Herbivore Impacts, Upland Red Deer Densities, Carbon Sequestration and Storage in the Upland Red Deer Range – a Report for Scottish Environment Link's Deer Task Force

Summary

The purpose of this work is to review available information about recent changes in impacts on the open hill red deer range; how they may change as the current suite of deer management plans are implemented; and to explore available information about carbon sequestration and storage in the open hill red deer range.

Detailed assessments of red deer and other herbivore impacts have been funded by Scottish Natural Heritage (SNH), covering a number of upland designated sites. SNH has recently published the data from these assessments. It has also undertaken an analysis of their results. This will look at changes in herbivore impacts over time, and the relationship between impacts and deer densities. It plans to publish this analysis imminently as a Commissioned Research Report. Given that, a duplication of this analysis has not been attempted here.

Prior to 2015 many Upland Deer Management Groups did not have collective deer management plans. Since then, almost all groups have produced and published a plan. Plans typically run for five or six years, ending between 2020 and 2022. During the lifetime of the current plans, most groups are monitoring herbivore impacts. Approaches to this vary between groups. To date the results of these assessments have not generally been published.

In the absence of comprehensive data about trends in herbivore impacts across the open hill red deer range, densities can be used as a proxy. Evidence suggests that woodland will not regenerate without fencing where red deer densities exceed 5 per km^2, and that impacts on open habitats (e.g. heaths, blanket bogs) can become moderate or high on at least some habitats above densities of above 8 per km^2.

The most recent count information used in the preparation of deer management plans suggests that 84% of the open hill red deer range currently has a density >5 per km^2, and 65% >8 per km^2 (Table 1).

Target densities at the end of the current deer management plan period could be established for 31 upland DMG areas, covering 1.8 million hectares. 86% of this area has a future planned red deer density >5 per km^2 and 60% >8 per km^2.

Changes to the way greenhouse gas emissions are accounted for will dramatically increase the emissions from peatlands recorded in Scotland's Greenhouse Gas Inventory. Published analysis to implement this approach suggests changing the way emissions from peatlands are recorded would increase Scotland's recorded emissions by around one-fifth.

If, as this recent analysis suggests ~9,500 kt CO2e[1] are emitted by Scotland's peatlands, over 3,000 kt CO2e could be emitted from peatlands within the area covered by Upland Deer Management Groups each year. This would equate to over 6% of Scotland's total GHG emissions in 2017.

Where red deer densities exceed 8 per km^2 across large areas, there is likely to be ongoing damage to some peatlands within that area, and the success of peatland restoration work may be compromised by deer impacts if deer densities remain above that level. Currently, close to 740,000 hectares of peatland are within upland Deer Management Group areas that have an average density >8 red deer per km^2. This is 54% of the peatland within all upland DMGs, and 40% of the peatland in Scotland.

[1] kt CO2e = greenhouse gas emissions equivalent to one thousand tonnes of carbon dioxide

Until the late nineteenth century the Highlands of Scotland and SW Norway had a similar landscape history. Since that time, SW Norway has been reforesting, mainly from natural regeneration. In the most deforested province in SW Norway (Rogaland) woodland cover is predicted to increase from 24% in 2007 to 52% over the next few decades, and in the wider West Norway statistical region, 2.6% of the land area is changing from open ground to woodland every 5 years.

Currently red deer densities in the uplands of Scotland are too high to achieve such rates of reforestation by natural regeneration without fencing. Achieving the same rate of woodland expansion in the area of upland Deer Management Groups as has been observed in West Norway (0.65% increase per year) would result in >16,000ha of new woodland per year. This is more than the area of woodland the Scottish Government plans to create by planting. If this rate of reforestation were to be achieved in Scotland, by 2030 it could sequester carbon equivalent to 5% of the GHG emissions target for Scotland set for that date.

Research done in the 1990s showed it would be possible to have a large decrease in numbers of female red deer (hinds) without a loss of revenue from stalking stags. Based on this research, and experience in Norway, it would be possible to reduce red deer populations in Scotland to ~5 per km^2 and still have a sustainable harvest of 12,000 stags per year, close to the current sporting stag requirements of upland DMGs.

Introduction

This short report was commissioned by Scottish Environment Link's Deer Task Force. The work had three main aims:

- To describe the approach taken to herbivore impact assessment and investigate what the results of assessments show about recent change in impacts in Scotland
- To describe the relationship between red deer densities and herbivore impacts, and to summarise deer densities at Deer Management Group level and how they are planned to change over the time period of current deer management plans
- To investigate the impact of current red deer densities on the sequestration, storage, and emissions of greenhouse gases within their open hill range, focussing on two habitats, peatlands and woodlands.

This work has been carried out in October and November 2019. The information on deer densities has been obtained from the plans published by Deer Management Groups on their websites and on the website of the Association of Deer Management Groups, and has built on previous analysis of this information by the John Muir Trust. Where information sought was not found in the published plans, or clarification was needed, Groups were contacted directly, and information was also sought from the consultants who co-authored Deer Management Plans. The results of a recent report to SNH which examines long-term trends in open hill red deer densities have also been reviewed.[2]

Analyses of the area of peatland, forest and woodland within upland Deer Management Group areas was conducted using QGIS, and using shapefiles downloaded from Scottish Natural Heritage (SNH) and Forest and Land Scotland websites. Upland Deer Management Groups were identified according to the Association of Deer Management Group's classification of groups as either upland or lowland. Where necessary, Deer Management

[2] Albon, S.D., McLeod, J., Potts, J., Irvine, J., Fraser, D. & Newey, S. (2019) Updating the estimates of national trends and regional differences in red deer densities on open-hill ground in Scotland. Scottish Natural Heritage Research Report No. 1149. Available at: https://www.nature.scot/sites/default/files/2019-11/A3115490.pdf and Albon, S.D., McLeod, J., Potts, J., Brewer, M., Irvine, J., Towers, M., Elston, D., Fraser, D. & Irvine, R.J. (2017). Estimating national trends and regional differences in red deer density on open-hill ground in Scotland: identifying the causes of change and consequences for upland habitats. Scottish Natural Heritage Commissioned Report No. 981

Group boundaries were adjusted to reflect the boundaries for which deer management plans have been prepared.[3] SNH data on recent red deer counts was used.[4] Densities have been calculated according to the areas stated in deer management plans. Where SNH deer count figures have been used, the area stated by SNH to have been counted has been used to calculate densities.

Academic experts at the University of Edinburgh, Climate Xchange, and the James Hutton Institute were consulted for advice. Literature consulted has been referred to in the text.

Herbivore Impact Assessment

Herbivores impact habitats by grazing and browsing vegetation; by enriching soils from their dunging; and large herbivores also impact habitats by trampling of vegetation and soil.

There are two main methods which use field observations of grazing, browsing, dunging and trampling to assess the level of impact which herbivores are having on open (non-wooded) habitats:

- A detailed assessment using the field indicators developed by SNH in their Guide to Upland Habitats (MacDonald et. al 1998). This method uses 10-15 indicators depending on the habitat being assessed, and is used by the Herbivore Impact Assessments (HIA) commissioned by SNH on designated sites.[5]
- A less detailed approach to assessment set out in Best Practice Guidance[6]. This is a simplified method which assesses one indicator each of grazing/browsing; trampling; and dunging for each habitat, and also records other features such as the presence/absence of certain plants, and the height of the vegetation.

