacts to be much reduced, but there are too few data to support or refute this suggestion.

Biodiversity impacts of burning v not burning heather moorland. It was traditionally thought that regular muirburn was necessary for *Calluna* to remain dominant, but this has been disproved at least for some moorland areas where heather remained dominant (through stem layering/rooting) for at least 40-60 years without burning. It is not known what proportion of Scotland's moorland has never been burnt, and we cannot even estimate what proportion of moorland might remain heather-dominated long term in the complete absence of fire. This information would greatly inform the debate about the 'need' or otherwise of regular moorland burning in terms of maintaining *Calluna* dominance (we consider that the 'benefit' of muirburn in terms of greater nutritive value of young heather shoots following fire is well established in the literature).

There is little comparative information on impacts of heather burning versus cutting, and the differences are not simple: old heather regenerates better after fire than cutting (strongly dependent on seed germination and seedbed), but the few data available indicate that younger heather regenerates better under cutting than burning. Discussions on relative impacts of muirburn v cutting on other elements of biodiversity are mostly speculative as there is so little information available.

Climate change and muirburn. The risk of uncontrolled fire is predicted to increase in Scotland as summers are predicted to become hotter and drier. Various data sources from both Scotland and England quote varying proportions of wildfires starting from muirburns. Given this connection, it is critically important that the Muirburn Code and regulation updates relating to muirburn use the best available evidence to minimise the chance of muirburn fires getting out of control. This includes explicitly addressing predicted climate-related changes of strong relevance to muirburn intensity/severity into the future. Muirburn (and grazing and cutting) can also play a role in reducing

fuel loads and possibly reducing the incidence or at least the severity (temperature) of wildfires, although there is a lack of data demonstrating how these management actions can be combined to best effect.

4.4 Grazing

Grazing has long been a feature of most moorland and, with burning, is responsible for its open character and characteristic biodiversity. However, too many grazers can result in conversion of heather-dominated vegetation to grassland and too few, especially without burning, in the invasion of scrub and woodland. However, as the grazers are often both domestic and wild then management of one group can have indirect effects on biodiversity. For instance, reduction/removal of livestock leaves more resources available for deer; but as deer forage more on heather than do sheep, the reduction in sheep grazing could mean higher grazing impacts on heather.

There are a number of evidence gaps with regard to grazing management of grouse moors and other moorland. In particular our knowledge of the long-term impacts of grazing and burning is limited to one experiment in Northern England – Moor House - so we have little knowledge of how impacts might differ in different contexts. We also know little about the short-term impacts of grazing on heather regeneration and how grazing can help or hinder grouse moor management, and in particular the impact of grazing on the length of required burning cycles. Finally, we know very little about how grouse moor managers decide whether management for grouse is their main focus, or whether management is for multiple objectives including livestock rearing and deer hunting.

4.5 Ecosystem services

The main ecosystem services delivered by areas managed for driven grouse shooting include some provisioning services (e.g. food and fibre provision), regulating services (e.g. carbon sequestration), and cultural services (e.g. outdoor recreation, field sports). The Natural Capital Asset Index indicates that service delivery potential in moorland has been declining since 2000, albeit with recent increases.

Different upland habitats provide different types and levels of ecosystem service delivery. Areas managed for driven grouse shooting may contain several different habitat types, but the habitat type of most direct relevance to driven grouse shooting is dwarf shrub heath. However, it is sometimes not possible to attribute levels of service delivery to specific habitats within the uplands; studies often assess service provision over large areas (e.g. service delivery by catchments) without attempting to attribute relative service delivery levels to specific habitats within those areas.

Where habitat-level attribution is possible, dwarf shrub heaths are often considered of relatively high importance, but very few studies explicitly examine the delivery of services by areas managed for driven grouse shooting. Furthermore, studies of service delivery by uplands or moorlands commonly focus on a small subset of services; information on the delivery of many services – particularly cultural ecosystem services – is lacking.

Taking the term 'biodiversity' to mean 'nature', some of the key ecosystem services and benefits from moorland systems, including those managed for driven grouse shooting, are clearly underpinned by their biodiversity. These include, for example, the provision of meat from grazing animals and grouse and deer for recreational hunting. For other services the relationship is much less clear. This is in part because of the lack of clarity concerning the attribution of service delivery to specific habitats, or to areas that are or are not managed for driven grouse shooting.

Another factor adding complexity to the biodiversity-benefits relationship is the role of people in co-producing ecosystem services. Because of the critical role of the interactions between people and nature in delivering some services, ecosystem service delivery can vary depending on the accessibility of land. Overall, we need to develop a better understanding not only of the flows of ecosystem services from areas of land managed for driven grouse shooting, but also of how

ecosystem service potential is converted into benefits, and when co-production is a key part of this process.

