Caenlochan Section 7 Agreements: Herbivore Impact Assessment and Deer Population Assessment – Caenlochan SAC and Glen Callater SSSI - a review of monitoring undertaken and progress made over the period 2003-19

June 2020

CONTENTS

REPORT PREPARATION

Authors

This report was produced under contract to SNH. SNH has exercised final editorial control and the contractor has elected not to be associated with, or identified in, the final report as presented here.

ACKNOWLEDGEMENTS

- Iain Hope (SNH) and Neale Taylor (SNH) oversaw the project. Iain Hope also helped to gather together all the historic information needed for the Review as well as introduce us to the estates.
- The estates of the Caenlochan Area Section 7 Agreement allowed access to the survey sites in summer-autumn 2018, during a very busy period for them, for which we are very grateful.
- Estate owners, managers and staff attended a sequence of meetings during the main fieldwork phase of the project to discuss findings and provide feedback. Many were held in the evening, mostly on a Friday and after long days at work. The contractor is very grateful for the attendees being attentive and courteous, and asking a lot of interesting and challenging questions.
- The contractor's field staff worked tirelessly in often challenging conditions to complete all the planned survey work, whilst accommodating the needs of the estates and their clients.

EXECUTIVE SUMMARY

1. **The aim of the current Caenlochan Area Section 7 Control Agreement (2014-19) is to ensure a set of designated upland habitat features are moving towards 'favourable condition'** across the combined land area of three sites: Caenlochan SAC, Glen Callater SSSI and Cairnwell SSSI.

2. Delivery is to be driven by a Deer Management Plan developed specifically for the Caenlochan area by the local landowners in 2014. **The DMP for the local area proposed to maintain winter deer densities of 19-21 per km^2 to allow the local estates to deliver their sporting aspirations. However, management is also be undertaken in parallel to reduce the amount of time deer spend on the designated sites thus allowing habitat recovery.** The proposed management activities include delivering the annual cull by targeting more of it to the designated sites, whilst concurrently feeding deer in areas distant to the designated sites to hold them in these less sensitive areas.

3. **Although the DMP is referred to in the current Section 7 agreement, it is a set of habitat condition targets set by SNH therein that underpins it. Achieving the habitat targets set, by autumn 2019, would signify that the agreement had been successfully delivered from SNH's perspective** because the conservation objectives of the designated sites would then be met in due course.

4. **The results of previous Herbivore Impact Assessment (HIA) surveys from 2008-2015 showed that habitat targets were consistently failing to be met, with few exceptions, during a period when winter deer densities were held in the range 17-20 per km^2**.

5. The results of a repeat HIA survey in summer 2018 reinforced this pattern and conclusion. **The 2018 surveys showed that habitat impacts in most cases remain well beyond the target levels agreed, and have therefore shown no real change since 2008, indicating that the current Section 7 agreement cannot be judged a success when it concludes in autumn 2019**.

6. Analysis of a wide range of data from site surveys in 2018, when viewed alongside evidence available from other upland study sites in Scotland, suggests that **to ensure that habitat targets are met in future a reduction in deer/sheep occupancy levels of 75% or more (from summer 2018 levels) could be required in the long-term on the designated sites in question. Achieving this with certainty would likely require a long-term reduction in site-wide winter deer densities to 5 per km^2.**

7. However, survey work indicates that other herbivores (e.g. mountain hare) are also implicated in the patterns of impact observed on site. **Modelling indicates that even a reduction in summer deer-sheep occupancy on the designated sites of 75% may only result in a decline in *overall* herbivore off-take levels of ~ 60%.** Therefore, management of other herbivores such as mountain hare would at least need to be considered as part of any future management planning exercise.

8. **Deer and sheep population reductions of the size predicted simply do not seem deliverable at the present juncture, under the current agreement and existing DMP**. **Not least, this is due to the potentially serious consequences that a rapid landscape-scale reduction in deer densities would cause in relation to the socio-economics of the estates and their local communities in the short-term.**

9. **It would seem important for SNH to have a period of reflection before deciding on its next steps at Caenlochan.** The fact that 15 years have passed since the onset of the first Section 7 agreement – a period sufficient to have seen some very marked changes in habitat condition already take place – lends further weight to the argument for hitting the 'pause button'. **This would give the landowners and SNH the time to participate in a thorough, objective and balanced debate about the future of the site**.

10. **This review concludes that potentially difficult decisions over the future management of the Caenlochan site will undoubtedly need to be made, but that the situation is highly complex and will take time to work through in a systematic and objective manner**. In our experience, any new package of solutions developed for the site would benefit immensely from being formulated and adopted jointly by the private and public sector in a new partnership. **The processes used to develop any new solutions, and to underpin their delivery, should be independently led and evidence-based to help ensure balance of debate as well as long-term sustainability of outcomes.**

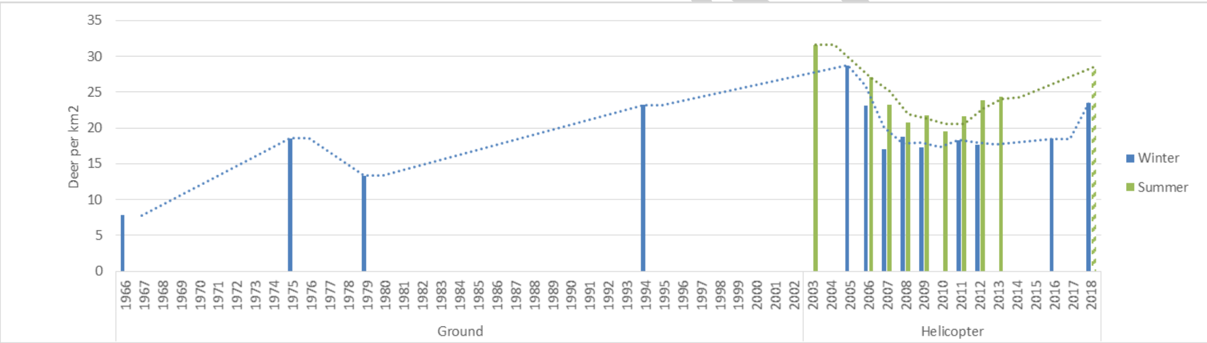
NON-TECHNICAL SUMMARY

Note: signposts have been put in place (e.g. "see Page 34") for readers wishing to read about an issue in more detail in the main body of the report.

11. In early 2003, a Control Agreement under Section 7 of the Deer (Scotland) Act 1996 (termed herein the 'original' Section 7 agreement) was set up between the Deer Commission for Scotland (DCS) and the owners of land in and around the Caenlochan Site of Special Scientific Interest (SSSI)[1].

12. The purpose of the agreement was "to prevent deer from causing damage to, and to avoid the deterioration of, the 10 habitat types … in the Damaged Site …in Caenlochan Glen".

13. The agreement lasted for 10 years, and involved winter deer densities across a large area centred on Caenlochan Glen being reduced quickly to an agreed target level of 19 per km^2 then maintained at that level for the duration.



Compiled results from SNH deer counts from within the current Section 7 Caenlochan Control Area. The dashed lines (blue and green) are 2-year moving averages of the winter and summer count data, used as a way to identify broad underlying trends. The 2018 'summer count' was estimated by modelling; all other summer data are actual counts. *Detailed analysis - see Page 67*

14. In 2013, following discussions, a further Control Agreement under Section 7 of the Deer (Scotland) Act 1996 (as amended) was set up between Scottish Natural Heritage (SNH)[2] and a slightly larger group of landowners. The new agreement was entitled the Caenlochan Area Deer Control Agreement, and was for a period of 5 years (ending October 2019; termed herein the 'current' Section 7 agreement).

15. The reason for setting up the current S7 agreement was that red deer were "causing damage to Natura upland interests across 'the designated sites'." The primary purpose of the agreement was therefore to "prevent deer from causing damage to designated habitats across the Caenlochan Special Area of Conservation (SAC) & Special Area of Scientific Interest (SSSI), Glencallater SSSI

[1] Document entitled "Caenlochan Glen Section 7 agreement – final – March 2003"
[2] By this time DCS had merged with SNH, and taken over its responsibilities.

& Garbh Coire SSSI”. This was a much larger area (6,737 ha in total) than the ‘Damaged Site’ of the original 2003 agreement (~600 ha).

16. The current S7 agreement states that the “success of the Agreement will be judged by monitoring delivery of habitat targets“. The agreement states that “SNH is likely to conclude that damage by deer is occurring if information from Herbivore Impact Assessment surveys shows that deer impact targets … are not being met and therefore the conservation objectives for the site are not likely to be met”.

	Habitat	**Blanket Bog**	**Dry Heath**	**Montane Acid Grassland**	**Alpine & Subalpine Heaths**	**Tall Herb**	**Species Rich Grasslands**	**Flushes**	**Mountain Willow Scrub**
	Impact type	Trampling	Browsing	Browsing &	Browsing	Browsing	Browsing	Trampling	Browsing
% Samples	Low	90%	90%	90%	90%	90%		75%	90%
	Low-Moderate						90%		
	Moderate	10%	10%	10%	10%	10%		25%	10%
	Moderate-High							0%	
	High								

Habitat condition targets set for the designated sites under the current Section 7 control agreement. The targets relate to the % of sampled squares falling in a particular impact class following survey. In most cases, a survey needs to show at least 90% of the sampled squares falling in either the ‘Low’ or ‘Low-Moderate’ impact classes in order to pass.

17. Herbivore Impact Assessment (HIA) surveys of the designated sites at Caenlochan had been conducted three times (2008, 2012 & 2015) in the lead up to 2018 when SNH commissioned contractors to undertake a repeat HIA.

18. The results of the summer 2018 HIA survey, and the trend in impact levels leading to it, were as follows (see charts overleaf also):

a) Alpine heath (assessed using grazing indicators; target is at least 90% of sampled squares with Low or Low-Moderate impact scores): **fail** (9.7% of squares met the target, with a variable trend preceding the 2018 assessment whereby in most years the target was far away from being met other than in 2015 when it came closer).

b) Dry heath (grazing indicators; 90% L or LM): **fail** (26.3% of squares met the target, with little or no sign in preceding assessments this was likely to change).

c) Montane acid grassland (grazing indicators; 90% L or LM): **fail** (20.0% of squares met the target, with a declining trend apparent from preceding assessments implying an improvement was unlikely to be seen).

d) Species-rich *Nardus* grassland (grazing indicators; 90% LM or M or MH): **fail** (9.6% of squares met the target, with a variable trend albeit typically far away from being compliant - preceding assessments implied an improvement was unlikely to be seen). *Note: the results imply the habitat is being under-grazed*.

e) Willow (grazing indicators; 90% L): **fail** (33.3% of squares met the target, with a declining trend apparent from preceding assessments implying an improvement was unlikely to be seen).

f) Bog (trampling indicators; 90% L or LM): **fail** (25.0% of squares met the target, with a variable trend preceding the 2018 assessment whereby in most years the target was far away from being met other than in 2015 when it came closer).

g) Flush (trampling indicators; 75% L or LM): **pass** (79.3% of squares met the target, with an improving trend apparent from the historic data set for preceding years).

h) Montane acid grassland (trampling indicators; 90% L or LM): **pass** (100.0% of squares met the target, with an improving trend apparent from the historic data set for preceding years).

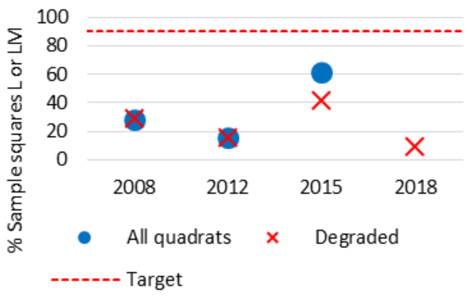
19. On the basis of the 2018 HIA survey results, and the historic trend in impact levels leading to it, it appears that the current Section 7 agreement cannot be judged a success by SNH when it ends in autumn 2019.

20. A range of additional work was undertaken by the contractor in 2018, in order to explore how low the deer density on the Caenlochan site might need to be taken to achieve the habitat targets set by SNH.

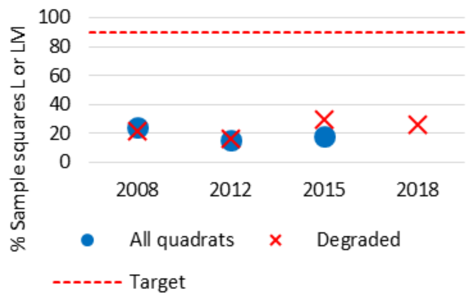
21. The results from previous HIA studies undertaken by contractors on other upland sites in Scotland were compiled. This exercise showed that deer densities may need to be reduced to as low as 5 per km^2 in order to reach the targets set with complete confidence.

Site	Deer per km^2 Winter count, entire range	% Plots = L or LM: WCSH	% Plots = L or LM: DH	% Plots = L or LM: BB	HIA Year	Count Year	HIA survey comments	Count comments
Invereshie NNR	3.0	100%	95%	88%	2019	2019		Dung count
Beinn Eighe NNR / Torridon SSSI	4.2	100%	94%	83%	2012	2017		Heli count
Drumochter Hills SAC	10.3	82%	80%	42%	2013	2012		Heli count
NFE South Affric	20.0	91%	17%	21%	2014	2014	WCSH very localised	Dung count
Caenlochan S7	23.5	44%	42%	26%	2018	2018		Heli count

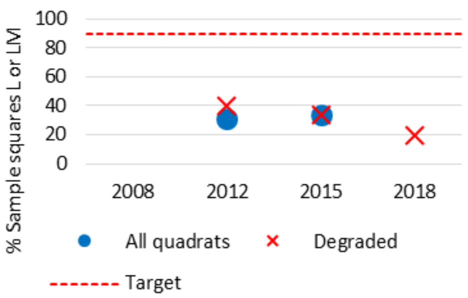
Outcomes of HIA surveys undertaken by contractors on a range of upland sites for government agencies, which included the 3 main habitat types assessed in 2018 on the grid-based survey at Caenlochan (Wind-clipped summit heath, dwarf shrub heath and blanket bog). Sites vary in size, but are typically at least 3,000-4,000 ha. Most of them lie within a broader altitude range than the Caenlochan site as they include more low ground (down to sea-level in the case of Beinn Eighe-Torridon). The deer densities quoted in the table are winter densities, calculated in the main from helicopter count data, rather than local 'range densities' (i.e. where count data adjusted so that they better reflect the local occupancy level of deer in the areas where – and at the times of year when - impacts were actually occurring). *Detailed analysis - see Page 111*



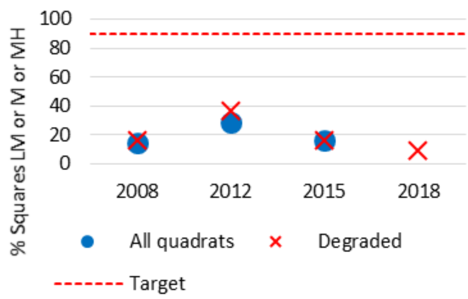
Alpine heath – grazing (official S7 target)



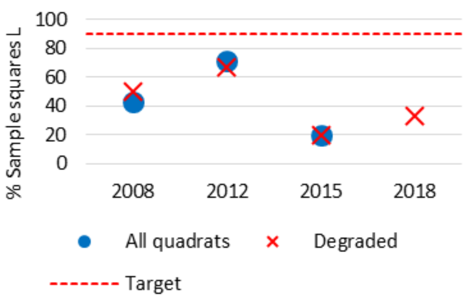
Dry heath – grazing (official S7 target)