For woodlands, a detailed methodology has been developed by SNH and Forest and Land Scotland[7]. This "woodland grazing toolbox" uses indicators of browsing of young trees and tree branches and shoots within browsing height; bark stripping; grazing and browsing of shrubs and ground vegetation; and trampling and tracking. Best Practice Guidance sets out two alternative methods for assessing impacts in woodlands which either measure the proportion of trees within a plot which show signs of deer damage; or which mark and monitor browsing of young trees over time.

The detailed approaches briefly described above[8] yield better quality and more reliable data than the Best Practice approach. A few examples serve to illustrate some of the problems of the Best Practice methods:

- If grazing is very high, heather is often stunted in a carpet form and thus not susceptible to stem breakage which is the only indicator of trampling used by Best Practice for assessing impacts on heaths.

[3] Separate plans were produced by the four subgroups of the West Sutherland Deer Management Group, and three subgroups of the East Grampian Deer Management Group, so the boundaries of these groups were split into these sub-group areas.
[4] Scottish Natural Heritage (2019). Red deer count information. [Online]. Available at: https://www.nature.scot/sites/default/files/2019-08/SNH%20Deer%20Census%20Results%202006-2018.pdf
[5] MacDonald, A. Stevens, P. Armstrong, H. Immirzi, P & Reynolds, P. (1998) A Guide to Upland Habitats - Surveying Land Management Impacts - Volumes 1 and 2. Edinburgh: Scottish Natural Heritage. Available at: https://www.nature.scot/guide-upland-habitats-surveying-land-management-impacts-volumes-1-and-2
[6] Best Practice Guides: Impacts. Available at: https://www.bestpracticeguides.org.uk/impacts/
[7] Scottish Forestry. Woodland Grazing Toolbox. Available at: https://forestry.gov.scot/woodland-grazing-toolbox
[8] i.e. the methods in the SNH Guide to Upland Habitats and the Woodland Grazing Toolbox

- Assessing vegetation by presence/absence as per Best Practice methods is not particularly meaningful. Heather or bog mosses could have a cover value of <1% to 100% and still have the same presence/absence scores.[9]
- Low vegetation does not necessarily indicate high grazing, nor tall vegetation indicate low grazing. For example, on a blanket bog which has been damaged and which has drier peat, heather will grow taller than on a functioning bog with a higher water-table.

Recent changes in Herbivore Impacts

SNH was contacted for information on the Herbivore Impact Assessments it has commissioned. In response SNH said that it had recently undertaken a project to collate, standardise and analyze all the HIA information it holds. SNH published data from HIA it has commissioned in September 2019.[10] As part of this work it has undertaken an analysis of change in impacts on sites where there has been more than one HIA carried out, and an analysis of the relationship between impacts and deer densities. SNH intends to publish this work as a Commissioned Research Report imminently. Given that, a duplication of this analysis has not been attempted here..

This HIA information is only available for a limited range of sites, and has been focussed on sites of nature conservation interest, often where high herbivore impacts were already known or were suspected.

During the lifetime of the current set of deer management plans, DMGs have begun collecting HIA information themselves, using a range of approaches, and methodologies, but typically using the Best Practice Guidance approach. As noted above this approach has limitations. Practices have also varied between groups, for example in the number of locations that have been assessed. Some estates have conducted HIAs using the more detailed methods developed and used by SNH. The results of this work carried out by DMGs and estates have so far largely not been published. In many cases, only one assessment has been carried out, so comparisons to look at change over time would not yet be possible.

Deer densities at Deer Management Group level

Counting deer

Where red deer live in woodland, whole population counts are impossible. Direct counts of deer in woodland can be used e.g. by comparing the changes in the number of deer seen in fixed time periods at fixed locations to build up an index of the population. Alternatively, indirect methods can be used – counting deer dung in sample areas and using this to estimate the population.[11]

Where red deer live wholly or mainly on the open hill, whole population counts can be attempted, and these have been preferred by deer managers to indirect methods as a means of estimating populations. As open hill red deer populations can range over large areas, these counts are more reliable if the count covers the whole of an area that deer are likely to range over. Collaborative counts of open hill red deer ranges have been carried out in Scotland since the 1960s by upland Deer Management Groups working with the Red Deer

[9] The Best Practice methods use a 2m by 2m quadrat divided into sixteen 50cm by 50cm squares. Presence or absence of heather and bog mosses (*Sphagnum spp*) within these sixteen squares is recorded.

[10] Scottish Natural Heritage. Upland habitat impact assessment surveys. [Online]. Available at: https://gateway.snh.gov.uk/natural-spaces/dataset.jsp?dsid=HIA

[11] Campbell, D. Marchbank, M. Watson, M. & Quin, S. 2017. Trends in woodland deer abundance across Scotland: 2001-2016. Scottish Natural Heritage Commissioned Report No. 948. Available at: https://www.nature.scot/sites/default/files/2017-11/Publication%202017%20-%20SNH%20Commissioned%20Report%20948%20-%20Trends%20in%20woodland%20deer%20abundance%20across%20Scotland%202001-2016.pdf

Commission and its successors the Deer Commission for Scotland and SNH. From the 1960s until 2000, these counts were foot counts – teams of counters would conduct coordinated counts of red deer by systematically searching the open hill range, marking sightings on maps, and communicating with each other by radio, to avoid errors from double counting. Since 2001 helicopters have been used to count red deer on the open hill. This has the advantage of allowing large areas to be covered on a single day by a single counting team. More recently the reliability of helicopter counts has been improved by taking digital photographs of large groups of deer, and counting them from the photograph on a computer screen after the count day.

Counts are typically undertaken in the late winter/early spring, after the stalking season has ended, and before the calving season. Counting at this time of year also increases the chance of there being snow cover, which inhibits deer movements between count areas, and makes them more visible.

While helicopter counting is now preferred, reviews have suggested that it is no more reliable than foot counting[12]. Daniels (2006) investigated the accuracy of different methods of deer counting.[13] He concluded that where foot counting was carried out well - i.e. with sufficient manpower to minimise time to cover the ground it produced results with similar co-efficients of variation to helicopter counts although the latter (at the time) were more cost efficient Whichever method is used, count results are an estimate of the deer population, as there is always an unknown risk of either over or under-counting, for example because the count area includes woodland within which deer cannot be counted, or because deer move onto or off the count area, or move within it, and so are either not counted, or counted twice. The cost in terms of both expense and time of conducting counts means that they are typically only repeated once every five to ten years.

SNH has commissioned research[14] which uses the time-series of counts available for any given count area to establish long-term trends in red deer densities, and to predict densities for years in-between counts. This research is discussed at the end of this section.

Linking densities and impacts

In the absence of comprehensive, detailed information about red deer impacts across their open-hill range, densities can be used as a proxy for likely impacts.