Considering how key management actions strongly associated with driven grouse shooting influence service delivery, targeted control of particular species (i.e. predators and hares) will have complex effects propagated through networks of interactions with other species and mediated through interactions between people and the environment. We suggest that the effects of these management actions will be relatively localised and to some extent dependent on distances to areas with large numbers of people. Overall, we can see that the response of wider ecosystem services to muirburn is complex and likely also to be highly context dependent, varying both with biophysical factors (e.g. vegetation types, climate) and human population densities (altering, for example, risks of wildfire). Grazing influences both locally-delivered services (e.g. meat, recreational hunting) but also some of the more dispersed benefits such as climate regulation and pollution mitigation. It also interacts with other management activities – such as muirburn – to regulate services provision.

Overall, we lack information in particular on the complex relationships between nature, people and the delivery of benefits from areas of land managed for driven grouse shooting, and the impacts of management for driven grouse on the delivery of these services. Given that dwarf shrub heath habitats are considered important for ecosystem service delivery in the uplands, it seems clear that we need to bring these issues together in new studies aiming explicitly to understand how management for driven grouse shooting affects ecosystem services and delivery of benefits to people.

4.6 Future research options

As indicated above, major knowledge gaps have been identified by each of the sections of the detailed biodiversity impacts review. To address the identified knowledge gaps, here we propose some future research options. We have prioritised these (high, medium, low) based on a combination of difficulty of delivery and the immediate importance of the evidence gap.

- Link new data emerging from analyses undertaken in this study – for example GIS-based estimates of grouse moor management intensity – with other geographically explicit datasets of biodiversity impacts (e.g. changes in populations of key species; distributions of confirmed raptor persecution incidents). It is important to include temporal and spatial analyses to address questions relating to frequency as well as spatial-intensity of muirburn and other moorland management activities. – *High priority*.
- Develop the new GIS-based techniques to assess the area of land in Scotland under management for driven grouse. – *High priority*.
- Further investigate the role of muirburn in causing wildfires and/or protecting against large wildfires through reducing fuel loads. This can be done by collecting and interrogating SFRS and other documented information on wildfire causes. Annual data collection by SFRS (and possibly many estates?) gives the opportunity to examine both temporal and spatial patterns, and to link these to climate and land management data. – *High priority*.
- Assess the distribution, intensity and impact of hare management and legal predator control, including assessment of by-catch by legal predator control. – *Medium priority*.
- Detailed assessment of hare-louping ill-grouse relationship. – *Low priority*.

Future research could also focus on purpose-designed experimental studies that:

- Compare areas of moorland managed and not managed for driven grouse shooting, enabling an explicit assessment of driven grouse shooting impacts.
- Manipulate the intensity of specific management activities (e.g. predator control, hare population control, muirburn) in a controlled fashion (and also possibly in combination with other factors, such as grazing, to look at interactions).

- Are adequately replicated to account for the impact of context (social and environmental) on responses.
- Are adequately monitored (for example recording muirburn fire intensity, or the response of target organisms such as hares or controlled predators outside – as well as inside – the management area).
- Analyse impacts of different intensities of muirburn on below-ground biodiversity. This would be labour-intensive work but would address an area with almost no current information.
- Examine the responses of both biodiversity and ecosystem service delivery, including tackling those services commonly overlooked (for example cultural ecosystem services).
- Explore the role of people in converting ecosystem service potential to generated benefits.

5 Use of GIS/remote sensing to identify areas of grouse moors, and to assess potential for alternative land uses

The GIS/remote sensing analysis provides a context for other parts of the study by giving an impression of the extent and geographical distribution of driven grouse moors and the biophysical characterisations of the holdings involved (without disclosing data that is not already in the public domain).

The specific objective for the analysis were:

1. To test options for using GIS based methods to identify land areas managed for driven grouse.
2. For those areas identified as possibly under such management to offer a preliminary assessment of alternative land uses.

The analysis concludes by summarising where there are limitations on the analysis and where there are opportunities for improvements in any subsequent work.

5.1 Identifying driven grouse areas

The GIS based analysis has been able to integrate existing spatial data sets to identify a population of holdings that are potentially involved in driven grouse shoots. While the population of holdings identified, using the presence of grouse butts alone, undoubtedly includes false positives, when combined with data such as strip burn proportions, it is certainly possible to have an indication of where regionally more intensive driven grouse activity is being undertaken (see Figure 1). Updating of the strip burning mapping would highlight where since 2010 there has been change in the intensity of this management practice.