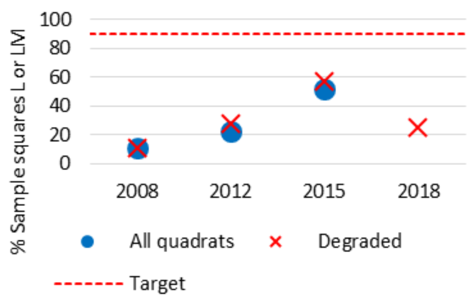
Montane acid grassland – grazing (official S7 target)



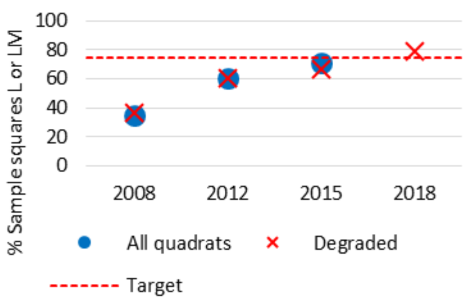
Species-rich grassland – grazing (official S7 target)



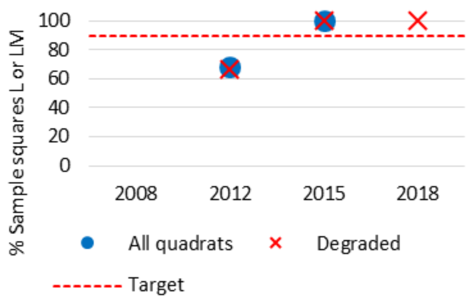
Willow – grazing (official S7 target)



Blanket bog – trampling (official S7 target)



Flush – trampling (official S7 target)



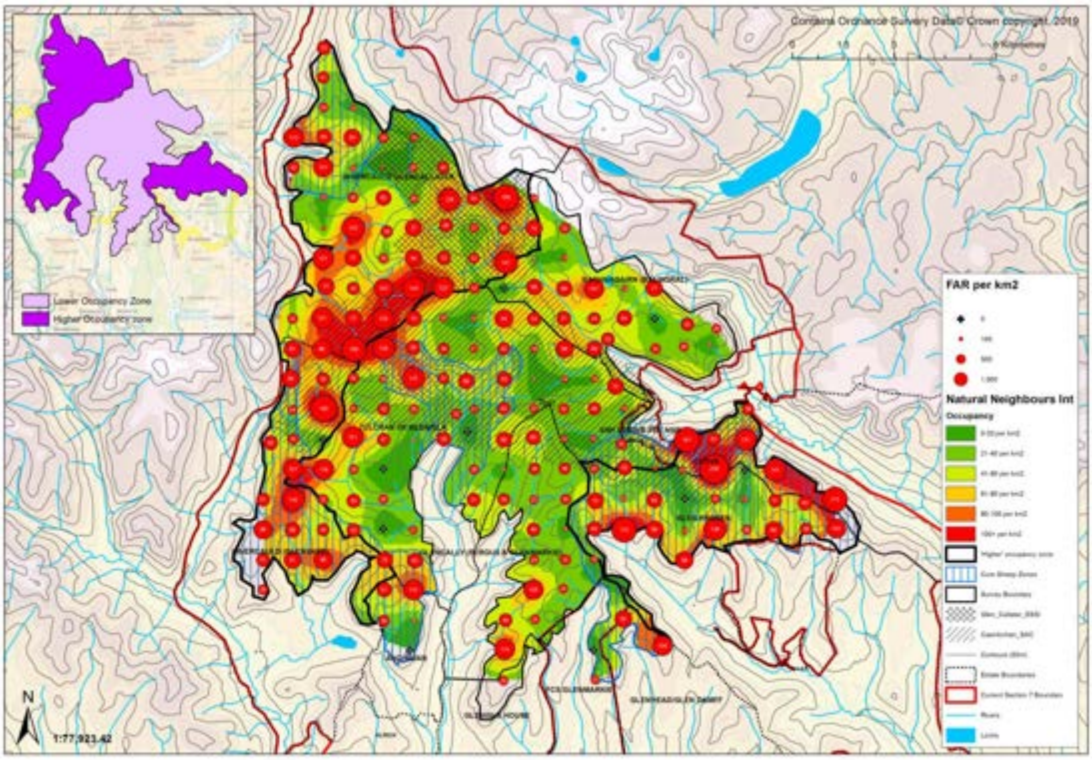
Montane acid grass – trampling (official S7 target)

The % sample squares falling in the Low or Low-Moderate impact class for the randomly-sampled HIA plots within the designated sites at Caenlochan in 2008, 2012, 2015 and 2018. The outputs presented are for the original sampling intensity (blue circles) and the degraded sample design as used in 2018 (red crosses; the 2018 study surveyed a smaller % of the quadrats present; previous survey results for 2008, 2012 and 2015 have been stripped back to be comparable). The target level is indicated (red dashed line). Note: most target thresholds are set at 'a minimum of 90% sample squares falling in the Low or Low-Moderate impact class' but some differ as per the axis titles. *Detailed analysis - Page 114*

22. Work was also undertaken in 2018 to explore local relationships between deer density and deer impact levels on the Caenlochan site.

23. The average density of deer and sheep using the study site (broadly, the designated sites plus all other adjacent land above 600m in their vicinity) in summer 2018 was estimated to be ~ 55 per km^2.

24. However, variation in density was evident across the site. The north-west of the site and the south-east both had noticeably higher levels of occupancy (termed herein the 'Higher occupancy zone'; 69 deer/sheep per km^2) compared to the central section of the site (termed herein the 'Lower occupancy zone'; 43 per km^2).

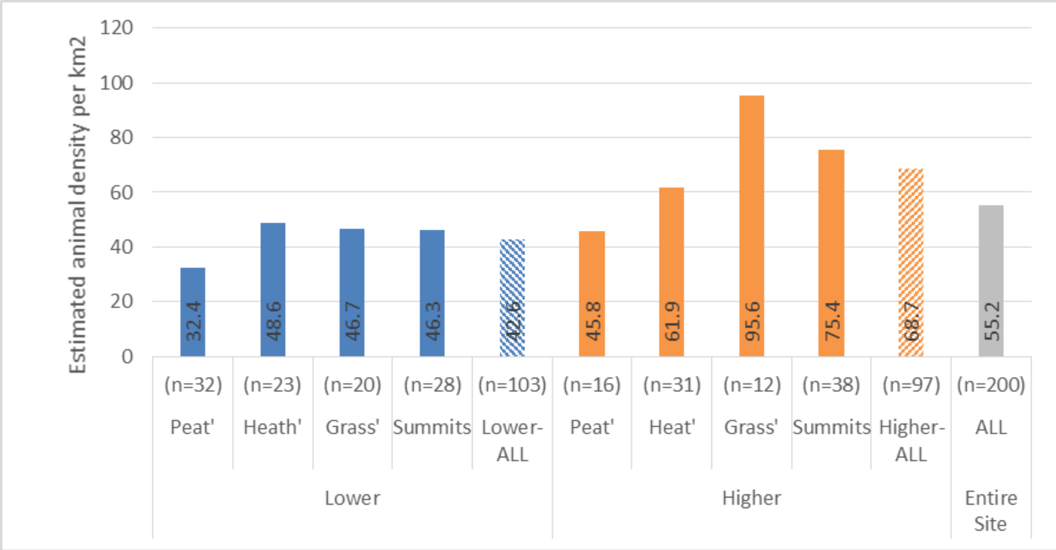


The deer/sheep faecal accumulation rate per km^2 per day over the period June-October 2018, along with a 'density surface' interpolated on ArcMap. The areas shown with a dark black line to the NW and SE are where occupancy levels were highest ('Higher zone'; the central area is the 'Lower' zone).
Detailed analysis - Page 84

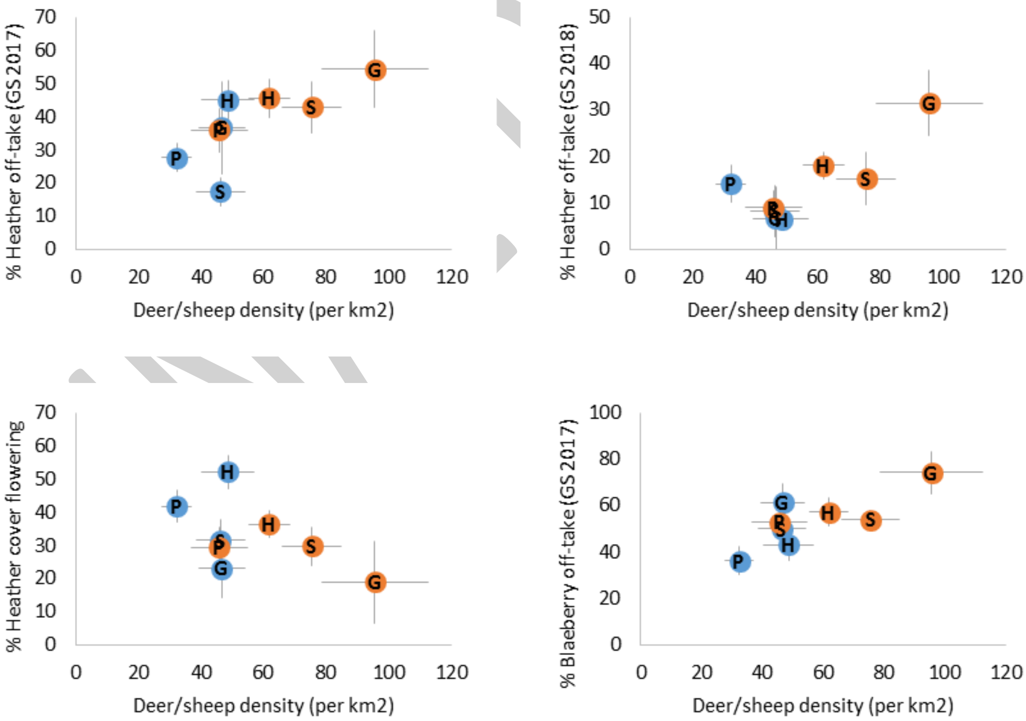
25. There were strong relationships apparent between the measured level of deer/sheep occupancy and the level of impact recorded on dwarf shrubs.

26. Levels of impact in each of the 4 main habitat types sampled (heathland, blanket bog, grassland summit heaths) were markedly elevated in the 'Higher occupancy zone' compared to the 'Lower occupancy zone'.

27. The results imply that a reduction in deer/sheep occupancy from the current levels on site is likely to result in a consequent reduction in impacts.

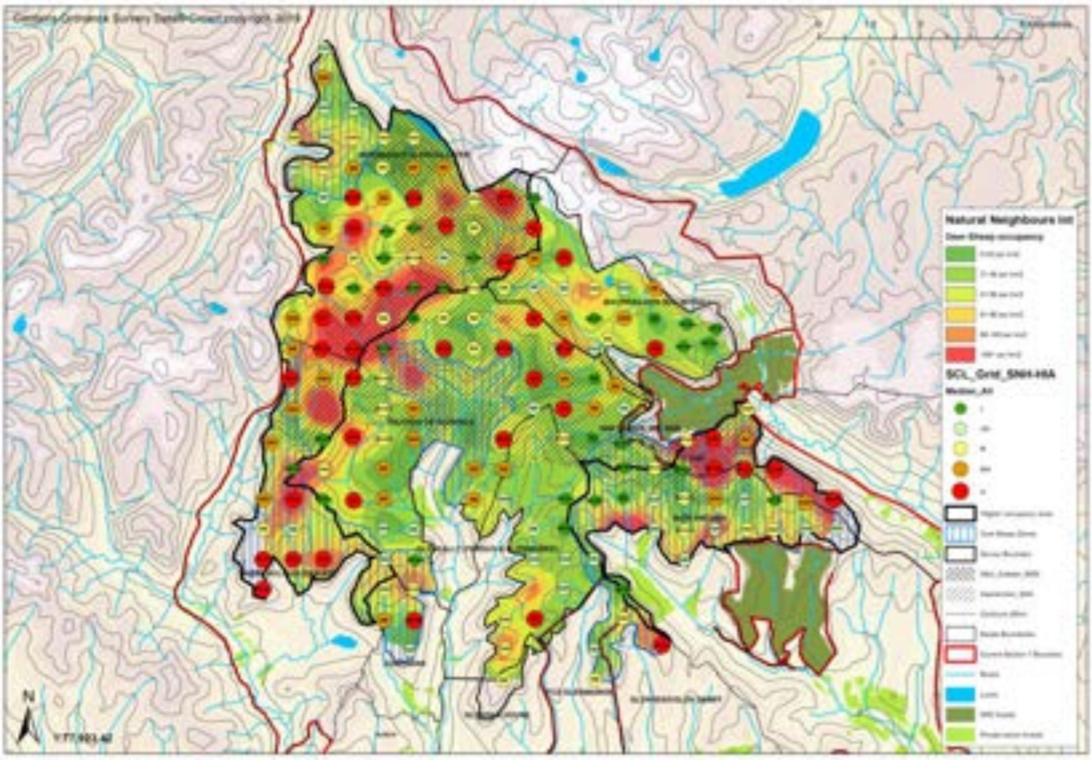


The estimated average deer/sheep density per km² as measured on the survey site over the period June – October 2018 from a sample size of 200 transects. The data are stratified by broad habitat type (peatland, heathland, grassland, summit communities) within each of the two main analysis zones identified using an interpolation model (see previous map): areas where the deer/sheep occupancy was on average Higher (to the north-west and the south-east; orange) and areas where the occupancy level was on average Lower (in the middle of the study site; blue). *Detailed analysis - Page 85*



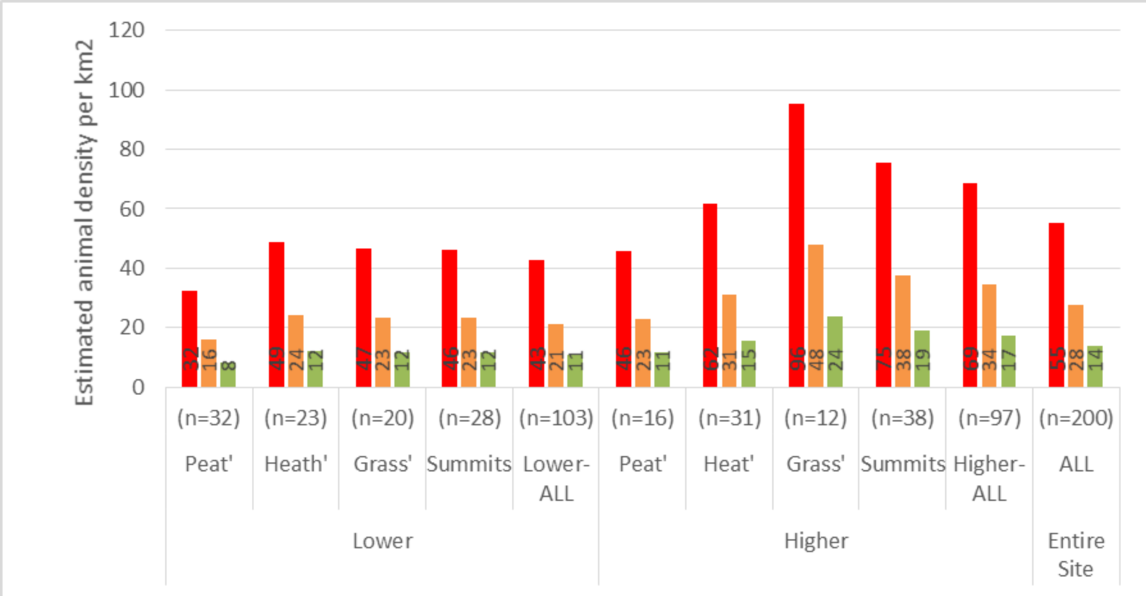
Impacts on dwarf shrubs: mean % off-take of heather long shoots from the 2017 growing season (upper left), for growing season 2018 to date (upper right), mean % heather canopy in flower in autumn 2018 (lower left) and mean % off-take of Blaeberry shoots (lower right). Blue = Lower zone and orange = Higher zone. Diagrams show the relationship between the variate measured (+/- 1 SE) and the deer-sheep occupancy level (+/- 1 SE) in that habitat/zone combination. Peatland = P, Heathland = H, Summit communities = S and Grassland = G. Standard errors (SE) shown for deer-sheep occupancy relate to pellet group density and not animal density. *Detailed analysis - Page 91*

28. During the 2018 survey, additional HIA data were gathered from across a wider area than in previous years (see overleaf). The extra quadrats were sampled at each of the locations where deer occupancy transects had been installed. This work showed that there was a strong relationship between the deer/sheep occupancy level on site and the % quadrats that had a 'High' impact score (see charts overleaf).