In a review, Putnam et. al (2011) suggest threshold densities for impacts. They state that unfenced woodlands will not regenerate naturally above a density of 4 to 5 red deer per km^2, and that impacts on open-habitats such as blanket bog or heath are light to moderate below 8 red deer per km^2, and so by extrapolation can become moderate or high above these levels, at least for some habitats. These densities for open habitats are derived from the work of Albon et. al (2007) who quantified the grazing and trampling impacts of wild and domestic herbivores in 11 DMG areas[15]. A more recent study investigated the relationship between Scots pine seedling growth and red deer densities over more than twenty years. It

[12] Discussed in Albon et. al (2019) *opp cit*, Box 1.
[13] Daniels, M.J. (2006). Estimating red deer (Cervus elaphus) populations in the open range of Scotland: an analysis of the variation and cost effectiveness of different counting methods. Mammal Review 36(3): 235 - 247.
[14] Albon et. al (2019) and Albon et. al (2017) *opp cit.*
[15] Albon, S. Brewer, M. O'Brien, S. Nolan, A. and Cope, D. (2007) Quantifying the grazing impacts associated with different herbivores on rangelands. Journal of Applied Ecology. 44, 1176-1187.

found that seedling growth increased once red deer numbers were maintained below 3.5 per km^2.[16]

In their deer management plans, upland Deer Management Groups have used deer counts, cull figures and other information on winter mortality[17] and calving rates to build up population models. These models are forward looking and include a projection of the future population based on the cull plans of the group.

The table overleaf shows the red deer densities reported in each upland DMG at the start and targeted at the end of their current deer management plan. Where there has been a deer count since the plan was produced, the table also shows whether the density of deer is higher or lower than it was at the start of the plan. Densities have been categorised as low <5 per km^2; moderate 5-10 per km^2; high 10-15 per km^2 and very high >15 per km^2. The table shows how the density will change in terms of these classes over the plan period if targets are met. The table is sorted in order of descending red deer density at the start of the plan. The actual count figures reported in the deer management plans or by SNH have been used i.e. they have not been fitted to models of long-term population trends.

[16] Rao, S. (2017) Effect of reducing red deer Cervus elaphus density on browsing impact and growth of Scots pine Pinus sylvestris seedlings in semi-natural woodland in the Cairngorms, UK. Conservation Evidence (2017) 14, 22-26.
[17] Information on winter mortality is limited.

Table 1 - Current and Future Deer Densities at Deer Management Group Level

DMG	Area (ha)	Start of plan	Density at start of plan (km^2)	Start Class	End date of plan	Target Density at end of plan (km^2)	End Class	Change in class	Count since plan
Glenartney	15,133	2015	21.0	Very high		Not available, contacted			Higher
Strathtay	6,086	2016	20.2	Very high		Not available, contacted			Lower
Glen Strathfarrar	43,395	2016	18.7	Very high		Not available, contacted			
Strathconon	46,044	2016	17.7	Very high	2021	17.1	Very high	No change	
West Grampian	75,849	2016	17.1	Very high	2021	15.7	Very high	No change	Higher
Lochalsh	41,750	2016	17.1	Very high	2021	24.1	Very high	No change	
East Loch Ericht	29,000	2016	16.7	Very high	2021	16.8	Very high	No change	Higher
South Deeside-North Angus	62,000	2016	16.4	Very high	2020	11.9	High	Reduce very high to high	
Glenisla - Glenshee	32,411	2016	16.1	Very high		Not available, contacted			
Monadhliaths	150,200	2013	15.3	Very high	2023-24	11.8	High	Reduce very high to high	Lower
Morven	24,500	2014	15.2	Very high	2022	6.9	Moderate	Reduce very high to moderate	Lower
Jura	36,505	2016	13.9	High		No plan			
East Ross	16,379	2016	13.6	High	2021	7.8	Moderate	Reduce high to moderate	
Islay	34,000	2016	13.0	High		No plan			
Affric and Kintail	27,508	2015	12.9	High		Not available, contacted			
W Sutherland North	22,158	2016	11.9	High	2020	10.5	High	No change High	
North Ross	123,142	2015	11.7	High	2024	9.0	Moderate	Reduce high to moderate	Lower
Glenelg	36,532	2016	11.5	High	2022	14.4	High	No change	Higher
Moidart	20,031	2016	11.4	High	2019	10.2	High	No change High	
East Sutherland	91,900	2016	11.3	High	2022	9.6	Moderate	Reduce high to moderate	Higher
West Lochaber	47,660	2015	11.3	High		Not available, contacted			Higher

DMG	Area (ha)	Start of plan	Density at start of plan (km^2)	Start Class	End date of plan	Target Density at end of plan (km^2)	End Class	Change in class	Count since plan
W Sutherland East	36,157	2016	11.2	High	2021	10.4	High	No change High	
Glenmoriston	33,405	2016	11.0	High	2020	10.4	High	No change High	
Breadalbane	78,575	2015	10.9	High	2021	10.7	High	No change High	Higher
Mull	88,000	2016	10.7	High	2020	9.9	Moderate	Reduce high to moderate	Lower
West Ross	105,153	2009	10.4	High	2023	8.7	Moderate	Reduce high to moderate	Lower
Mid West	101,397	2011	10.1	High		Not available, contacted			Higher
Knoydart	74,056	2014	9.6	Moderate		Not available, contacted			
Rum	10,731	2017	9.4	Moderate	2023	7.9	Moderate	No change moderate	
W Sutherland West	18,049	2016	8.5	Moderate	2021	7.0	Moderate	No change moderate	Higher
Ardnamurchan	21,510	2016	8.4	Moderate	?	7.8	Moderate	No change moderate	
East Loch Shiel	46,233	2016	8.3	Moderate	2022	8.3	Moderate	No change moderate	Higher
Arran	18,560	2014	8.3	Moderate	2022	10.1	High	No change High	
Blackmount	101,364	2015	8.2	Moderate	2024	7.4	Moderate	No change moderate	Higher
Northern	150,678	2013	7.8	Moderate	2020	5.7	Moderate	No change moderate	
Inveraray & Tyndrum	38,143	2016	6.8	Moderate	2022	6.6	Moderate	No change moderate	Higher
South Perthshire	72,289	2010	6.7	Moderate		Not available, contacted			Higher
South West Ross	62,789	2017	6.7	Moderate		Not available, contacted			
Upper Deeside and Donside	67,348	2016	6.4	Moderate	2022	7.9	Moderate	No change moderate	Higher
Balquhidder	35,101	2010	6.3	Moderate	Date not set	6.0	Moderate	No change moderate	Higher
Cairngorm Speyside	75,082	2010	5.5	Moderate		Not available,			Lower

DMG	Area (ha)	Start of plan	Density at start of plan (km^2)	Start Class	End date of plan	Target Density at end of plan (km^2)	End Class	Change in class	Count since plan
						contacted			
North West Sutherland	158,082	2012	4.9	Low	2023	3.9	Low	No change low	
W Sutherland South	40,900	2016	4.4	Low	2023	4.3	Low	No change low	
Gairloch	42,600	2017	3.2	Low		Not available, contacted			
Lewis and Harris	115,277	2013	2.8	Low		Not available, contacted			
Uist	62,799	2015	2.7	Low	2020	2.2	Low	No change low	Lower
Skye	17,707	2015	1.8	Low		No plan			

Was information available?