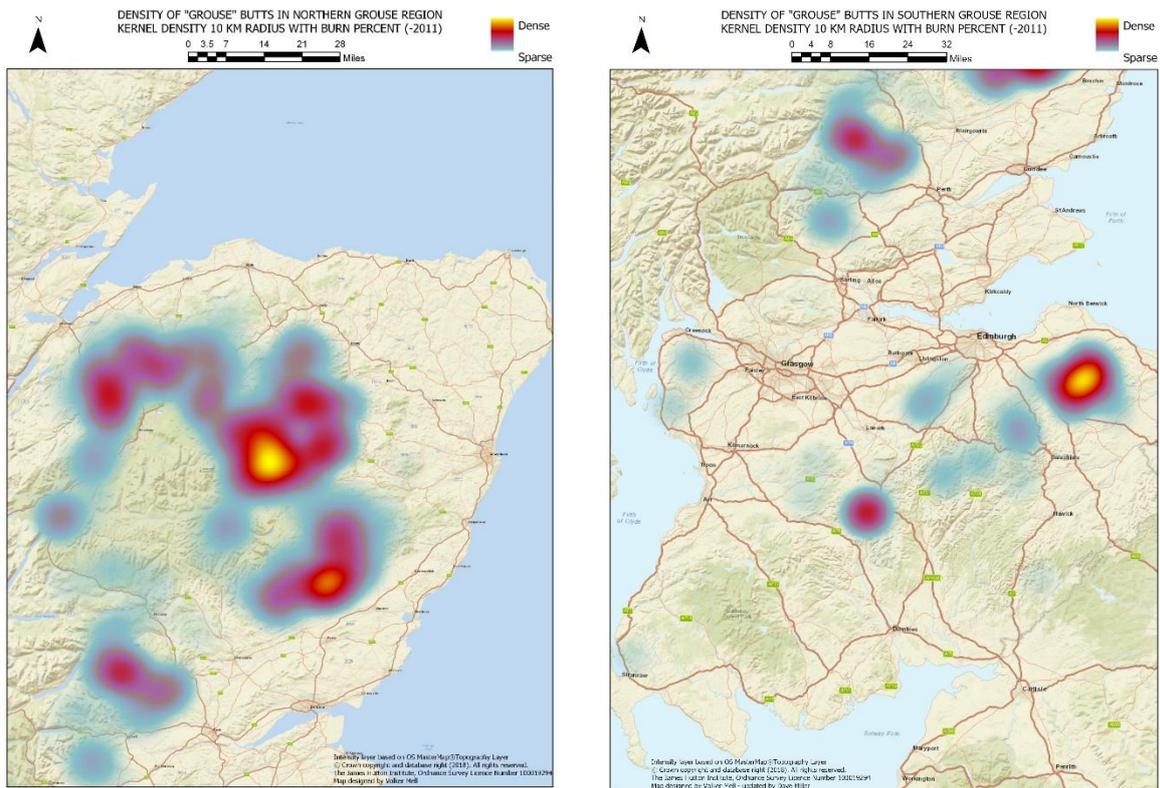


Figure 1: Density of grouse butts that exist before 2010 weighted by strip burning percentage between 2005 and 2010³

The analysis has also been able to use data on when grouse butts have been mapped to provide time lines and locations where grouse butts have been established. The density and distribution of butts mapped as new between 2013 and 2016 is shown in Figure 2.

³ The image on the right of this figure is a replacement for the version published in the original report.