The median impact class (grazing & trampling indicators) recorded on the survey grid for blanket bog, dwarf shrub heath and summit heaths at Caenlochan using the methods of MacDonald et al 1998. *Detailed analysis - Page 102*

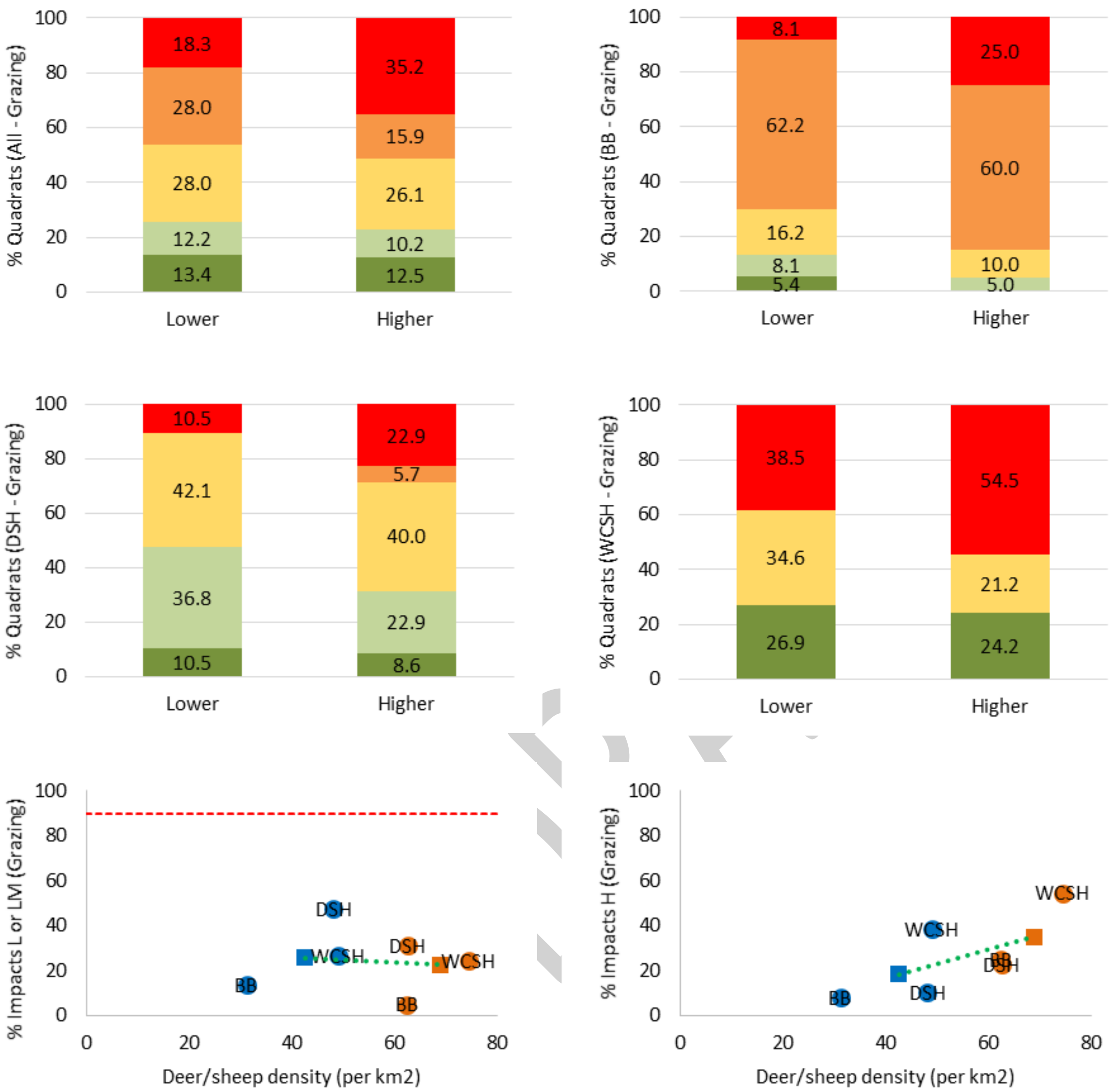
29. The analysis suggests that occupancy levels would need to be reduced very markedly on site (75% or more – see chart below) before SNH's desired target levels of impact can be reached. This is because most of the targets are set at a minimum of 90% sampled quadrats being Low or Low-Moderate. The 2018 grid survey indicates that *summer* occupancy levels on the designated sites would need to be reduced from their current levels to ~ 10-30 per km^2 (depending on the habitat; average of ~ 14 per km^2 across all habitats) simply to ensure that the % High quadrats was minimised. Obviously, this is a precursor stage to achieving the very low impact scores SNH desires. To ensure at least 90% of quadrats are in the L/LM category it would seem that site occupancy levels would need to be lower still.



The mean occupancy level (FAR per km^2) as measured (i) in summer 2018 (red), (ii) as predicted if overall deer/sheep densities in the current Section 7 area were reduced by 50% (orange) and (iii) if reduced by 75% (green). Model assumes a linear response across all areas and habitats, which of course would not necessarily be the case. *Detailed analysis - Page 110*

30. A further complication is the presence of considerable densities of hare and red grouse, both of which consume dwarf shrubs (and grasses) like deer and sheep (see Page 86). Models were built to estimate the possible contribution of sheep, hare and grouse to the overall level of grazing off-take on the site. The approach used was to assess the total dung dry weight of each species, by undertaking counts of the numbers of their faecal pellet groups present. The analysis indicates that ~20% of dung by dry weight on the site comes from 'non-deer' sources (~14% in the Lower zone and ~25% in the Higher zone). A 75% reduction in deer/sheep occupancy on the designated sites, and their environs, is forecast to only reduce overall herbivore off-take by ~ 60% because contributions from the other species could remain broadly unchanged.

31. Reductions in deer density of the scaled calculated would result in potentially serious socio-economic impacts arising on the estates, and their local communities, in the short-term especially. Subsequent recovery to favourable condition would also take a long time, once densities of deer had been reduced to the level calculated.



The % sampled quadrats falling in each HIA impact class (grazing indicators only) on the grid-based survey: all habitats (upper left), quadrats sampled with blanket bog indicators (upper right), dwarf shrub heath indicators (middle left), and wind-clipped summit heath indicators (middle right). Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. Scatter diagrams show the relationship between the % sampled plots in the Low or Low-Moderate category (target 90%) and the measured occupancy (lower left) and the % sampled plots in the High category compared to occupancy (lower right). Blue = Lower zone and orange = Higher zone. Circles = habitats-specific results and squares = overall results for all samples combined. The red dashed line is the target level set by SNH for the designated sites, for reference. The green trend line has been added to help readers visually track relationships evident between occupancy and impact level (only presented for all data combined - this masks habitat-specific trends but uses a larger sample size). Ideally, these charts would be generated from a larger sample size of observations obtained from multiple study sites all with a wider range of occupancy levels present. Presently, only the limited data displayed above are held for Caenlochan. Extrapolation beyond the limits of these data points (i.e. to infer what result might be obtained at a lower occupancy level) is not ideal but in the circumstances is the best option available. That said, see the previous table which presents the findings of similar studies from other sites – these data help place the Caenlochan data in context. *Detailed analysis - Page 107*

32. A range of recommendations is made at the end of this Review on how to move forwards (see Page 153):

a) A key future focus for SNH and the landowners, ideally working in close partnership, should be on designing and implementing a new planning process to produce a robust and integrated strategic land management plan for the area.

b) Careful consideration needs to be given as to how to monitor the Caenlochan site going forwards, taking into account the insights gained by using a number of new survey techniques in 2018.

INTRODUCTION

BACKGROUND

33. In early 2003, a Control Agreement under Section 7 of the Deer (Scotland) Act 1996 (termed herein the ‘original’ Section 7 agreement) was set up between the Deer Commission for Scotland (DCS) and the owners of land in and around the Caenlochan Site of Special Scientific Interest (SSSI)[3].

34. The reason for the agreement was that at the time the DCS was “satisfied that red deer have caused and are causing damage to the natural heritage [4] generally within the area extending to about 600 hectares at Caenlochan Glen, Angus (hereinafter referred to as “the Damaged Site”) ... The Commission is also satisfied that it is therefore necessary to reduce the number of red deer within the Control Area”.

35. The purpose of the agreement was “to prevent deer from causing damage to, and to avoid the deterioration of, the 10 habitat types … in the Damaged Site for which Caenlochan candidate Special Area of Conservation qualifies and which occur in Caenlochan Glen”.

36. The ‘Control Area’ for the original Section 7 Control Agreement covered approximately 250km^2. Red deer numbers were to be managed with the aim of reducing the deer density within the Damaged Site from 178 per km^2 (as counted in August 2000) to a density which did not exceed 19 per km^2. Densities of deer within the wider Control Area were also to be reduced so they did not exceed 19 per km^2. The reduction in deer density was proposed to take place over a period of 3 years leading to a target population of no more than 4,750 deer (1725 stags, 2240 hinds + calves) by the third year of the agreement.

37. An operation to reduce deer densities was duly conducted by the estates with the help of DCS staff. For a period of 7 years thereafter - the original Section 7 agreement was for 10 years in total - maintenance culling was undertaken by the estates. A sequence of direct deer counts, using helicopters, was also undertaken during the period 2003-2013 to help inform management decisions. Some counts were undertaken in winter conditions and some in summer conditions.

38. Monitoring of the condition of the upland habitats on the Damaged Site was to be undertaken as part of the original Section 7 agreement. The aim of monitoring was to establish if a set of habitat condition targets[5], proposed at

[3] Document entitled “Caenlochan Glen Section 7 agreement – final – March 2003”

[4] As reported by Macaulay Research and Consultancy Services Ltd (Hewison, R. L., Nolan, A. J. and Alfaro, P. (October 2000) Assessment of Grazing and Trampling Impacts, Caenlochan Glen, Angus)

[5] The habitat targets in this original agreement were later superseded by those listed in a successor Section 7 agreement signed in autumn 2014 (2014-19); this report focuses on the most recent set of targets set.

the outset of the original agreement, were being met following completion of the planned culls. A habitat monitoring scheme was designed by SNH and later installed by external consultants within the designated sites [6], with baseline data gathered in 2008[7]. Repeat monitoring of the 2008 survey was undertaken in 2012[8].

39. Although SNH later reported[9] that original Section 7 agreement “was successful in reducing the population of red deer within the Caenlochan area” they noted that “Site Condition Monitoring (SCM) surveys between 2004 and 2011 have demonstrated that a variety of qualifying features within ‘the designated sites’ are in unfavourable condition and that red deer are a significant contributing factor.”

40. In 2013, following discussions, a further Control Agreement under Section 7 of the Deer (Scotland) Act 1996 (as amended) was set up between Scottish Natural Heritage (SNH)[10] and a slightly larger group of landowners signed it (Map 1[11]). The new agreement was entitled the Caenlochan Area Deer Control Agreement, and was for a period of 5 years (ending October 2019; termed herein the ‘current’ Section 7 agreement).

41. The reason for setting up the current S7 agreement was that red deer were “causing damage to Natura upland interests across ‘the designated sites’.” The primary purpose of the agreement was therefore to “prevent deer from causing damage to designated habitats across the Caenlochan Special Area of Conservation (SAC) & Special Area of Scientific Interest (SSSI), Glencallater SSSI & Garbh Coire SSSI” (Map 1). This was a much larger area (6,737 ha in total[12]) in comparison with the ‘Damaged Site’ of the original 2003 agreement (~600 ha).

42. The current Section 7 agreement referenced a new deer management plan[13] prepared by the estates - the agreement stated that by “By implementing the new Caenlochan Area DMP, the aim is to prevent damage by red deer to ‘the designated sites’ within the control area … and ensure that the features within these sites are moving towards favourable condition.” The DMP provided

---

[6] Based on the following: MacDonald, A., Stevens, P., Armstrong, H., Immirzi, P. & Reynolds, P. 1998. A Guide to Upland Habitats, Surveying Land Management Impacts. Part 1 and 2. Scottish Natural Heritage, Battleby.
[7] Headley, A.D. (2009a) An assessment and evaluation of herbivore impacts on notified habitats within Caenlochan Special Area of Conservation. Unpublished report to DCS and SNH. 2 additional reports by the same author (2009b and 2009c) referred to Glen Callater and Cairnwell.
[8] Headley, A. (2012) Repeat assessment of herbivore impacts of designated habitats and features in the Caenlochan Special Area of Conservation (SAC), Glen Callater and Cairnwell Sites of Special Scientific Interest (SSSI). Unpublished report to SNH.
[9] In the introductory text to the current Section 7 agreement.
[10] By this time DCS had merged with SNH, and taken over its responsibilities.
[11] The original agreement did not include Glen Prosen, Glenhead/Glen Damff or Clova (South). Note also: in 2003 Glencally was part of Glen Isla.
[12] 5201 + 1513 + 23ha respectively
[13] This was a plan funded by the owners of the estates within the current Section 7 area: Deer management plan for the Caenlochan Deer Management Group Area by R. J. Putman (2014).

initial population targets for delivering 340-360 sporting stags within the Control Area (spring adult stag population of 2390-2650; adult hind population of 2680-3030). The key underpinning assumption of the new DMP was that the target population proposed – on the basis of sporting aspirations - could still enable site recovery if a raft of other management actions were delivered in tandem. These included taking a disproportionate % of the annual culls from the SAC/SSSI area (i.e. cull targeting), moving existing deer feeding locations away from the designated sites to reduce their 'draw' plus setting up new locations in distant areas again to try and draw deer away from the designated sites.

43. The agreement stated that during its course "deer populations will not increase beyond the level agreed within the DMP." SNH agreed to undertake 2 helicopter-based deer counts during the period of the current agreement to help quantify population size, with estates undertaking annual ground counts in addition.

44. However, the agreement also stated that the "deer population will be adjusted as required to respond to monitoring of impacts both of designated sites and on individual estates habitat monitoring information." The agreement confirmed that the "Results from monitoring of selected habitats, when compared to the baseline Herbivore Impact Assessment (HIA) in 2012, will determine whether or not damage has been prevented to Natura interests over 'the designated sites': Dry heath, blanket bog, montane acid grassland, flushes, mountain willow scrub, tall herd communities, alpine and subalpine heaths and species rich grassland".

45. The agreement went on to say that the "success of the Agreement will be judged by monitoring delivery of habitat targets". The agreement stated that "SNH is likely to conclude that damage by deer is occurring if information from Herbivore Impact Assessment surveys shows that deer impact targets set out in paragraph 30[14] are not being met and therefore the conservation objectives for the site are not likely to be met" (Table 1).

Table 1 Habitat condition targets set for the designated sites under the current Section 7 control agreement. The targets relate to the % of sampled squares[15] falling in a particular impact class following survey. In most cases, a survey needs to show at least 90% of the sampled squares falling in either the 'Low' or 'Low-Moderate' impact classes (for an explanation, see Appendix 2) in order to pass. Later presentation of herbivore impact survey results in this report relates to these targets.