Out of 47 upland DMGs and sub-groups:

- Target deer populations at the end of the plan period were available from published information, and following contacts with groups for 31 groups
- Target deer populations at the end of the plan period could not be ascertained for 13 groups
- 3 DMG areas had not published a plan on either their website or the website of the Association of Deer Management Groups

Impacts at DMG level implied by current densities

Upland DMGs cover an area of around 2.6 million hectares. At the start date of the plans, or at the most recent red deer count for those areas without plans:

- 84% of this area had a red deer density >5 per km^2. Woodland cannot establish by natural regeneration without fencing when densities exceed this level and the condition of existing woodland is likely to be adversely affected.
- 65% of this area had a red deer density >8 per km^2. Moderate to high impacts on at least some open habitats can occur above this level.

Impacts at the end of the current set of DMPs

Thus far, it has been possible to establish the planned density at the end of the current set of deer management plans for around 1.85 million hectares. At the time the plans end:

- 86% of this area would have a red deer density >5 per km^2
- 60% of this area would have a red deer density >8 per km^2.

Counts since plans were published

23 DMG areas have been counted by SNH since the start of their deer management plan. Results of these counts show that:

- Deer numbers have increased in 15 DMG areas (57% of the area counted) and decreased in 8 DMG areas (43% of the area counted).
- For those DMGs that have been recounted, the total number of deer counted at the time the plan was written was 155,718 and the total number of deer counted in recounts since the plan was published was 162,092.

Change in deer density summary

Red deer densities have been classed as low <5 per km^2; moderate 5-10 per km^2; high 10-15 deer per km^2; and very high >15 per km^2. Figure 1 in the appendix shows current red deer densities averaged at DMG level using these class intervals, and Figure 2 shows red deer densities at the end of the current deer management plans.

The table overleaf shows the change in density over the period of the current plans for those 31 groups for which it has been possible to establish this information.

Table 2 - Change in density class between start and end of DMPs

	Number of DMGs	% of area
Remain very high	4	10%
Reduce from very high to high	2	11%
Reduce from very high to moderate	1	1%
Remain high	7	13%
Reduce from high to moderate	5	23%
Remain moderate	9	26%
Reduce from moderate to low	0	0%
Remain low	3	14%

SNH Commissioned Research on Red Deer Densities

As noted above SNH has published Commissioned Research Reports on red deer densities[18]. The most recent report was published in November 2019 and provides an update to include counts carried out since the previous report was published in 2017. This work uses a population model to project long-term trends in densities, which allows them to be predicted between count years. The model shows an average density of around 6 deer per km^2 in the 1960s, rising to a peak of around 10 deer per km^2 in 2000. Since then the central estimate of density has fallen slightly (10.25 deer per km^2 in 2000 to 9.35 per km^2 in 2019), although the 2019 estimate is within the confidence intervals for 2000 (95% confidence interval 8.96 to 11.53 red deer per km^2). The authors conclude that since estimates over the last 20 years all lie within the same range of confidence intervals, the overall density appears to be stable over this time period.

The research includes projections of densities at Deer Management Group level. These show that 17 DMGs were projected to have a density of less than 8 red deer per km^2 in 2019 (compared to 13 using the count figures reported at the start of the deer management plans per Table 1).

An annex to the report includes time series of densities for each DMG going back between 40 to 60 years. Out of the 47 upland DMGs, 32 show an increase in average density at the end of the time series compared to the start, average density has decreased in 5 DMG areas, and is stable / similar in 10 DMG areas.[19]

[18] Albon, S.D., McLeod, J., Potts, J., Irvine, J., Fraser, D. & Newey, S. (2019) Updating the estimates of national trends and regional differences in red deer densities on open-hill ground in Scotland. Scottish Natural Heritage Research Report No. 1149. Available at: https://www.nature.scot/sites/default/files/2019-11/A3115490.pdf and Albon, S.D., McLeod, J., Potts, J., Brewer, M., Irvine, J., Towers, M., Elston, D., Fraser, D. & Irvine, R.J. (2017). Estimating national trends and regional differences in red deer density on open-hill ground in Scotland: identifying the causes of change and consequences for upland habitats. Scottish Natural Heritage Commissioned Report No. 981

[19] These figures have been calculated from examining the graphs of deer densities in Deer Management Areas included in Annex 2 of Albon et. al (2019) *opp cit*.

Impacts from other herbivores

The main large herbivores which are also present within the open-hill red deer range are hill sheep. Roe deer are also present within the red deer's open hill range. Their browsing impact may be significant in woodland, especially in browsing of young trees and shrubs, but they do not generally have a significant impact on open habitats. Mountain hares are also present. In western Scotland mountain hares are at very low density, typically less than one per km^2 and so have a negligible impact. On grouse moors in the Central and Eastern Highlands, mountain hares can occur at much higher densities. Evidence suggests that densities are now much reduced here also, following culling.[20]

Changes to the EU's Common Agricultural Policy in 2005[21] accentuated an ongoing decline in Scotland's sheep flock, with the reduction particularly pronounced in the North and West where sheep rearing is most economically marginal. Many areas of the Northwest Highlands saw a reduction in sheep numbers of between 35 and 60% between 1999 and 2007.[22] This decline continued in the NW Highlands from 2007-10, but at a slower rate.[23]

Whilst the reductions in hill sheep numbers will undoubtedly lead to a reduction in impacts from sheep grazing and trampling in the areas from which sheep have been removed, it is important to note that the threshold densities described above for red deer relate to the impacts from red deer alone. Thus in those areas of their open hill range where red deer densities remain above these levels, these impacts are likely to continue to occur.

One of the consequences of the reduction in hill sheep numbers was expected to be that red deer would expand their range and increase in number where competition from sheep grazing was reduced. To date there is no evidence that changes in sheep numbers have had any influence on trends in red deer densities at the Deer Management Group scale, though at the parish scale, red deer densities were lower in areas with higher sheep density.[24]

Greenhouse gas emissions, sequestration and storage in the open hill red deer range

Emissions from peatlands

Changes to the way greenhouse gas emissions are accounted for will dramatically increase the emissions from peatlands recorded in Scotland's Greenhouse Gas Inventory. Currently the Inventory is based on the Intergovernmental Panel on Climate Change's guidelines from 2006. These guidelines include only a small fraction of emissions from peatlands. A new approach to accounting for emissions from wetlands (including peatlands) was agreed at the Conference of the Parties (COP) summit of the United National Framework Convention of

[20] Watson, A. & Wilson, J.D. (2018) Seven decades of mountain hare counts show severe declines where high-yield recreational game bird hunting is practised. Journal of Applied Ecology.
[21] The reforms removed headage payments which required farmers to keep sheep to receive the payment, and replaced them with a "decoupled" single farm payment. As many hill sheep enterprises were loss making without subsidy, once the requirement to keep sheep to receive the subsidy was removed, many farms and estates reduced their sheep numbers.
[22] Scottish Agricultural College. (2008) Farming's retreat from the hills. [Online]. Available at: https://www.sruc.ac.uk/downloads/download/18/2008_farming_s_retreat_from_the_hills
[23] Scottish Agricultural College. (2011) Response from the hills: Business as usual or a turning point? [Online]. Available at: https://www.sruc.ac.uk/downloads/file/57/response_from_the_hills_business_as_usual_or_a_turning_point
[24] Albon et. al (2017) and (2019) *opp cit*.