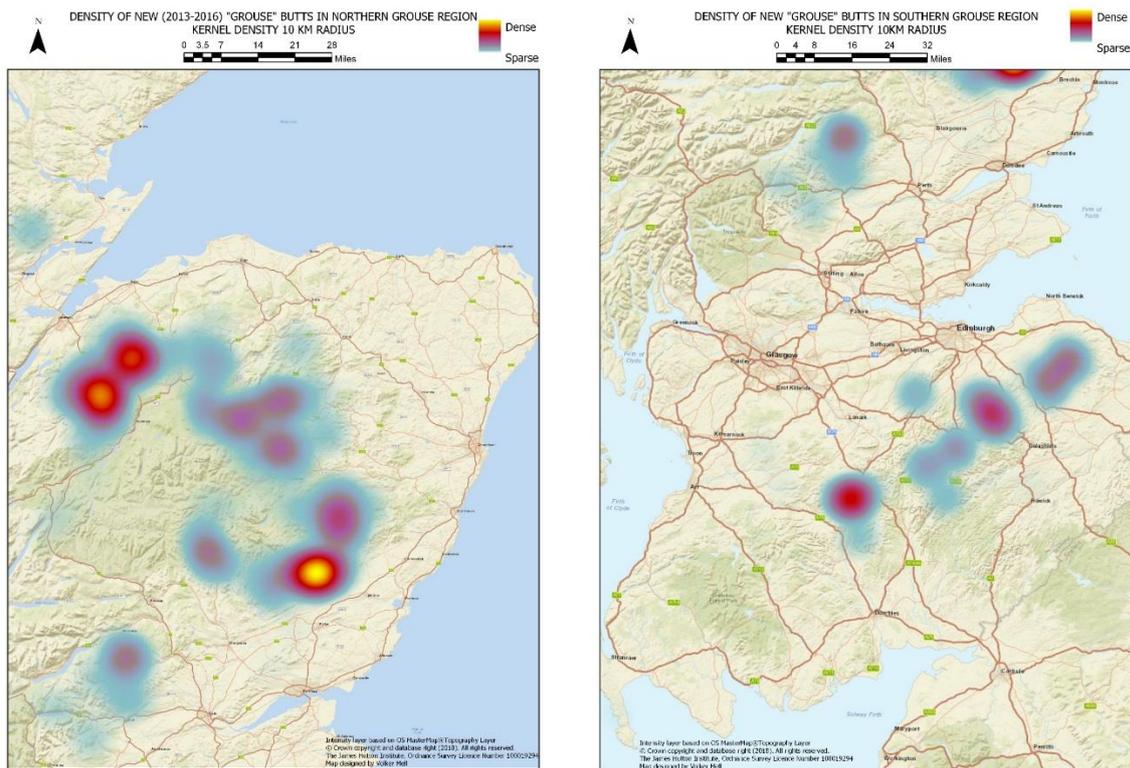


Figure 2: maps of the density and distribution of grouse butts mapped after 2013

5.2 Holding characteristics

The characterisation of the holdings with grouse butts present emphasises that the driven grouse enterprise occurs at a wide range of scales (more than two orders of magnitude) and in a wide range of circumstances. There are clearly holdings that, for land-based industries at least, appear to specialise in little else, others in which driven grouse can be a substantial element in a mix of enterprises and others where it is a minor part of an enterprise mix dominated by other land-based industries. This means the consequences of any policy, regulatory or management prescriptions are likely to vary strongly, and the *ex-ante* estimation of such effects will be non-trivial.

5.3 Intensity of management

There are also clearly significant localised variations in intensity of management with density of butts per hectare varying by over an order of magnitude. Such differences can even occur between neighbouring holdings reflecting not biophysical drivers but historical and current proprietor resources and preferences. There is some evidence to suggest that there may be regions in which on aggregate the intensity of management is substantially higher than would be typical elsewhere for the same conditions. If intensity of activity in such regions can be linked to undesirable consequences, then the spatial analysis could provide the start of a framework to guide monitoring or licensing of activity.

5.4 Alternative land use: agriculture

Typically, the land capability for agriculture of the holdings is low, particularly for the land parcels on which the grouse butts are found, and the recorded land use is rough grazing of unimproved pastures. The presence of rough grazing on land which could, based on land capability alone, be used for improved grassland or even mixed agriculture suggests that either the LCA mapping has

been too optimistic, or socio-economic factors mean that the land has not been historically improved or that proprietors have placed a higher value on maintaining the semi-natural pastures for use as grouse moors. While grazing of unimproved pastures could be feasible it seems unlikely to be viable given the reduction in stocking of hill land seen across Scotland since decoupling of CAP payments in 2003. Improvement of land to create permanent pastures is also likely to be prohibitively costly, not to fit with the desires of the proprietors and to potentially conflict with designations.

5.5 Alternative land use: forestry

Land capability for forestry is also typically low for the holdings with grouse butts present. Indeed, the areas considered unsuitable for trees with any expectation of delivering harvestable timber are substantially greater than the areas considered as having very little capability for agriculture. The areas with very limited or even limited flexibility are substantial but it would be better to make specific analyses of afforestation options using the Forestry Commission's forest management alternatives where the mix of public and private benefits can be judged. The need to avoid net carbon losses occasioned by current or alternative management practices means the need to integrate more sophisticated assessments of soils into future assessments.

5.6 Future research options

There are many options for how the assessments made here could be improved either incrementally or fundamentally, depending on the priority given to any follow up analysis. In the judgement of the research team the most valuable option would be to update the strip burning maps using more up-to-date imagery. There would also be significant value in better integrating the socio-economic perspectives with the GIS analysis presented here.