[14] Of the current Section 7 agreement

[15] The original 2008 sampling design comprised a grid of 250x250m squares overlain on the site. A random set of these were selected for sampling each habitat type. Multiple quadrats were sampled in each habitat type. The target relates to the % of sampled squares which fell in each 'impact class'. The classes (e.g. Low, Moderate, High) relate to an increasing level of herbivore impact being measured on the site according to the 'small-scale indicators' of MacDonald et al. (1998).

<table>
<tr><th></th><th>Habitat</th><th>Blanket Bog</th><th>Dry Heath</th><th>Montane Acid Grassland</th><th>Alpine & Subalpine Heaths</th><th>Tall Herb</th><th>Species Rich Grasslands</th><th>Flushes</th><th>Mountain Willow Scrub</th></tr>
<tr><td></td><td>Impact type</td><td>Trampling</td><td>Browsing</td><td>Browsing &</td><td>Browsing</td><td>Browsing</td><td>Browsing</td><td>Trampling</td><td>Browsing</td></tr>
<tr><td rowspan="5">% Samples</td><td>Low</td><td rowspan="2">90%</td><td rowspan="2">90%</td><td rowspan="2">90%</td><td rowspan="2">90%</td><td rowspan="2">90%</td><td></td><td rowspan="2">75%</td><td rowspan="2">90%</td></tr>
<tr><td>Low-Moderate</td><td rowspan="3">90%</td></tr>
<tr><td>Moderate</td><td rowspan="3">10%</td><td rowspan="3">10%</td><td rowspan="3">10%</td><td rowspan="3">10%</td><td rowspan="3">10%</td><td>25%</td><td rowspan="3">10%</td></tr>
<tr><td>Moderate-High</td><td rowspan="2">0%</td></tr>
<tr><td>High</td><td></td></tr>
</table>

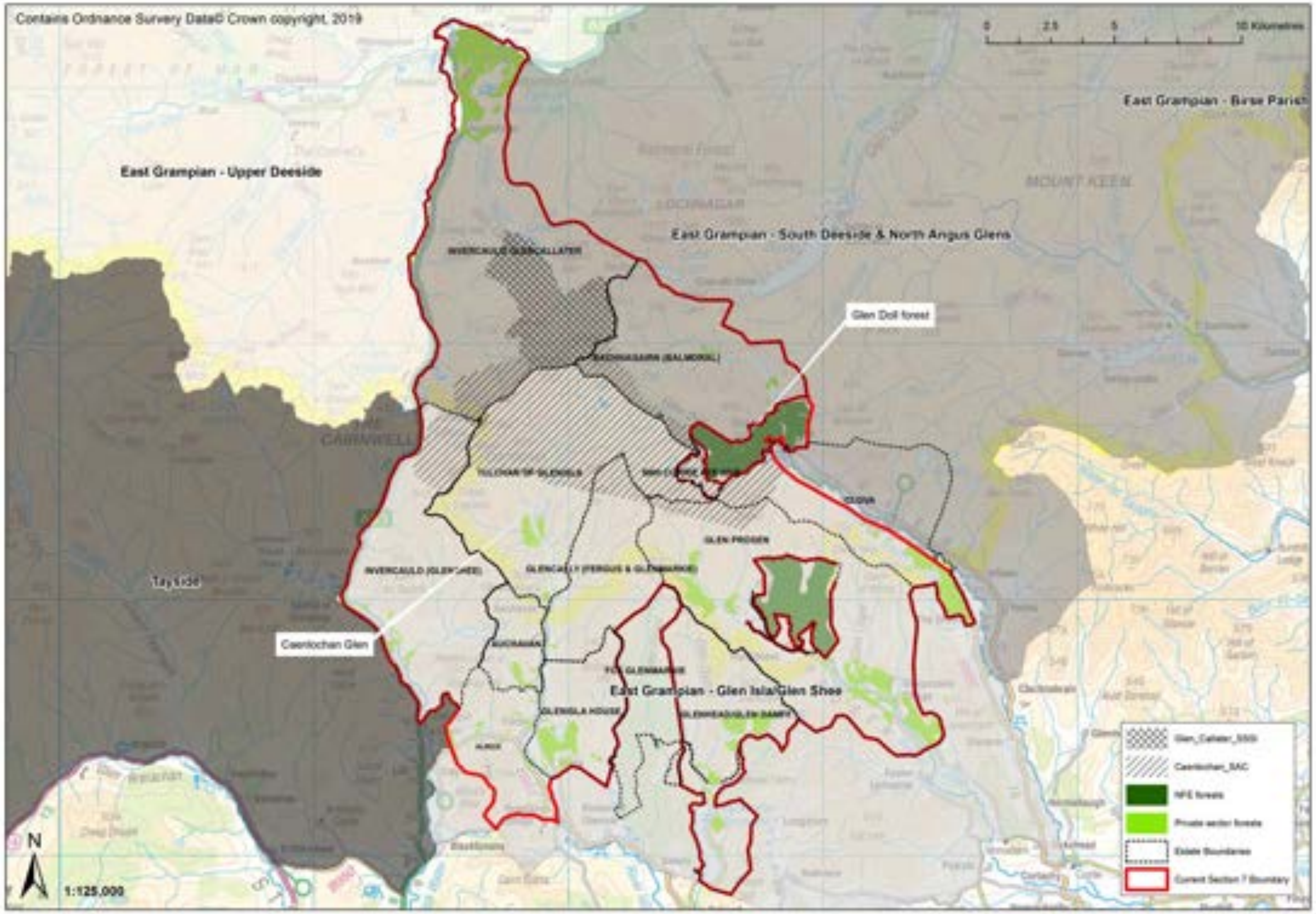
46. A program of repeat monitoring was put in place as part of the current agreement, to help assess whether targets were being met, with a repeat of the original 2008/2012 survey being conducted in 2015.

47. As part of the current Section 7 agreement, a Control Agreement Steering Group was formed. The aim was to meet at least annually to "discuss progress in preventing damage by red deer by implementing the Caenlochan Area DMP". Meetings have been held in the period since 2013, to discuss the results of monitoring as planned.

48. The most recent activity of significance at the site, under the current agreement, was a winter deer count undertaken in January 2018. The results of this count were fed back to the estates involved, soon after it was completed, at a meeting. Some additional hinds were culled at the end of the 2017-18 season because deer numbers were somewhat higher than had been expected. A further heavy cull was undertaken in the winter of 2018-19 in follow up.

49. One other noteworthy activity of recent times was the production of two updated deer management plans for the area, prepared at DMG scale rather than for the current Section 7 control area itself. These were commissioned in order to bring older DMG-scale plans up to date in advance of SNH assessing the performance of deer management groups nationally[16] - they were funded partly by SNH and partly by the two DMG's who have land within the current Section 7 Control Area (Map 1): South Deeside & North Angus DMG and East Grampians Sub-Area 1 DMG.

[16] https://www.nature.scot/sites/default/files/2017-06/A1497639.pdf



Map 1 Location of the current Caenlochan Section 7 control area, showing the DMG's and estates involved along with the extent of the key designated sites.

PROJECT BACKGROUND

50. In spring 2018 SNH commissioned a new study, the primary purpose of which was "to establish the extent to which deer management measures are preventing damage by deer and thereby resulting in an improvement of qualifying habitats" in the area covered by the current Section 7 agreement. The proposed new study had several elements to be delivered in tandem, the aim being to deliver all the required work in the most cost-efficient manner possible to make best use of public funds:

a) The first task was to repeat the 2012 / 2015 Herbivore Impact Assessment (HIA) survey[17], because the "success of the 2014 - 2019 Control Agreement will be measured by comparing the results from the 2018 monitoring of selected habitats to the HIA's carried out in 2012 and in 2015."

b) A related task was to coordinate monitoring and provide the field data required by SNH to formally report on the condition of designated features using the Site Condition Monitoring (SCM) methodology[18]. This is work SNH needs to do regularly on all designated sites nationally anyway, and it made sense to undertake the work in parallel for efficiency.

c) SNH also wished to undertake a deer population assessment using the 'Combination Plot Method'[19]. This 'dung count' survey (see Appendix 1 for an overview of the method) would produce deer occupancy[20] data, to help "assess the number, distribution, density and levels of utilisation by deer across the Caenlochan SAC; and thereby allowing for an investigation of the spatial and temporal relationships between deer population parameters and habitat condition."

d) In addition, proposals were sought from prospective tenders for the collection of any additional survey data they thought might be of use "to help better understand the relationship between utilisation by deer and the condition of blanket bog in the Caenlochan SAC."

---

[17] The 2008 data are also presented in this report, as they were gathered using the same methods and sampling framework, and reflect conditions on site just after the end of the big deer culls taken from 2005-07.

[18] Sites of Special Scientific Interest (SSSI) and Special Areas of Conservation (SAC) are designated on the basis of notified features of interest. These include habitats, species, or geological features (for SSSI's). Site Condition Monitoring (SCM) is a six year programme of assessment of the state of all notified features of interest on designated sites. Reporting is based on feature types and is to common standards across the four UK country conservation agencies (http://jncc.defra.gov.uk/page-2237).

[19] Swanson, G, Campbell, D & Armstrong, H. (2008). Estimating deer abundance in woodlands: the combination plot technique. Forestry Commission Bulletin no. 128. Forestry Commission, Edinburgh. This document in turn references previous work: Campbell, D., Swanson, G.M. and Sales, J. (2004). Comparing the precision and cost-effectiveness of faecal pellet group count methods. Journal of Applied Ecology, 41, 1185-1196).

[20] The amount of time deer spend on each part of a site.

e) Moreover, in delivering the combined survey effort SNH wished consultants to provide “information on the relative nature and extent of current herbivore impacts (including deer, sheep and hares).”

f) Further to gathering survey data, SNH requested “a critical analysis and appraisal of key survey information relating to Caenlochan since 2012. The analysis and appraisal is to be used to assess whether or not the objectives of the Control Agreement have been achieved in terms of achieving favourable condition of, and preventing damage to, key habitats.” SNH was particularly interested in the direction of any apparent trends in impact levels, as well as what the survey data in totality implied in terms of what “risks, if any, are posed in relation to the site’s condition and conservation objectives.”[21]

g) The reporting stage must “include the main findings and is also likely to include conclusions, recommendations and proposals. Any recommendations and proposals may relate to the way forward based on the outcomes of the 2018 surveys.”

h) Finally, SNH felt “there may be ways to improve the project, by amending or modifying the methods, to obtain better value for money or better information.” They therefore asked those submitting tenders “to suggest ways in which this project may be optimised - while still satisfying the fundamental SNH requirements.”

DEVELOPMENT OF THE PROJECT SCOPE

51. The project was advertised by SNH on Public Contracts Scotland (PCS) in February 2018 and was thereafter awarded following a formal tender process.

52. In preparing their tender proposal, and therefore having the opportunity to review the study specification alongside available online data, the contractor reflected on a number of key issues:

a) An estimated project value of £40,000 – 60,000 ex VAT was stated when the contract was advertised on PCS. Unless this cap was raised, the budget was potentially restrictive if covering a relatively large and remote upland area with so many different types of survey.

b) The repeat HIA was an essential element in any scope of work, as were the SCM surveys – but in undertaking all of this ‘essential’ work only a certain portion of the budget was left to deliver the ‘remainder’. Analysis of a suite of historic and contemporary data sets – expected to be a complex task - would further erode the available budget.

c) SNH requested that the deer population assessment covered the Caenlochan SAC, which covers only a relatively small portion of the ‘current’ Section 7 Control Area despite the fact that deer using the SAC are part of a population

[21] Given data were available over a much longer timescale, most notably in relation to deer count and cull data, it was deemed useful to include it all in the analyses presented herein most notably because a large reduction in deer numbers was reported between 2005-07 (i.e. long before 2012).

using a much wider area in both summer (when SNH felt most of the impacts were arising) and winter (when hinds are culled, to regulate population density, at the wider landscape scale).

d) SNH wished occupancy data to be gathered so that relationships between it and impacts could be explored spatially. However, based on deer count data available online it seemed that densities were likely to be very high on the designated sites in summer. Therefore, there might be only limited variability in deer density across the proposed study area. Variation across the site is needed for this approach to work well, as it relies on a density gradient being apparent between sub-areas. Moreover, the SNH sampling framework for herbivore impacts on the designated sites was based on highly-clustered random quadrats - the uneven distribution could make it inherently difficult to explore spatial relationships at anything below overall site scale. These factors might conspire to make the required 'occupancy-impact' analysis difficult if not impossible.

53. Given that SNH had asked prospective tenderers to consider value for money when proposing a final scope, the contractor took this to mean that variations to the proposed SNH scope would be considered if coherent arguments were put forward for an alternative approach. The contractor prepared a 'compliant' tender proposal (including all the elements SNH asked for) but also prepared an 'alternative proposal' which put forward some different ideas about how to gather an optimal suite of evidence from site to meet (i) SNH's current requirements but, crucially, also (ii) furnish SNH *and* landowners with the types of evidence they might *jointly* need to help make objective, informed decisions about future site management.

54. The key elements of the alternative proposal that the contractor submitted to SNH, and which eventually became the final scope of works for the project, were as follows:

a) **Occupancy-Impact Assessment** (OIA): a survey to quantify spatial variations in the level of deer occupancy and deer impacts on the designated sites *and* all adjacent land lying at a similar altitude. Data to be gathered on a grid-based system, of 200 transects at ~ 500m intervals, so that spatial variations in occupancy can be modelled at overall site scale but also in sub-areas below it. To ensure a powerful and robust analysis of relationships can be undertaken, the survey aims to gather a wide range of quantitative deer impact data at the same time and from the same locations as the deer occupancy survey data. In order to help understand how hare and sheep contribute to the pattern of impacts observed, the survey will quantify spatial variations in their distribution and occupancy concurrently using a combination of indirect sign surveys and direct counts as suits conditions. A particular focus of the study is to be on peatlands, so additional quantitative data on peatland condition and mammal impacts will be gathered. In order to enable monitoring in the future of changes in occupancy and impact patterns over time, set up the sampling scheme so that it can be repeated as required.

b) **Herbivore Impact Assessment** (HIA): the original sampling scheme for the HIA – as used in 2008, 2012 and 2015 – was designed to try and make the fieldwork more 'efficient'. A set of ¼ km^2 'squares' were selected at random from within the site, and within each multiple quadrats (up to 5) were sampled in each target habitat present[22]. However, the contractor viewed this design as being somewhat inefficient from a statistical perspective because quadrats in each square are related to each other (i.e. are not independent). It was instead proposed that the survey be repeated, but that only 3 quadrats were sampled (numbers 1, 3 and 5) and that two were omitted from each square (numbers 2 and 4) as it would yield a very similar result for less effort; this effort would be re-allocated to other survey work to help add value to the project. The alternative work involved adding an HIA quadrat to each of the n=200 OIA sampling points to provide a much more geographically extensive HIA data set, but also one which was much easier to analyse spatially now and in the future. There would arguably be a marginal loss of statistical power from the original HIA scheme in doing so, but the pros were judged highly likely to outweigh the cons. SNH agreed that on balance this approach was likely to produce the best outcome for the project overall.

c) **Montane willows**: one of the rarest and most important habitats in the survey area is montane willow scrub, according to the citations for the site. The contractor proposed to SNH that the paucity of data for this habitat might usefully be addressed if possible. SNH agreed that the contractor should attempt, whilst traversing the site, to identify additional locations at which to sample willow.

d) **Site Condition Monitoring** (SCM): queries were raised with SNH about the need to undertake some of the proposed SCM surveys, as they covered similar habitats to the HIA (and OIA) (e.g. dry heath, bog) but SNH decided, in the end, that they needed to be done as planned to comply with wider national reporting requirements.

e) **Strategic Review** (SR): The contractor suggested that the scope of the critical analysis be broadened somewhat, to cover not only analysis of historic count and HIA data sets but also: (i) building of deer population models for the current S7 Control Area and wider areas if deemed necessary, (ii) production of a set of 'planning maps' to help the DMG and SNH scope out the next steps for the site, (iii) reviewing existing deer management plans for the area, (iv) analysis of estate management objectives (using info in available DMP's), (v) reviewing the S7 agreements and related documents (e.g. original DCS board papers) and (vi) undertaking an 'options analysis'. The options analysis would consider how different levels of future cull were likely to affect future site condition, as well as affect delivery of estate sporting objectives - various scenarios would be presented to help each party understand the pros and cons of a range of different ways forward. SNH agreed that a more holistic

[22] Headley (2009a) describes the rationale for the original design.

and integrated approach to the review, such as the one proposed, would be very useful.

f) **Project Steering Group** (PSG): a steering group would be formed to help guide the project, formed from owners and SNH staff. In the end, SNH did not wish to take up this suggestion.

g) **Project meetings** (PM): The contractor would present the findings of the work at a series of technical seminars, to ensure that both parties fully understood the project results and were able to make best use of them. This was agreed.