Climate Change in 2013. The UK is in the process of adopting this approach and accounting for emissions from peatlands differently in its Greenhouse Gas Inventory[25].

The table below shows the emissions from peatlands and other wetlands currently included in Scotland's Greenhouse Gas Inventory, compared to the estimates of emissions from peatlands using this new approach. To put these figures into context, Scotland's total emissions recorded in the National Atmospheric Emissions Inventory (NAEI) are also shown.

Table 3 – Changes in Greenhouse Gas Emissions from peatlands in 1990 and 2013 following the adoption of a new methodology of accounting for emissions

	1990	2013
Emissions from peatlands and other wetlands included in NAEI	874	-30
Scotland Net Emissions in NAEI	74,864	49,361
Additional emissions from peatlands in Scotland using revised methodology	8,832	9,667
Scotland Net Emissions including additional peatland emissions	83,696	59,028
% change in Total Emissions from adding additional peatland emissions	+12%	+20%

Sources: National Atmospheric Emission's Inventory, Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland 2017 and Evans et. al (2019) Implementation of an Emissions Inventory for UK Peatlands.

Table 3 shows two important things: firstly the dramatic extent to which emissions from peatlands have not been included in the Greenhouse Gas Inventory to date; and secondly, that while overall net emissions have declined substantially, emissions from peatlands have scarcely reduced at all.

To add further context to the scale of emissions from peatlands, assuming that emissions from peatlands remained at ~9,500 kt CO2e in 2017, this would represent around one-fifth of all emissions, and more than was emitted by agriculture or energy supply (8,104 kt CO2e and 6,036 kt CO2e).[26]

Peatlands within Upland Deer Management Groups

GIS analysis using the Carbon and Peatland of Scotland dataset shows that there are a total of 1.86 million hectares of peatland[27] in Scotland. Of this 1.36 million hectares (73%) are within the 47 upland Deer Management Groups (Appendix, Figure 3).

[25] Evans et. al (2019) Implementation of an Emissions Inventory for UK Peatlands. Online. Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1904111135_UK_peatland_GHG_emissions.pdf

[26] Using a figure of 9,500 kt CO2e for emissions from peatlands, and 38,648 kt CO2e as the total for all emissions for Scotland according to the National Atmospheric Emissions Inventory, Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland 2017. Available at: http://uk-air.defra.gov.uk/reports/cat09/1906110855_DA_GHGI_1990-2017_Issue1.1.xlsb

[27] This dataset was produced by SNH in 2016 using James Hutton Institute soils data. Class 1 and Class 2 peatland which comprise the nationally important peatland resource have been selected from

Evans et. al (2019) calculated emission factors for different types of peatland, and the total area for each type of peatland.[28] These data can be used to calculate a weighted average emission per hectare for the types of peatland found in the open hill red deer range, 2.26 $tCO2e\ ha^{-1}\ yr^{-1}$.[29] This would suggest that over 3,000 kt CO2e could be emitted from peatlands in upland DMGs, equating to over 6% of Scotland's total GHG emissions in 2017.

Implications of red deer numbers for emissions from peatlands

The current condition of peatlands results from an interaction of factors over centuries. The peatlands within upland Deer Management Group areas may have had, and continue to have hill sheep stocks, and they may have been damaged by burning, or by drainage for farming or forestry. The hags and gullies which cause peat to dry out and the carbon stored in the peat to be oxidised may have begun to form decades ago. The main cause of continued erosion of peat where extensive hag and gully systems have formed may now be erosion from weathering. Thus, without knowing how a particular area of peatland has been managed over time, it is not possible to know what factors have led to its current condition, nor to make an assessment of the proportion of emissions due to a particular factor.

Red deer impact on peatlands in two main ways, by grazing and browsing the vegetation which grows on peatland, and more importantly, through the effect that the trampling action of their hooves has on peatland vegetation. Trampling creates tracks and areas of bare peat which become focal points for erosion. Eventually bare peat erodes to form hags and gullies, which dry out the bog, and cause the carbon it contains to be oxidised.[30]

As explained above, evidence suggests that impacts from red deer on open habitats including peatlands are light to moderate below a density of around 7 or 8 deer per km^2, and so can become moderate to high above that level. Where red deer densities exceed 8 per km^2 over a large area, there is likely to be ongoing damage to some of the peatlands within that area. Also, the success of restoration works to restore past damage to peatlands, for example by reprofiling eroded peat hags so that they can revegetate, may be compromised by deer impacts in places if deer densities remain above that level.

According to the most recent set of count figures, close to 740,000 hectares of peatland are within upland Deer Management Group areas that have a density of 8 red deer per km^2 or more. This is 54% of the peatland within all upland DMGs, and 40% of the peatland in Scotland.

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this dataset using GIS. The total area for these two classes is close to the total area of peatland estimated by Evans et al (2019) of 1.95 million hectares.

[28] Evans et. al (2019) *opp cit*

[29] The categories of peatland included in this calculation are eroded modified bog; heather dominated bog; grass dominated bog; extensive grassland; and near natural bog. The emissions factors for each have been weighted according to the proportion of each of these types of peatland estimated to occur in Scotland.

[30] Lindsay, R. Birnie, R & Clough J. (2015) Grazing and Trampling. IUCN Peatland Programme Briefing Note 7. Available at: https://www.iucn-uk-peatlandprogramme.org/sites/default/files/2019-05/7%20Grazing%20and%20trampling%20final%20-%205th%20November%202014.pdf

Peatland restoration in upland DMG areas

Restoration of peatlands is a priority under the Scottish Biodiversity Strategy[31] and the Climate Change Plan.[32] The plan includes a target to restore 250,000 hectares of Scotland's peatland by 2030.

SNH published an assessment on progress in deer management in November 2019. The report provides an update to the report on deer management that SNH published in 2016.[33] The 2019 update reports that a total of 21,000 hectares of peatland have been restored in Scotland since the peatland action programme began in 2012, including many projects within upland DMG areas. Seven Peatland Action projects have been led by DMGs themselves, out of which three have involved restoration works and four have been feasibility studies.

Neither the SNH Review of Deer Management published in 2016 nor the 2019 update include an assessment of the implications for peatlands of different open hill red deer population densities. The 2019 update does state that "an acceleration of peatland restoration will require associated measures to ensure herbivore impacts do not negatively impact on these efforts."

Forests and woodland in Upland Deer Management Groups

GIS analysis of the National Forest Inventory 2017 dataset shows that there were 432,987 ha of forest and woodland within upland DMGs. Forest cover as a % of their planar area was 13%.[34]

GIS analysis using the Native Woodland Survey of Scotland dataset shows that upland DMGs contain 149,156 hectares of native woodland. This is just under 5% of their planar area, and represents just under 40% of all native woodland in Scotland.[35]

The potential for woodland expansion: evidence from Norway

Halley (e.g. 2015 and 2017a)[36] has contrasted the landscape history of the Highlands of Scotland and SW Norway. They were similar until the 19th century, with SW Norway, in

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[31] Scottish Government (2015) Scotland's Biodiversity: a Route Map to 2020. [Online]. Available at: https://www.gov.scot/publications/scotlands-biodiversity-route-map-2020/ Priority Project 1 is to restore peatlands to contribute to the target to restore degraded ecosystems.

[32] Scottish Government (2018) Climate Change Plan. [Online]. Available at: https://www.gov.scot/publications/scottish-governments-climate-change-plan-third-report-proposals-policies-2018-9781788516488/

[33] Scottish Natural Heritage (2019) Assessing Progress in Deer Management. [Online]. Available at: https://www.nature.scot/sites/default/files/2019-11/Publication%202019%20-%20SNH%20Assessing%20Progress%20in%20Deer%20Management.pdf and Scottish Natural Heritage (2016). Deer Management in Scotland: Report to the Scottish Government. [Online]. Available at: https://www.nature.scot/sites/default/files/Publication%202016%20-%20Deer%20Management%20in%20Scotland%20Report%20to%20the%20Scottish%20Government%20from%20Scottish%20Natural%20Heritage%202016.pdf

[34] Based on a total area for upland DMGs of 3,157,010 hectares, calculated from the SNG GIS shapefile of DMG boundaries

[35] The survey found a total of 385,980 hectares of native woodland in Scotland.

[36] Halley, D (2015) Landscape history and land use in SW Norway. [Online]. Available at: https://www.nina.no/Portals/NINA/Bilder%20og%20dokumenter/Nyheter/Engelsk/Landscape%20history%20and%20land%20use%20in%20SW%20Norway%20-%20Duncan%20Halley%20.pdf and Halley, D. (2017a) Woodland History in SW Norway: Comparative Insights from a Parallel Universe. [Online]. Available at: https://www.nina.no/Portals/NINA/Bilder%20og%20dokumenter/Halley%2C%20D%202017_%20Woodland%20history%20in%20SW%20Norway%20-%20comparative%20insights%20from%20a%20parallel%20universe_%20Proc%20Scot%20Woodl%20Hist%20Conf%202015%2C%2042-53.pdf

common to the Highlands of Scotland, having been deforested for centuries, and in coastal districts, for millennia. The geology and climate of the two areas are also similar, with SW Norway being, if anything less favourable for tree growth, as it is on average wetter and windier.

The landscape histories diverge from the late nineteenth century, since when SW Norway has been reforesting, mainly from natural regeneration, and especially since the 1950s. Research has shown that natural regeneration has followed a reduction in grazing pressure and cessation of other management practices such as muirburn and fuelwood collection.

Halley (2017a) reports that in the most deforested province of all (Rogaland) woodland cover is predicted to increase from 24% in 2007 to 52% over the next few decades, and that in the West Norway statistical region, 2.6% of the land area is changing from open ground to woodland every 5 years.

Halley (2017b) has suggested that it would be possible to *exceed* these rates of forest expansion in Scotland by strategic planting to provide seed sources, as opposed to the largely unmanaged woodland expansion that has occurred in SW Norway.[37]

Implications of red deer numbers for carbon sequestration in woodland

As noted above, based on the red deer count figures included in deer management plans 84% of the area within upland DMGs has an average red deer density of >5 per km^2. This is above the level at which woodland expansion by natural regeneration without fencing, as observed in SW Norway, can occur.

As also noted above, it has been possible to establish the planned deer density at the end of the current period of deer management plans on ~1.8 million hectares. At the time they end, if the deer densities targeted by the plans are achieved, 86% of this area would have a deer density of >5 per km^2.

Thus at the present time, there is little prospect of the sort of natural reforestation as has been observed in SW Norway being achieved on the open hill red deer range in Scotland.

To contextualise the potential for woodland expansion - achieving the same rate of woodland expansion in the area of upland Deer Management Groups as has been observed in West Norway (0.65% increase per year) would result in >16,000ha of new woodland per year. This is more than the area of woodland the Scottish Government plans to create by planting under its Climate Change Plan (10,000ha per year in 2019-20 rising to 15,000ha per year from 2024-25).

In its report to the Scottish Government on emissions targets for 2028-32, the Committee on Climate Change (2016) advised that increasing woodland planting to 16,000 ha per year would result in sequestration of 1,450 kt CO2e by 2030.[38] This represents 5% of the Scottish Government's emission target for 2030.[39]

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[37] Halley, D. (2017b) A summary of deer management in SW Norway. Written submission to Environment, Climate Change and Land Reform Committee. Available at: https://www.parliament.scot/S5_Environment/Inquiries/20170112_Duncan_Halley_Written_Evidence.pdf

[38] Committee on Climate Change. (2016) Scottish emissions targets 2028-2032 – The high ambition pathway towards a low-carbon economy. [Online]. Available at: https://www.theccc.org.uk/wp-content/uploads/2016/03/Scottish-Emissions-Targets-2028-2032.pdf. It is important to note that the carbon sequestered by woodlands depends on factors such as the existing vegetation composition, tree species, density of establishment, and rotation length.

[39] Article 2 of the Climate Change (Annual Targets) (Scotland) Order 2016 sets an emissions target for 2030 of 28,089 kt CO2e.

Woodland restoration and creation in upland DMG areas

The Scottish Biodiversity Strategy set a target to create between 3,000 and 5,000ha of native woodland per year up to 2020. SNH's 2019 assessment reports that this target is on course to being achieved, with an average of 3,300 ha of native woodland having been planted per year between 2014 and 2019.[40] It is not clear from the statistics what proportion of this area has been created within upland DMGs. According to the SNH assessment, Scottish Forestry does not capture information on fencing spatially, and therefore it is not possible to say what proportion of native woodland creation has been supported by deer fencing and where other deer management and or tree protection has helped to contribute to these establishment figures. SNH does report that from April 2015 to March 2019 a total of £12.8m was awarded from the Scottish Forestry Grant Scheme for deer fencing, and £2.2m for tree protection products. These figures are for all woodland types, not just native woodlands.

The SNH assessment does not evaluate the implications of deer densities for woodland creation without fencing. It does suggest that responding to the declaration of the climate emergency by the First Minister and achieving net-zero emissions by 2045 are going to lead to woodland creation being given increased priority compared to the last decade.

What are the implications of lower deer numbers for stag harvests?

The open hill red deer range extends to 2.65 million hectares, with a total red deer population of 264,000 using the most recent count figures, an average population across the whole area of ~10 deer per km^2.

Halley's (2017b) evidence[41] to the Scottish Parliament's Environment Climate Change and Land Reform Committee cited earlier work by Buckland et. al (1996) of the then Macaulay Land Use Research Institute (now Hutton) which concluded that it would be possible to have a large decrease in numbers of female red deer (hinds) without a loss of revenue from stalking. This is because at lower densities red deer reproduce more efficiently – more hinds have a calf each year, and there would also be fewer losses from natural mortality in winter. Halley (2017b) explained that a harvest of 50 stags per year could be sustained by a total population of 550 animals.

If the average red deer density on the open hill range was reduced to 5 per km^2, it would support a total population of 133,000 animals. This population could sustain an annual harvest of 12,000 stags.

It has been possible to establish the number of sporting stags ideally required for sporting shooting for 35 of the 47 upland Deer Management Groups – a total of 11,265.[42] This suggests that it would be possible to reduce the total population of red deer on the open hill in Scotland, without significantly compromising stag harvests.

The population model used in research to predict long-term trends in red deer densities now suggest that the average open hill red deer density in Scotland in the 1960s was ~6 red deer per km^2.