55. Immediately upon starting the project, the Strategic Review process began in earnest. It rapidly became apparent that the early findings of this work – such as compilation of historic count and cull data alongside population models – would be worth sharing with owners at an early stage. A sequence of extra meetings were scheduled, in part to share the early findings from the review but also so that the preliminary survey results from summer 2018 could be shared quickly. The aim was to ensure that owners and SNH had as much information as possible, as early as possible, with which to help guide discussions on (i) the likely success of the current Section 7, due to end in autumn 2019, and (ii) the future management of the site.

56.

THIS REPORT

57. The remainder of this report comprises the following sections:

a) **Site description**: a brief description of the Caenlochan site. It is not meant to take the place of the much more detailed information already available, but rather it provides an overview for readers unfamiliar with the site.

b) **Methods**: the methods employed in the OIA, HIA and Strategic Review.

Note - SCM methods and findings are included in a separate report to SNH, in part for sake of brevity but also because they are not judged to be central to the review of the Section 7 agreement contained herein - the habitat condition targets described in the current Section 7 agreement were designed by SNH upland habitat advisors to help ensure the site moves towards 'favourable condition'.

c) **Findings**: the key findings from the work undertaken, including:

i) Historic deer culls, deer count data and population modelling outputs.

ii) Mammal occupancy assessment, including comparison of the distribution of deer, sheep and hare alongside their potential contribution to impacts observed on site.

iii) Mammal occupancy-impact relationships evident on site, derived from the various impact surveys undertaken on site in summer 2018 on the systematic sampling grid.

iv) Analysis of HIA survey results from SNH monitoring over the period 2008-2018, obtained from the random sampling scheme on the designated sites.

d) **Interpretation**: discussion of the project findings, set in the context of what the Section 7 agreements originally set out to achieve.

e) **Conclusions**: the key points of learning from the review, and what they mean for the organisations involved in determining the future of the Caenlochan Control Area.

f) **Recommendations**: a range of suggested activities to undertake as a follow-up to this project, to help the various parties involved in the site chart the road ahead

g) **A Way Forward**: a section outlining a sequence of possible 'next steps' for the site. These include a proposed process for creating a new strategic land management plan, as well as a brief of analysis of future options based on a variety of deer densities.

h) **Appendices**: a set of appendices is included in this report, in part to reduce the length of the main report and in part to provide supporting material for interested readers:

i) Appendix 1: an overview of dung counting methods, and how the data are analysed.

ii) Appendix 2: a brief explanation of SNH's Herbivore Impact Assessment (HIA) method for readers unfamiliar with it.

iii) Appendix 3: an overview of a method that can be employed to calculate the variance of a systematic sample.

iv) Appendix 4: a brief overview of the scientific literature concerning the diets of deer, sheep and mountain hare in the uplands of Scotland.

v) Appendix 5: a brief overview of the ecology of montane willows in the uplands of Scotland.

58. The report has been written with a number of different audiences in mind: land managers and keepers, SNH specialist staff, SNH area staff and government policy advisors. As a result, taking all needs in to account:

a) It does not comply with all the stricter conventions of scientific publications, because this can render documents impenetrable to non-specialists. For example, it has been prepared for ease of reading and reference so footnotes are used to de-bulk the main text and signpost readers to supplementary material where deemed valuable.

b) As the methodologies used in the project involved a degree of iteration over time, the text reflects this process. Some key results are briefly referred to in the Methods, for example, whilst certain key methodological developments are described within the Findings section as the narrative is more easily developed using this approach.

c) The report is necessarily lengthy, given the complexity of the subject matter, hence a Non-Technical Summary has been prepared with signposts into the main text.

d) Conditional formatting has been used in many of the tables, in order that readers can easily visualise trends apparent in the data presented.

e) A set of maps was prepared as part of the reporting process. Copies are included within the report, but as some of the detail is difficult to discern a separate 'PDF mapbook' has also been prepared.

SITE DESCRIPTION

59. The current Caenlochan Section 7 Control Area is located partly in Perth & Kinross and partly in Aberdeenshire, to the east of the village of Spittal of Glenshee and north of the town of Blairgowrie.

60. The site comprises a large upland expanse dominated to the north by a high plateaux into which various glens and corries have been sculpted during the last glaciation (Map 2). The altitude of the site varies from ~ 300m to over 1,000m.

61. The site has a complex surface hydrology, with runoff draining in a variety of directions from the central plateau into streams and eventually major river systems such as the Isla (Map 3). There are however few lochs.

62. The site is underlain by a wide variety of bedrock types, ranging from base poor to base rich (Map 4). On top of the bedrock lie a variety of superficial deposits including till. In turn a variety of soil types, many relatively well-drained and some relatively fertile in upland terms, overlie these deposits (Map 5).

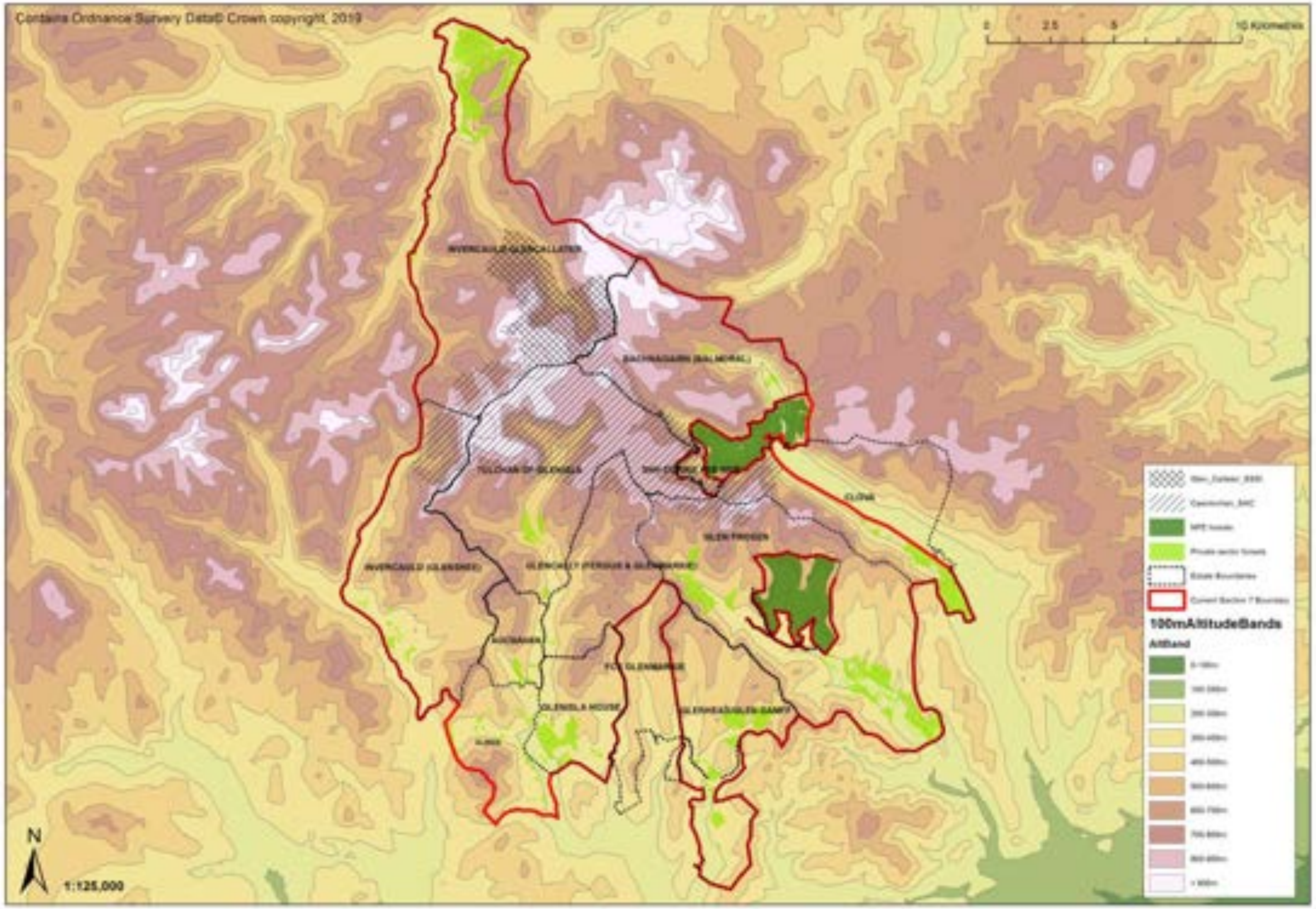
63. Variations in soil type alongside variation in topography, altitude and surface hydrology drive a complex pattern of upland habitats (Map 6). These include heathlands and (mainly) unimproved grasslands on the lower and mid-slopes leading to blanket peatland and summit communities on the high ground. The site is considered to be exceptional for its floristic diversity and has an atypically large number of rare plants, mainly montane species, represented. Caenlochan Glen is the main locus for these but other areas hold a considerable interest for botanists too. Whilst there are very few examples of semi-natural woodland

present the site does hold a highly significant population of montane willow scrub alongside some tall herb communities similarly restricted to cliffs.

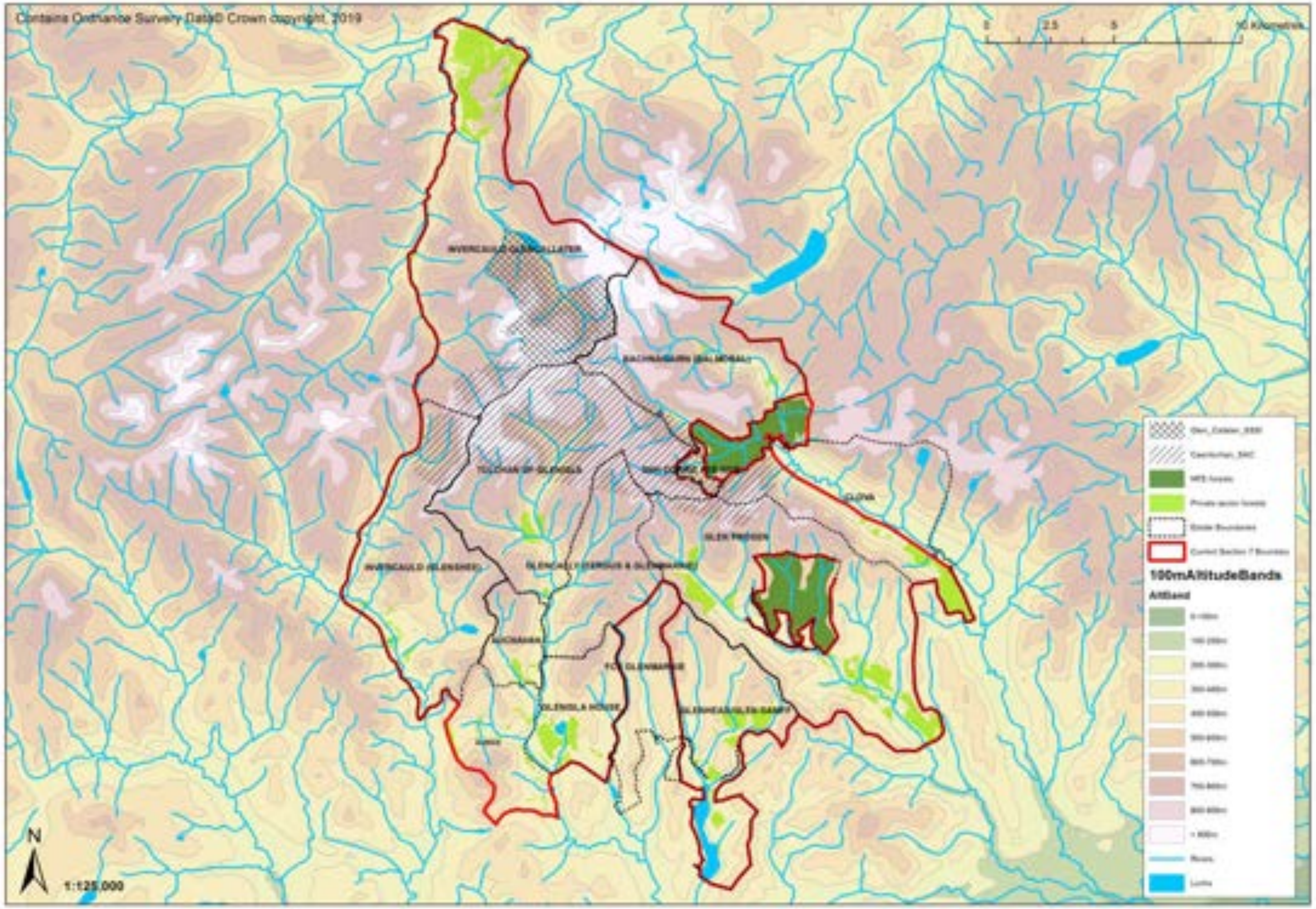
64. Land management influences the extent and status of the habitats present. The area is used predominantly for rough grazing, for deer stalking and for grouse management. Related activities, which can cause impacts, include land drainage, track construction and muirburn (Map 7). Surface erosion is also evident. Regional and private drinking water supplies are located near or in the area.

65. In addition to fieldsports, which generates an important source of employment in the area, and farming which are commonplace other activities such as downhill skiing and general tourism/recreation are also important. This includes hillwalking - several Munros are located within the site and are very popular along with other local walking routes. Some areas locally have been planted with trees, normally to produce a commercial crop, but they cover a small proportion of the site hence economically are of limited importance. Most of the plantation woodlands are deer fenced but some – most notably Glen Doll – currently have porous fences.