[40] Scottish Natural Heritage (2019) *opp cit*
[41] Halley, D. (2017b) *opp cit*
[42] This figure has been derived from analysis of deer management plans carried out by the John Muir Trust

Recommendations and suggestions for further work

1. SNH's Commissioned Research uses the whole available count series at both the national and DMG level to establish long-term trends and predict deer densities. Population models and cull plans developed by DMGs have tended to use the most recent unadjusted deer count as their start point. The reliability of DMGs population models could be improved if they used predicted densities based on the trend line produced by a population model from the whole count series.

2. SNH's forthcoming Commissioned Research report analysing herbivore impacts at different densities primarily involves assessments of open habitats. It will allow a re-examination of the threshold density quoted by Putnam et. al (2011) for low to moderate impacts of 7 to 8 red deer per km^2. Thresholds should be established using the densities in the areas where herbivore impact assessments have been carried out predicted by long-term trend lines from population models, rather than the densities observed in the most recent count to the time of the study.

3. The areas of upland Scotland where average red deer densities are below 5 per km^2 are limited. Evidence from those areas of upland Scotland where woodland regeneration without fences is a management objective as to whether regeneration, particularly of broadleaved species, can be achieved at this density would be valuable in informing deer management decisions going forward.

4. During the lifetime of the current deer management plans, DMGs have carried out herbivore impact assessments, using a range of approaches. The publication of the results of these assessments, and the methods used would allow a synthesis of information across the whole open-hill range to be attempted. It would also allow comparison with the results of HIA commissioned by SNH, and of impacts observed at different densities using different HIA methods. This would allow comparison and review of the methods used, and an assessment of the need for standardisation of approach. Ideally this would be completed to inform the next round of deer management planning.

5. Peatlands are a substantial source of GHG emissions and the full incorporation of emissions from peatlands into inventories will lead to an increased focus on the abatement of emissions from peatlands. Evidence on the current impacts of red deer on peatlands at different densities, and on the impacts of red deer and other herbivores on the success of peatland restoration would be valuable in informing peatland restoration decisions going forward.

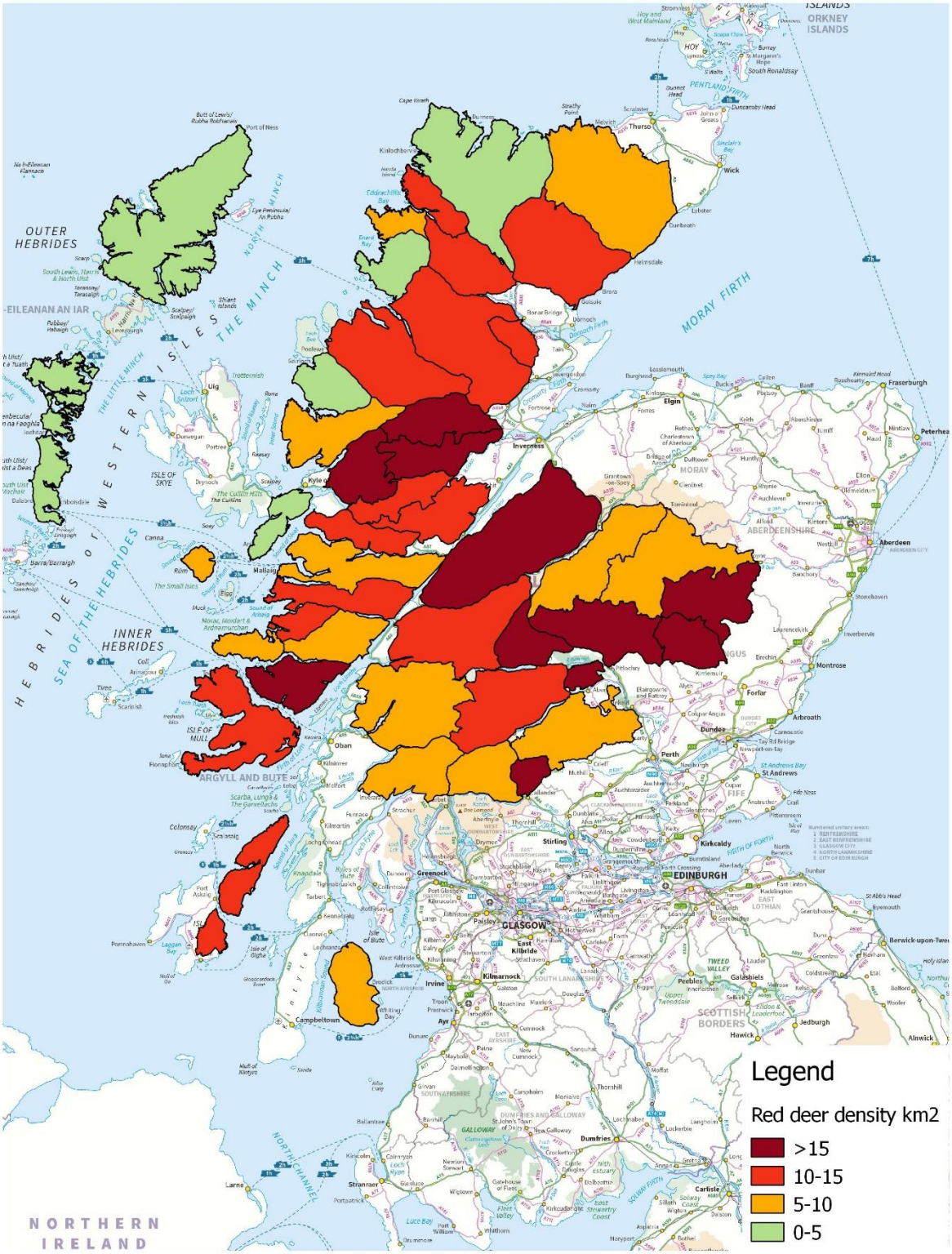
6. Experience in SW Norway has shown that reducing herbivory can substantially increase woodland cover through natural regeneration. In Scotland, planned woodland expansion is almost entirely through planting behind fences, at substantial cost to the taxpayer. Evidence from Scotland suggests that red deer densities could be reduced substantially without compromising the number of stags that could be sustainably harvested. The Scottish Government and its agencies should assess the contribution that natural regeneration could make to achieving woodland expansion targets, and the costs and benefits of such an approach.

Tom Edwards, 3E Services Ltd

December 2019

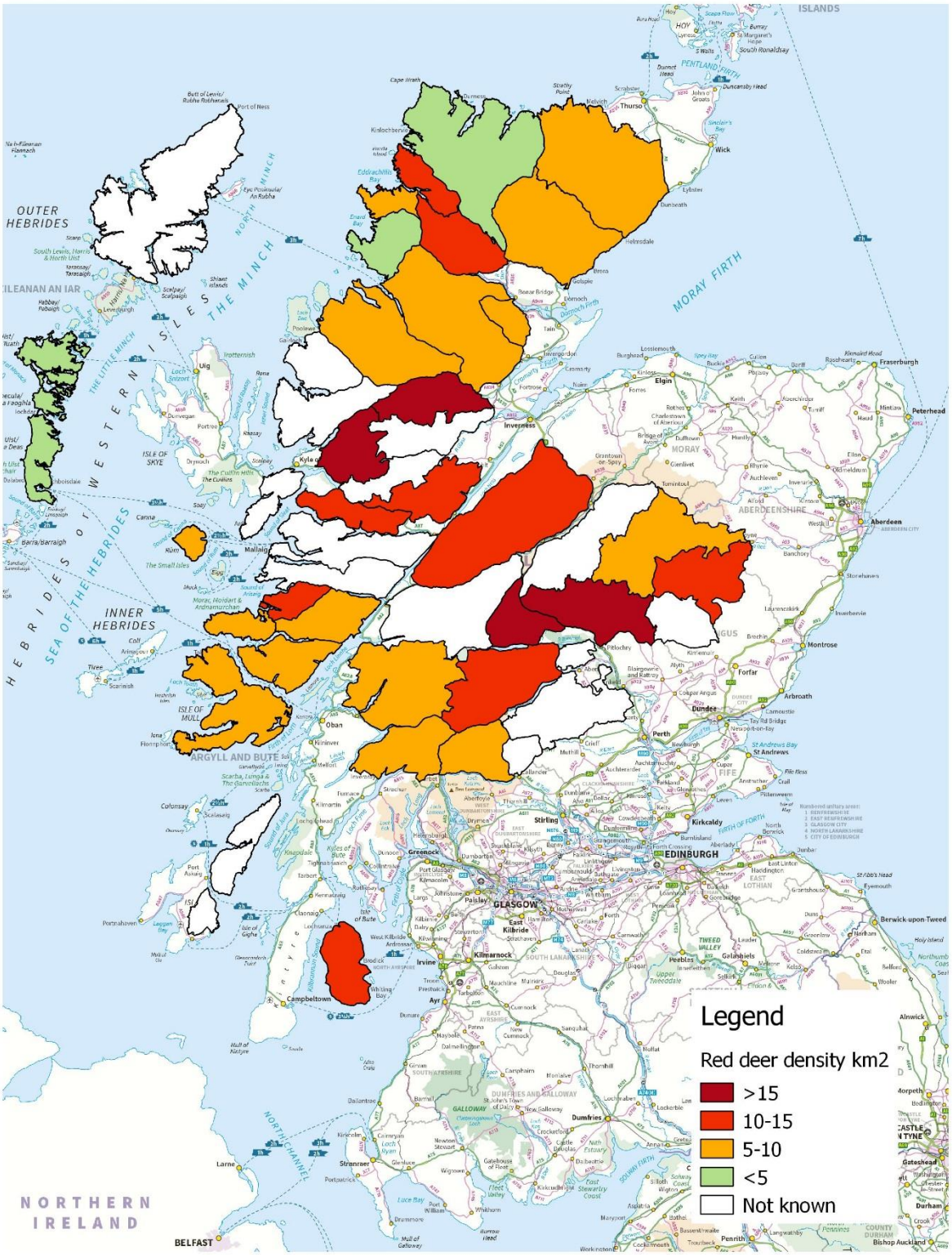
Appendix – Maps

Figure 1 – Upland DMG Areas by Current Red Deer Density Class



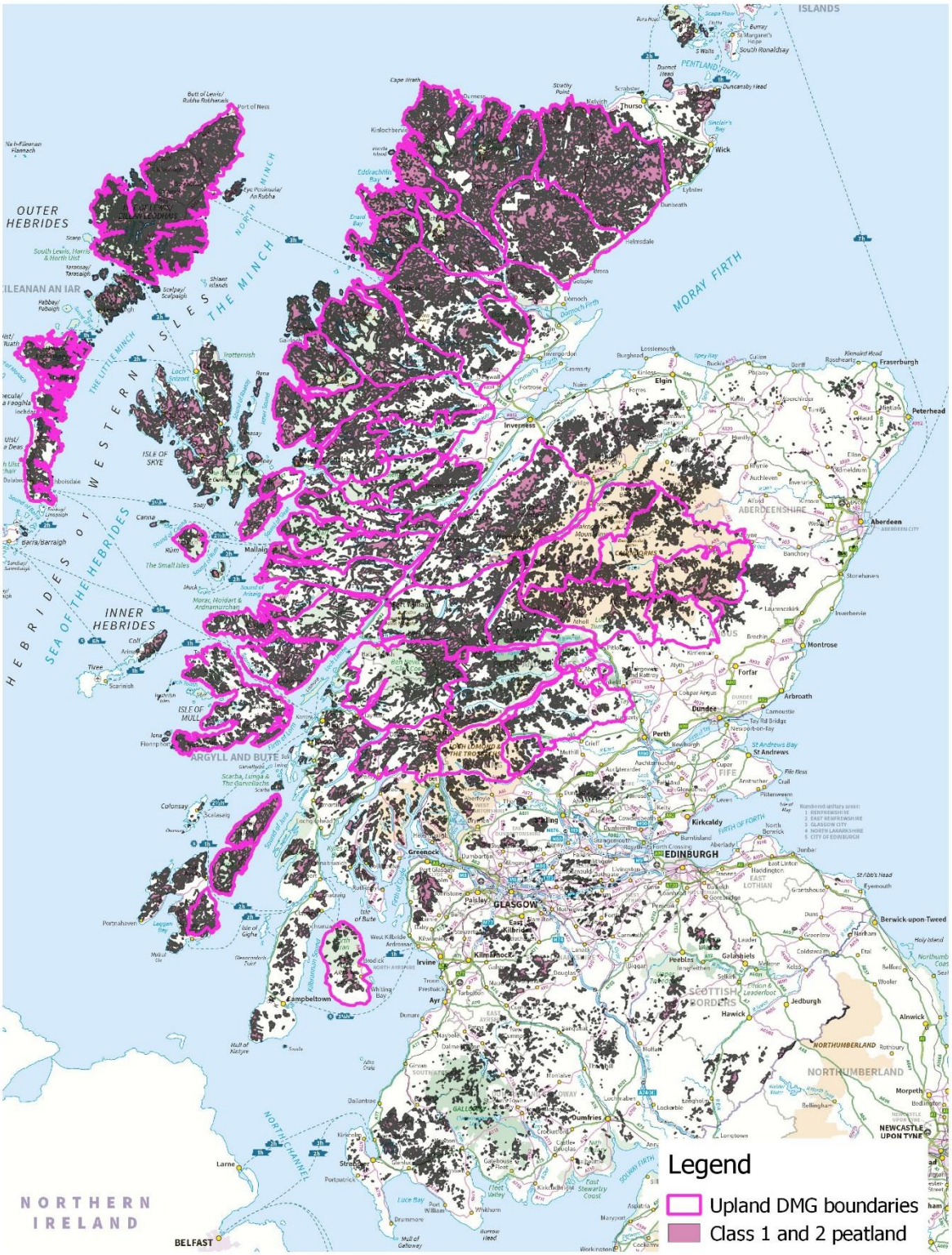
Source: Table 1

Figure 2 – Upland DMG Areas by Future Red Deer Density Class



Source: Table 1

Figure 3 – Peatland and Upland Deer Management Groups



Source: Scottish Natural Heritage (2016) Carbon and Peatland Map. Data downloaded from Natural Spaces: http://gateway.snh.gov.uk/natural-spaces/