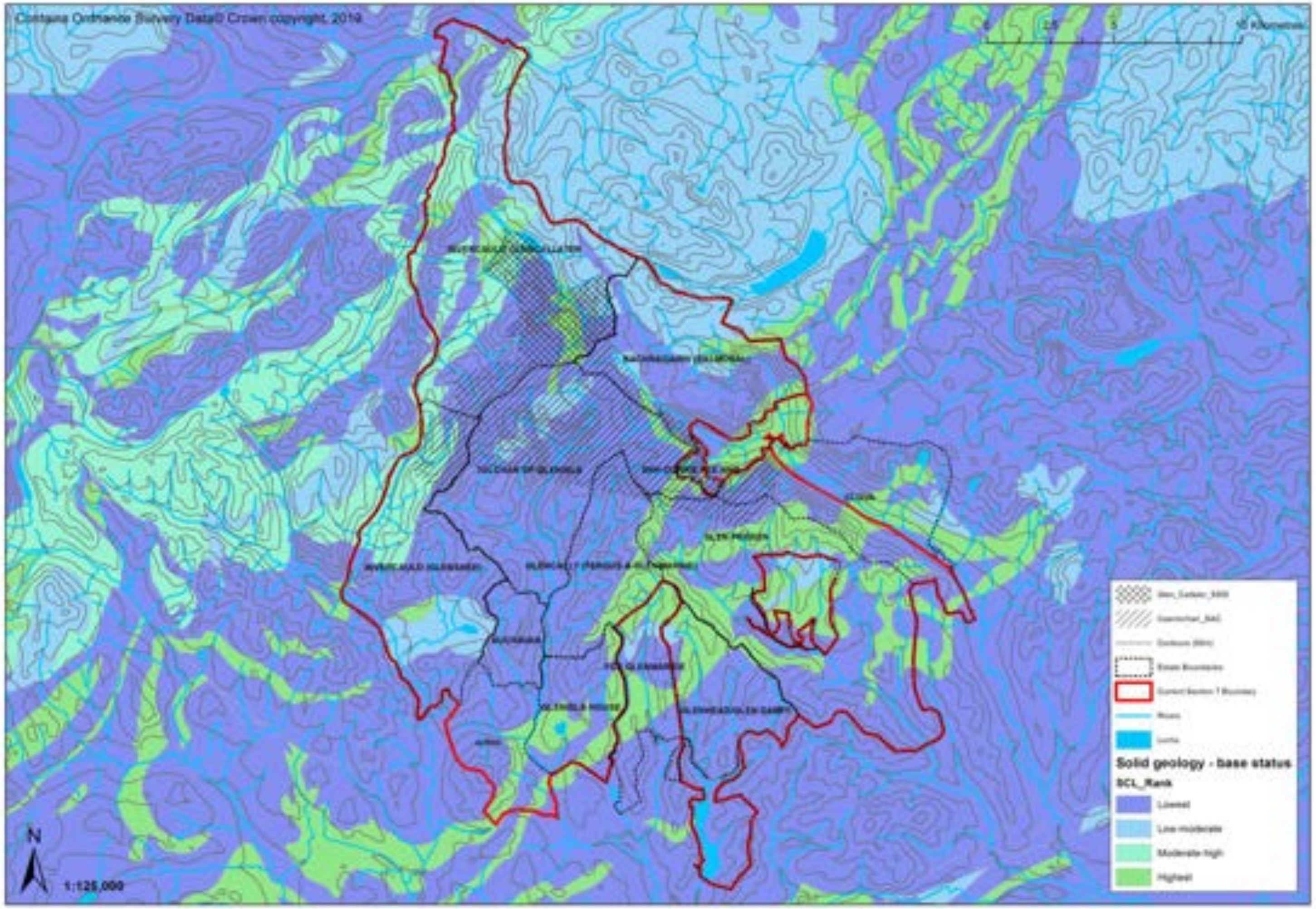
66. Red deer are commonly seen across the site in considerable numbers, as are mountain hare. Roe deer are also present locally. Red grouse are present predominantly in areas which are actively managed by burning.



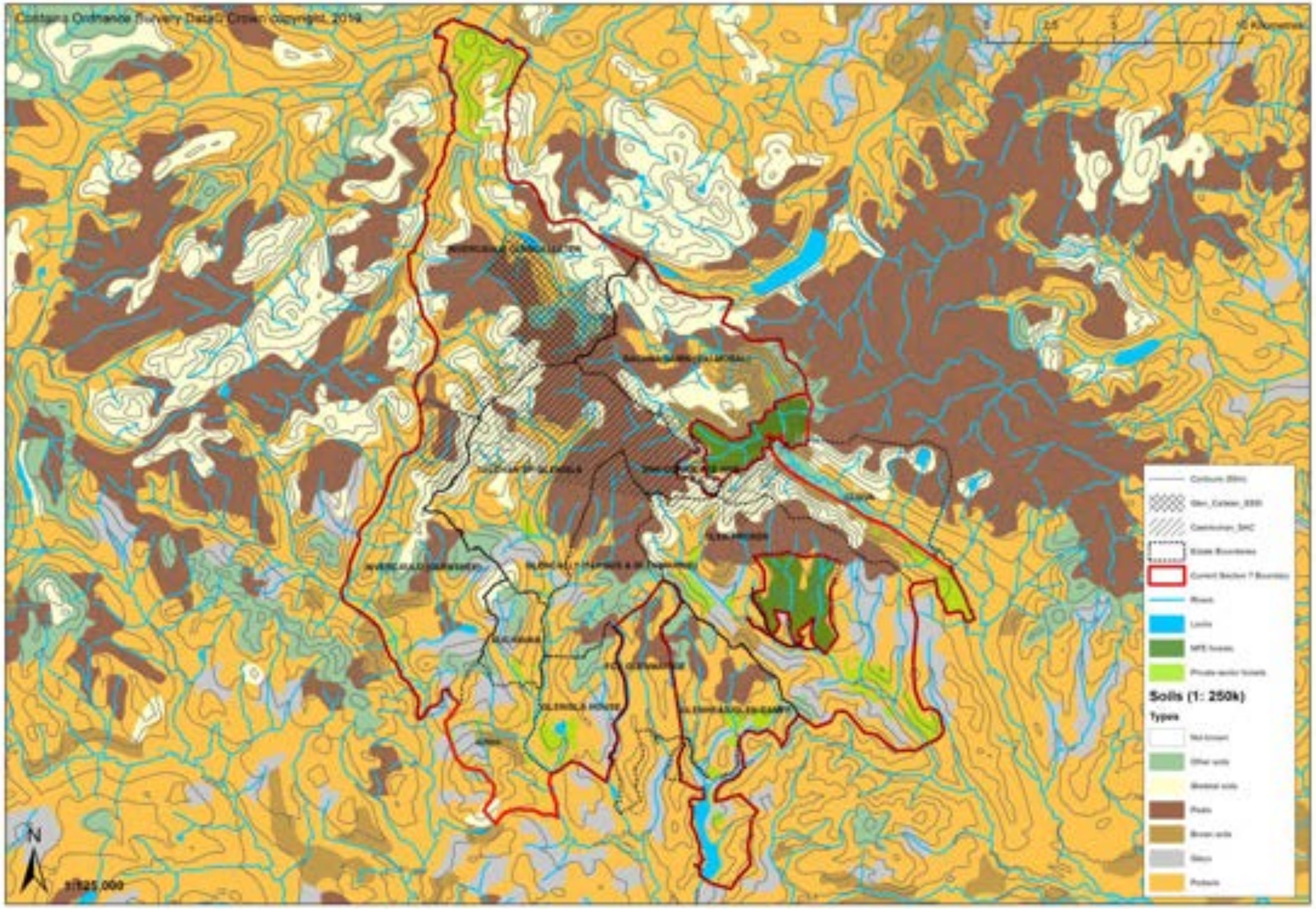
Map 2 Altitude and topography of the Caenlochan Section 7 control area and its environs



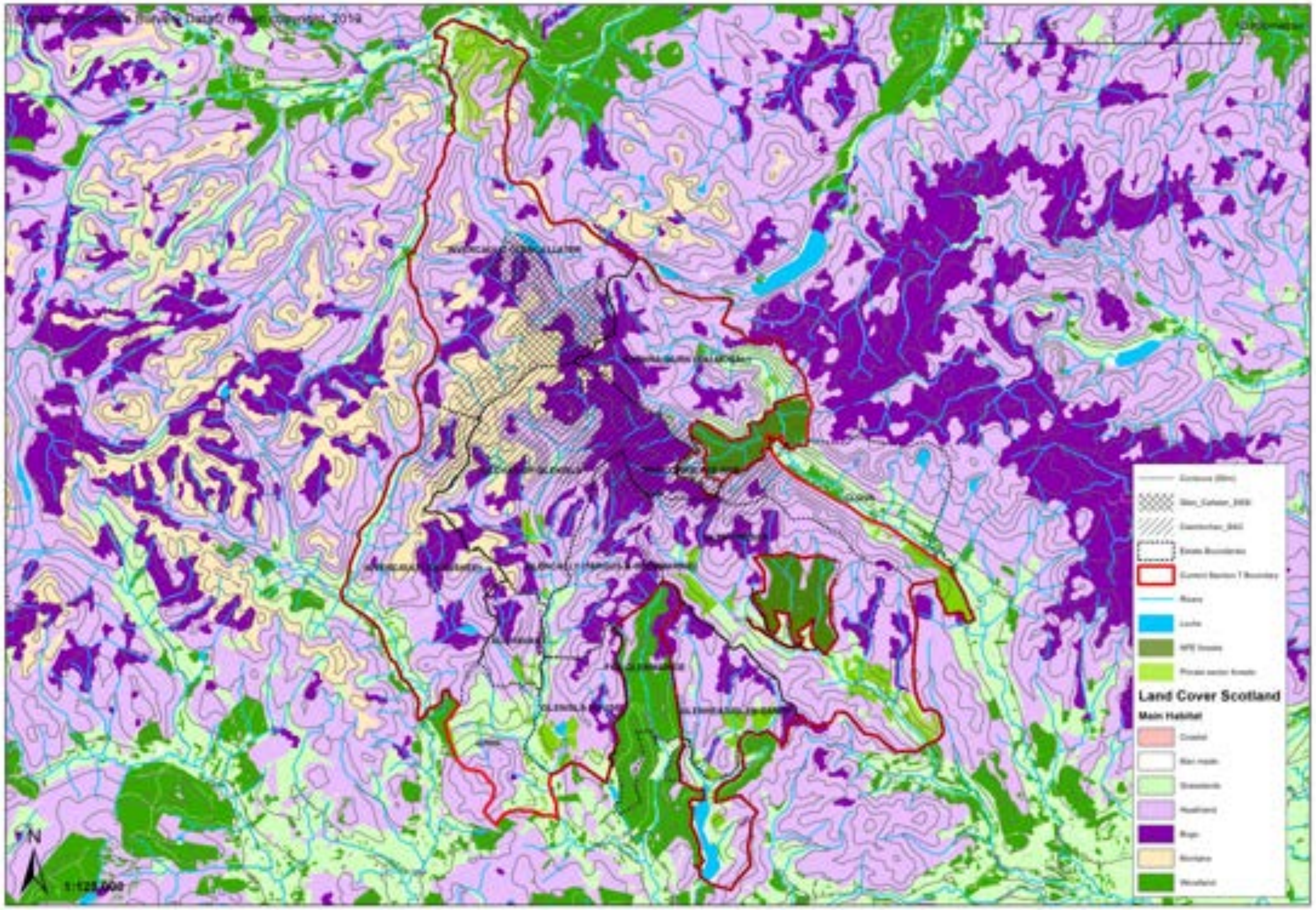
Map 3 Surface hydrology of the Caenlochan Section 7 control area and its environs



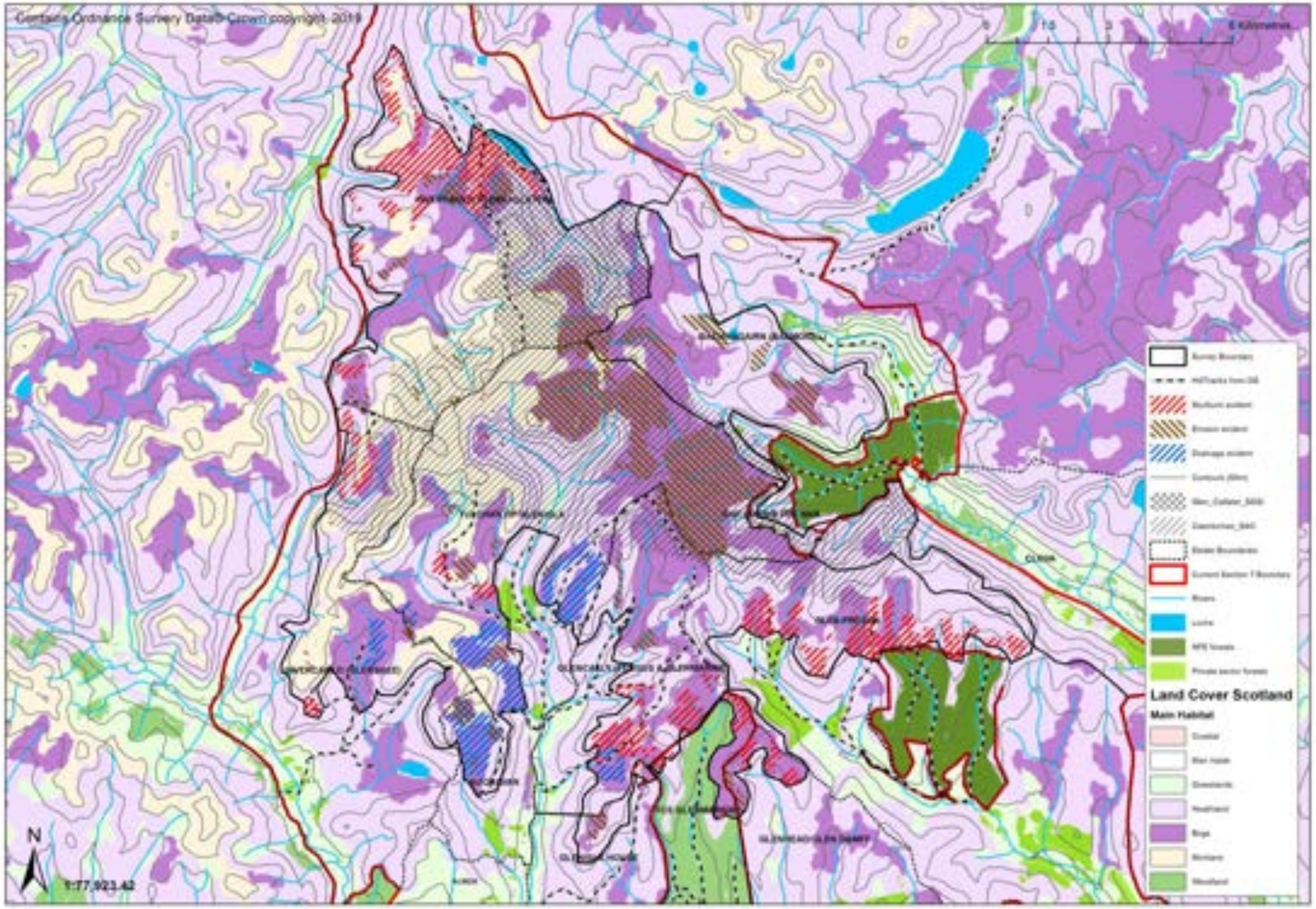
Map 4 Solid geology of the Caenlochan Section 7 control area and its environs



Map 5 Soils in the Caenlochan Section 7 control area and its environs



Map 6 Habitat types in the Caenlochan Section 7 control area and its environs



Map 7 Land management impacts visible on aerial photography in the Caenlochan Section 7 control area.

METHODS

DEER COUNTS, CULLS & POPULATION MODELLING

67. Helicopter deer count data were downloaded from the SNH website in the first instance, in Excel and ArcMap shapefile formats. The Excel and shapefile data were joined in ArcGIS to enable count data to be tagged with survey date[23]. A review was conducted to check which data related spatially to the current Section 7 Control Area, with other data then being excluded.

68. The next stage in the review confirmed that some of the earlier count data, from the time of the original Section 7 agreement, were not present in the data set available online. A request was sent to SNH and further data from their archives was sent over, in the form of shapefiles. These data were also reviewed, and the data relevant to Caenlochan extracted.

69. The data sets obtained spanned the period 1966-2018. Data sets prior to 2000 were assumed to be from ground-based counts conducted by a combination of DCS staff and estate staff; data sets after 1999 were all assumed to be helicopter counts[24].

70. The two cleaned count data sets were merged and loaded into a Geographic Information System (GIS) of the project site, to which was added Ordnance Survey background mapping and estate boundaries (obtained from SNH online sources).

71. Data sets were then checked to establish which estates within the current Section 7 area had data showing for each count, and which estates seemed to be missing a record (Table 2):

    a) It became apparent that some count data sets only covered a sub-section of the current S7 area, with several important estates often missing data [25]. Where this was the case, the data sets were discarded and not included in any subsequent analysis (Table 2).

    b) In some cases, only a few smaller properties were missing data – whether they were actually counted or not, it was judged unlikely that their 'omission' would make a substantive difference to any analysis subsequently undertaken. These data sets were left in the analysis albeit it is accepted that the count for that year may be an undercount, with all else equal.

---

[23] An initial join, undertaken at the time of the tender, later was found to be corrupted. This resulted in an early presentation of compiled count data being somewhat erroneous. The join was later re-run and found to be reliable. The more recent data set is employed in this report whereas in presentations sent to the landowners previously the older corrupt data were used.

[24] As suggested by Iain Hope of SNH

[25] Larger estates, which are significant contributors to the landmass of the Section 7 Control Area, or estates where considerable numbers of deer were often counted historically and whose omission might therefore be important.

c) In a few cases, a larger estate was missing from the count records. It may be that deer were simply absent on the day of the count, or their records were merged (e.g. the two Invercauld properties) or changes in ownership (e.g. Glen Isla being partly sold off, thus Glencally appearing in the records) leading to administrative changes in count allocation may be the explanation. In these cases, data were considered marginal but still worthy of inclusion as the count totals for these years were still relatively substantial (Table 2).

d) Late autumn counts were omitted as only a few such counts existed, and handling the data in a population model is difficult because part of the hind cull might already have been taken at this time making adjustment of the data to a common point in time (with other data sets) difficult to achieve.

e) Other forms of bias in the count data are known about, but are somewhat difficult to control for, and hence were ignored – they may of course be important:

   i) Winter counts were sometimes undertaken before the end of the hind season, and thus some deer may have been killed after that date but cull records are supplied as annual totals hence cannot be adjusted in retrospect. The data may therefore be biased upwards. That said, animals often die later in the spring, depending on the weather, hence this produces a further upwards bias if not allowed for in models. Summer count data may partly suffer from a similar problem, relating to culling early in the stag season but most of the counts were done in July before the majority of the cull would generally be taken.

   ii) Countering the upwards biases caused by late or early culls, and from late winter or spring natural mortality, data may be biased downwards as a result of undercounting. The most notable source is from deer concealed in thick woodland cover during winter, because counts are often made in snowy conditions when deer are most likely to seek shelter therein. This is particularly true in the case of Glen Doll (National Forest Estate) which is a large forest block in the east of the current Section 7 area (860 ha) which hill deer have access to but the helicopter cannot count within[26]. In summer, many red deer will move to higher ground hence the bias due to concealment in woodland may well be reduced in relative terms. Downwards biases may also arise, most notably in summer counts, from calves being concealed within larger groups of hinds or from late calves still remaining hidden (i.e. not yet running at foot); this could also happen in winter counts but is less likely to be a serious source of bias.

   iii) Counts generally are prone to various forms of human error, for example deer being double counted (e.g. if moved by the helicopter from one side of a ridge to another) or small groups of deer being missed (e.g. if

[26] A study, based on dung counting albeit with a small sample size, in Glen Doll Forest in the winter of 2008-09 indicated that the level of red deer occupancy was equivalent to ~ 150-200 animals using the forest.

observers are focused on a larger group in the vicinity). Obviously, count staff from SNH will try to minimise these biases but they cannot be entirely discounted.

72. Despite there being various forms of potential bias, the count data were compiled and then employed in a variety of ways:

a) A summary of the counts was produced to provide an overview of the likely trend in numbers over time (summer and winter) in the current Section 7 area. Where winter count data contained unclassified data (i.e. groups of deer where hinds, calves and young stags had not been distinguished between) a modelled adjustment was made[27].

b) Data were imported into population models (see later section) in order to compare with modelled trends. This included 'inflating' the winter count data to provide an estimate of summer numbers[28].

73. Cull records were provided by SNH covering the period from 2000-01 onwards; it was not possible, in the time available, to extract earlier data from the archives. Various complications were encountered when reviewing the data, due for example to changes in property ownership and the naming conventions employed in databases provided. In addition, the data supplied for Balmoral (Bachnagairn) was difficult to handle as the Control Area only included part of the land in question. By checking through Deer Management Plans it was however possible in almost every year to obtain accurate cull data for the area of Bachnagairn required. Overall, once data were cleansed and tagged with common names then aggregated it was felt that a sufficiently useful summary of historic culls had been produced to enable a robust analysis. That said, biases in the data may well still be present such as: (i) some deer may have been shot illegally and not recorded, (ii) some records may contain administrative errors, (iii) some farms or crofts may have shot deer but left them unrecorded etc.

[27] We followed the SNH convention for this, which is to assume 10% of counted deer are young stags then to split the remaining deer into hinds and calves based on an assumed proportion of calves (e.g. 45 calves at foot means that 0.45/1.45 of the remaining deer are calves with the remainder being hinds). This approach has a known bias, as the proportion of young stags present would be better estimated taking into account the actual stag: hind ratio, but for the sake of convention and because the alternative calculation needed has a number of additional assumptions we followed the standard process.

[28] Assumptions of this process were as follows: half of all calves counted were added to next year's male stag population; half of the calves were added to next year's female hind population; the number of new calves was estimated by multiplying the level of calving (e.g. 45 calves per 100 hinds) to the number of hinds.

Table 2 Deer count data extracted for the Caenlochan area from various data sets supplied by SNH. Many of the data sets have occasional properties missing. It is not clear – and with the passage of time it is not possible – to be sure if these were genuine 'zero counts' or were properties not counted. Pink cells show potential missing data. A degree of judgement had to be used when deciding which counts to include and which to omit from subsequent analysis. Those marked Yes, With Caution and Historic Interest were included in chart-based analysis later in the document. Others are shown here for the purposes of forming an audit trail.

			Area (ha)		2,355	3,401	1,230		868	1,544	5,689	2,075	2,827	6,973	4,062	4,926				
Year	Season	Month	Count ID	Alrick	Auchavan	Balmoral-Bachnagairn	Clova	FE land	SNH Corrie Fee	Glen Isla	Glen Prosen	Glencally/Fergus /Markie	Glenhead/Glen Damff	Invercauld-Callater	Invercauld-Glenshee	Tulchan	Unattributed	Total count	Apparent coverage of the count?	Include in analysis?
1966	Winter	2	None	5	447	321	88			-	299	5		672	353	620		2,810	Insufficient	Historic interest
1975	Winter	2	None	9	209	799	253			606	537	624	27	1,761	1,524	328		6,677	+/- Complete	Yes
1979	Winter	3	None	183	390	606	248			731	20	126		1,413	882	194		4,793	Marginal	Historic interest
1986	Winter	2	None	754	520	618	690			1,899			438	1,687	848			7,454	Insufficient	No
1994	Winter	3	None	506	199	647	218	8		980	410	948	488	1,329	2,041	581		8,355	+/- Complete	Yes
2000	Winter	2	None	546	299					1,386	496	848	1,216	1,521	2,263			8,575	Insufficient	No
2002	Autumn	11	None	658	658	1,076			27	1,399				1,863	2,011	1,666		9,357	Insufficient	No
2003	Winter	2	None	557	388	1,083	297			371		800		1,461	2,053	984		7,994	Insufficient	No
2003	Summer	7	None	119	1,742	1,555						752		2,601	2,182	2,423		11,374	**See footnote***	Yes
2005	Winter	2	84	504	673	999		101		1,031	921	1,543	707	1,437	1,921	500		10,337	Marginal	With caution
2006	Winter	3	111	185	504	968			45	594	962	1,992	442	1,642	905	55		8,294	Marginal	With caution
2006	Summer	7	123	246	345	704					1,813	531		2,434	771	2,888		9,732	**See footnote***	Yes
2007	Winter	1	124	105		565	184		3	420	976	640	22	1,406	1,400	1,162		6,883	+/- Complete	Use March count
2007	Winter	2	125				82			875	204	912	638		861	274		3,846	Insufficient	No
2007	Winter	3	202	69	24	610	168			935	556	199	199	1,340	1,340	616	85	6,141	+/- Complete	Yes
2007	Summer	7	134	102	375	791	694	11			1,182	420	158	1,865	2,066	678		8,342	Marginal	With caution
2008	Winter	3	135	7	99	735	52			640	1,103	486	678	1,213	1,465	254		6,732	+/- Complete	Yes
2008	Summer	7	143		17	955	748				435	2	328	2,051	4	2,936		7,476	Marginal	With caution
2009	Winter	3	154	42	87	581	72			200	989	876	401	1,217	1,697	63		6,225	+/- Complete	Yes
2009	Summer	7	175	649	90	903	493				362	585	710	1,684	1,110	1,230		7,816	Marginal	With caution
2010	Winter	1	177	32	990	1,021	35		64	1,072	333	70	275	932	806			5,630	Insufficient	No
2010	Summer	8	186	23	191	685	411				1,081	687	171	1,785	244	1,726		7,004	Marginal	With caution
2011	Winter	1	194		76	1,035	56	10		195	1,115	520	32	1,142	919	1,480		6,580	Marginal	With caution
2011	Summer	7	200		294	1,350	807			2	522		28	2,107	3	2,644		7,757	Marginal	With caution
2012	Autumn	11	220	139	94	761	544		6	9	343	622	384	803	524	2,199		6,428	+/- Complete	Wrong season
2012	Winter	2	205	132	96	599	88	57		224	1,130	165	485	892	1,409	1,082		6,359	+/- Complete	Yes
2012	Summer	7	218	251	98	861	370			15	1,019	668	260	1,574	2,016	1,462		8,594	+/- Complete	Yes
2013	Autumn	10	237	29	513	663	121	9	2	530	605	161	318	935	1,344	1,232	43	6,505	+/- Complete	Wrong season
2013	Summer	7	232	58	45	790	528			127	678	1,137	123	1,940	1,743	1,576		8,745	+/- Complete	Yes
2016	Winter	1	273	271	111	1,123	220	20	49	866	560	423	447	921	1,624	21		6,656	+/- Complete	Yes
2018	Winter	1	None	453	1,366	1,346	786		72	211	637	1,402	361	951	758	97		8,440	+/- Complete	Yes

74. Records were firstly used to produce charts of the trend in culls by area, and by sex (male or female) and age-class (adult or juvenile) over time. A proxy for the productivity of the herd was also obtained by calculating the number of calves culled per 100 hinds culled each winter. This measure does not reflect true summer recruitment, nor arguably the final recruitment following late spring mortality, but in the circumstances is considered as good a measure as any available given it comes from multiple properties and multiple years. Data from the actual count data were also summarised for comparison (i.e. numbers of calves counted 'at foot').

75. The number of deer culled each year was then input into a retrospective population model[29]. This was developed to try and predict how many deer might be expected to reside in the current Control Area, in spring 2019. It was based on count results obtained at the outset of the original Section 7 period in 2005[30], along with culls taken and allowances made for other deaths along with annual recruitment. This modelled prediction could then be compared to the actual helicopter counts obtained by SNH in the intervening period, to assess the predictive power of the model. If good agreement was obtained, with biologically sensible parameters, then the model might prove useful to SNH and owners to help support future decision-making.

76. If the degree of agreement was poor, it may mean some of the parameters were erroneous or could mean that the population using the area being modelled was not entirely resident within it. Another possible reason relates to the modelling framework itself. The modelling framework, does not include age-specific functionality (other than splitting juveniles and adults) and does not take into account density-dependent effects over time. Whilst allowing for both of these is theoretically possible, and could of course make the predicted trends more accurate, gathering robust field data on ages of deer (alive as well as culled) and obtaining reliable site-specific density dependent data on population performance is in reality more or less impossible in our experience. Hence, on balance, our preference is to operate a simpler framework using fewer relatively well understood and robust parameters to avoid over-complication.

77. The parameters and assumptions employed in the retrospective model, in order to obtain an output which broadly mirrored the pattern of the count data provided by SNH, were as follows:

a) The model was set to cover the land area of all properties in the current Section 7 Control Area but did not at the outset include any adjacent land[31].

---

[29] The retrospective model used all historic data available to try and help explain the dynamics of the Caenlochan population, at a landscape-scale, from the early 2000's to the current day.

[30] The lack of earlier cull data, and lack of earlier count data with complete coverage, meant that 2005 was the first sensible point to use for modelling.

[31] Arguably some of the deer using these adjacent areas may use the Control Area (e.g. deer to the west of the A92 Glenshee road) and *vice versa*. Also, deer from the south may use the Section 7 area also. However, for the purposes of the modelling exercise we assumed these effects might cancel

b) The initial count used to start the model was from February 2005; prior count data sets had too many properties missing to justify using them as the start point (and prior to 2000 there were no cull records available anyway). However in later iterations of the model the starting abundance was varied in an attempt to produce lines of best fit, given it was possible that the original input count could itself be somewhat biased.

c) The adult sex ratio employed at the outset of the modelling period was estimated using the 2005 count data. However, these data had large numbers of unclassified animals included which meant a model had to be used to split off young stags and calves from hinds (see previous footnote). This calculation produced a sex ratio of 2.3: 1 which seemed to be high given the general patterns in the other count data around that time. A value of 1.5 hinds: 1 stag was used to start the model in the end. Once the model ran, it then calculated the subsequent adult sex ratio annually. Iterations of the model were run which included varying this initial ratio somewhat during attempts to produce lines of best fit.

d) The juvenile sex ratio at birth was assumed to be equal (1: 1) for the duration of the period. It is possible that the ratio could have been skewed, but cull records do not include separate records of male and female calves shot and it is otherwise difficult to select an appropriate value.

e) We assumed that any deer vehicle collisions and poaching would act on adults and juveniles equally, hence it was not allowed for (any such death was assumed to be allowed for by the use of a net recruitment rate).

f) The two other main parameters the model required were natural mortality (e.g. from weather/starvation/old age etc) and the annual recruitment rate from births.

    i) A fixed annual recruitment rate was employed each year of the model, for simplicity and in recognition of the fact that trying to model the rate annually (to account for weather etc) involved many assumptions whilst using the actual proportion of calves shot annually ignored the possibility that selective culling could influence the data markedly. Of course, the model would ideally have employed a variable annual recruitment rate as it is known that, for example, several exceptionally harsh winters have been experienced since the early 2000's in the Grampians. Cull records indicated that the recruitment rate had varied in recent years but between 40 and 45 calves per 100 hinds annually seemed an appropriate start point. However, rates were subsequently varied in the model in an attempt to iterate manually towards obtaining lines of best fit through the historic count data (see Findings). The rate employed in the model was a net rate (i.e. numbers entering next year's adult population) as opposed to a gross rate (actual numbers born in summer, before

---

each other out - at least for hinds and calves – because there appeared from count data for the wider region to be relatively few populations of hinds present in the vicinity during large-scale counts.

predation and mortality thinned the numbers down by the following spring).

ii) Natural mortality was assumed in the first instance to be zero across adult males and adult females; juvenile natural mortality was assumed to be encapsulated in net annual recruitment rates. In later model iterations - when trying to manually obtain lines of best fit through the male, female and calf count data individually – we varied the % rates iteratively (see Findings).

78. In order to compare actual count data with retrospective model predictions, we had to adjust some counts. Summer counts were left unadjusted as they were taken to include calves[32]. Winter counts were adjusted upwards to include predicted summer recruitment. This was done by applying a modelled net recruitment rate (45%) to the predicted number of hinds present at the time of births (i.e. all adult hinds counted in winter + 50% of the previous year's calves).

79. The retrospective model was run to show both the numbers of deer present, and the densities of deer present, each summer. Models were also run to show the effect on total deer numbers as well as separately for stags, hinds and calves.

80. The retrospective modelling proved to be complex - not unexpectedly - and multiple lines of best fit were able to be obtained depending on the exact parameterisation employed. Our aim in settling on a final retrospective model (see Findings) was to produce a useable conceptual tool for managers, whilst recognising at the same time that it is not possible to rely entirely on its outputs. The outputs from the model reflect our attempts to take available reliable data sets and assess whether the various strands could be brought together to produce broadly plausible model outputs. If it could, the tool would provide a robust platform to aid future decision-making.

81. Whilst there was undoubtedly the potential for deer to move into the modelled area at any time, as there are no perimeter fences, they could also move out of it. Also, male and female red deer tend to range in different ways with males tending to range markedly further[33]. For this reason, we chose to try and 'balance' the model for the hind and calf population as a priority – the majority of counted hinds are likely to be resident, and hence their calves also will be in early life. Stags, on the other hand, may be present in the area and shot during the rut but for much of the year reside elsewhere hence not be counted in winter (and *vice versa*). Moreover, stags are reported to be more

[32] That said, Iain Hope of SNH has commented that calving may well be underestimated as calves can be too young to be at foot, or can otherwise be hidden in between adults in the herd, when being counted in early summer.

[33] Pemberton, J.M. and Kruuk, L.E.B. (2015). Red deer research on the Isle of Rum NNR: management implications. SNH, Battleby

prone to winter mortality than hinds[34] and hence the absence of actual mortality data meant that the stag model might be, in relative terms, more erroneous. The strand of the model pertaining to stags was therefore balanced last, accepting that in trying to force the model to match actual stag count data there were likely to be parameters used which may not reflect reality on the ground very closely.

82. A prospective model was also built to consider the likely future dynamics of the Caenlochan population at landscape scale, albeit with the same limitations and caveats in mind with respect to stag numbers. Its starting point was the results of the January 2018 deer count. In the end, however, it was not used in the production of this report.

OCCUPANCY-IMPACT ASSESSMENT & ANALYSIS

83. The aims of the Occupancy-Impact Assessment (OIA) were to:

a) Quantify spatial variations in the level of large mammal occupancy (deer and sheep) using faecal pellet group count surveys.

b) Quantify the occupancy patterns of sheep to help assess their likely importance as contributors to (i) the faecal accumulation measured during the large mammal occupancy survey and (ii) the impact levels measured on site (see below).

c) Quantify the occupancy patterns of hare and grouse to help assess their likely importance as contributors the impact levels measured on site.

d) Estimate deer abundance within the study area, using the large mammal occupancy data, taking into account the likely contribution of sheep to the pellet group count totals.

e) Quantify spatial variations in mammal impacts on open range habitats within the study area.

f) Use the data obtained from site to assess to what extent impact levels vary in line with mammal occupancy (the corollary being that if they are related, then it might be possible for SNH and land managers to identify, empirically, the likely level of occupancy needed on site to deliver any agreed set of habitat condition targets; in turn, deer culls could then be set to try and deliver the required level of occupancy along with any other measures needed e.g. reduce sheep numbers, manage mountain hare numbers etc).

84. The target area for the OIA study was decided upon by firstly considering SNH's aspirational survey boundary at the tender stage (i.e. covering the Caenlochan SAC and Glen Callater SSSI only) and considering the likely outcome of restricting the survey in this way. In essence, with a large number of deer likely to be using the SAC (historic summer count data made this evident) there was a risk that

[34] Pemberton, J.M. and Kruuk, L.E.B. (2015). Red deer research on the Isle of Rum NNR: management implications. SNH, Battleby

deer densities might be uniformly high in the area thus preventing occupancy-impact relationships from being identified (variation across the site is needed for this approach to work well, as it relies on a density gradient being apparent between sub-areas). In addition, the SAC contains habitats that are in fact much more widely distributed in the local area – it seemed logical to place any survey results from the SAC in the context of this wider area of land. If they were similar then in fact a much larger area of land was being 'damaged' and if they were lower then knowledge of this would presumably be useful context for any discussion on the future of the designated sites. Therefore, a decision had to be made about how extensively to survey taking into account that a fixed sample size of 200 transects was available due to budgets – moreover, it was important that the survey results should not be overly-diluted spatially. An appropriate focus was considered to be on open range habitats above the natural tree-line as these habitats are what the SAC is mainly designated for and also count data made it clear that a majority of deer from the Section 7 area spent much of their time in this area in summer. The boundary of the survey was thus determined (Map 8) by including all land above 600m altitude, but with exceptions being:

a) Caenlochan Glen – the SAC includes some land lower than 600m in this area, and it was the subject of the original Section 7 agreement, thus SNH asked for it to be included. Similarly, some of the land in Glen Callater SSSI was included on this basis.

b) Balmoral – Bachnagairn: a subjective decision had to be made about where to 'draw the line' in this area given the plateau extends at a high elevation across onto Broad Cairn. Broadly, the selected boundary line follows watersheds.

85. A sampling grid of 200 transect points was employed across the survey area, with ~ 510m intervals between points (Map 8). The start point for the grid was generated at random on ArcMap.

86. Surveyors navigated to each point using hand-held GPS units for the first time in June 2018[35]. Start locations were micro-sited so that where possible they began in the vicinity of a permanent and easily identifiable feature (e.g. boulder, grass mound, stream junction, head of a flush etc) – this would help with future relocation – and images were taken to help fix the location in cases where markers disappeared in time.

87. Surveyors set up a line transect of 80m length and 1m width at each point. Pre-determined bearings for each transect were selected at random on Microsoft Excel, to preclude bias in transect orientation arising. The only exception was that where possible the bearing was micro-varied so that it passed over a permanent feature (e.g. head of a peat hagg, small boulder on the horizon etc)

[35] The exception to this was Glen Prosen Estate which did not allow access until late July 2018, and which also was surveyed last later in the autumn than other estates as a consequence.

on the line so that, even with the future loss of marking, its general route would be identifiable.

88. Transects were laid out with a small wooden stake (inserted deeply into the soil, typically with 10-15cm proud of the ground) and every 10m with small sections of bamboo cane inserted deeply and angled to minimise visibility - these elements were left in place for the duration of the study. A line of Walktax thread was strung between the canes, in effect creating a centreline, to help with counting work.

OIA: Deer Population Assessment

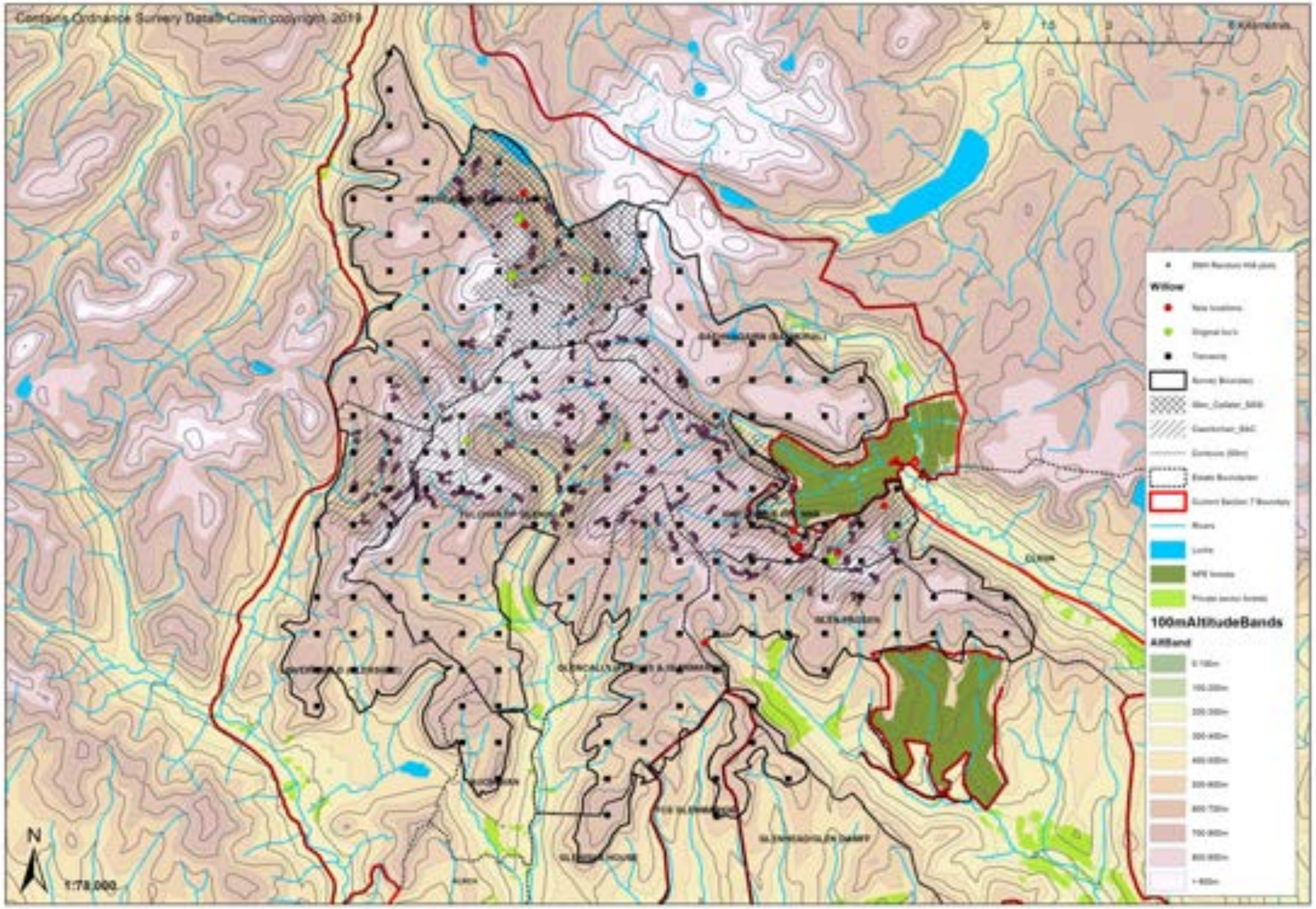
89. An overview of how faecal pellet group counts (FPG) or dung counts is provided in Appendix 1 for readers unfamiliar with the techniques.

90. All faecal pellet groups of deer/sheep[36] on each transect were mapped out, measured and marked (with a wooden lollystick, deeply inserted) on the June visit. Each side of the line was sampled separately to ensure accuracy of count. The state of decay of each group, and its morphology (spread of pellets, pile of pellets, string of pellets, coagulation) were recorded to help with later identification. Upon leaving, the thread line was removed. Transects were then left to accumulate new groups of deer/sheep dung for a period.

91. All transects were re-visited to assess faecal pellet group accumulation in September or October 2018. The last transects visited were in Glen Prosen, as the initial visit had been undertaken late. On the return visit, all new pellet groups (no marker[37]) were counted and mapped out plus the state of old groups was assessed (still present or decayed). Thread lines were again removed.

92. The total number of newly-accumulated pellet groups was calculated for each transect, and then a rate of accumulation per m^2 per day of accumulation time was calculated (this data is termed the Faecal Accumulation Rate or FAR). Values were then scaled up to pellet groups accumulated per km^2 per day for further analysis.

[36] In our experience it is not possible to distinguish unequivocally between these in all field conditions.
[37] Unless the original data recording form indicated that a similar group had previously been present at that location in which case it was assumed to be ‘original’ and thus not recorded as accumulation.



Map 8 The locations at which data were gathered during the 2018 study at Caenlochan

93. The FAR data were used to estimate the abundance of deer using the survey area, over the period that pellet groups accumulated, as follows:

a) All faecal pellet groups were assumed to be red deer or sheep to simplify the analysis in the first instance (occasional roe deer are known to be present, and were seen, but their contribution to overall measured occupancy was assumed to be negligible given the altitude of the study area[38]).

b) Checks were undertaken to ensure that all pellet groups deposited on the transects after the date of the first visit (June/July) were still likely to be present at the time of the second visit in Sept/Oct (i.e. had not decomposed, due to weathering or dung beetle activity etc). Of 59 freshly-defecated groups marked in June 2018, 4 (6.8%) had completely decomposed by the second visit. Given that the frequency of complete decomposition of deposited groups would decline as the accumulation period progressed towards the second visit, the measured rate could not apply to the entire population of new groups entering the system as with passage of time the likelihood of accumulating new groups decaying completely before the second visit would tail off quickly . We assumed that the actual rate affecting the entire cohort of accumulating groups would be therefore be much lower (we used ¼ of the measured rate to be conservative) and assumed no more than 1.7% of deposited groups in total may have disappeared. For the purpose of calculating deer abundance, the measured rate for the site was therefore inflated upwards to adjust for this bias.

c) Deer were known to have been culled during the period of accumulation, and therefore some of the dung groups counted would relate to deer now dead (‘ghost groups’). The only deer being culled were males, and as active culling operations had not been completed at the time of survey completion we employed the stag cull record from 2017-18 to estimate an appropriate adjustment. To be conservative, we assumed the entire stag cull (529) had been taken from within the survey area and all stags had been culled within the survey period. In reality, these assumptions were likely to be overly-conservative. However, as we had no record of when deer were shot we assumed they were culled evenly. In reality, more were probably shot later in the summer meaning we might be underestimating the adjustment necessary. Overall, we assumed the two biases might broadly cancel each other out. The adjustment was made by calculating the number of groups defecated by each culled deer for each day they were alive during the study then deducting the summed total from the overall estimate of pellet groups accumulated across the entire site for the entire accumulation period. The adjustment resulted in a ~5% decrease in measured accumulation.

d) An upwards adjustment should ideally have been made to allow for the presence of red deer calves at a time when they were mainly feeding on milk, and when their faecal deposits were either eaten by their mother (reported

[38] And given Putman’s 2014 DMP for the area makes several mentions of mainly being a minor activity only.

to occur as an anti-predation measure) or decomposed very quickly due to their texture. However, the size of such an adjustment is difficult to estimate accurately hence it was not addressed thus leaving the estimate conservative.

e) The variance and standard error of the pellet group accumulation rate estimate was calculated as per Forestry Commission Bulletin 128. In some circumstances, we employ an alternative approach to variance calculation for systematically-sampled transects (see Appendix 2) but for this project, at this stage, we chose not to[39]. The variance associated with pellet group defecation rate was also incorporated as per Bulletin 128. The defecation rate employed in the analysis was an average of 20 pellet groups per day (estimated SE of +/- 2.5 groups) - this is a rate somewhat below the levels for summer and early autumn previously reported in the literature for Scottish conditions[40]. The reason for reducing rate from those reported is that in our experience of working with the technique over 2 decades we believe, if anything, the rates in the literature under-estimate abundance. This conclusion has been arrived after intense culling was undertaken in many of our sampled forests, following which results indicated there were more deer present than estimated. Moreover, a formal trial (unpublished) in Galloway Forest Park on captive red deer on natural feed in winter time indicated that the over-winter rate in this case was ~ 12-13 groups per day and not the ~ 20 groups per day often suggested. Being cautious in this case, we chose to use a reduced rate to ensure deer density was not grossly under-estimated.

f) A final adjustment was made to the deer abundance estimate because we knew that sheep were present on the study site, and yet it is not possible to unequivocally distinguish deer and sheep faecal pellet groups from each other in field conditions. Instead, an estimate of the number of sheep using the site was made (see next section) and the number was then deducted from the total abundance estimated, given this number had been derived from a count of deer and sheep pellet groups combined.

94. Dung count survey results were also mapped using ArcMap, to illustrate spatial variations in the FAR between the different transects surveyed. A Natural Neighbours interpolation was run on ArcMap, using FAR data, which helped to identify areas where the occupancy level was generally below average, average or higher than average.

95. The mapping outputs were then used to identify zones for subsequent analysis of impact survey data ('Occupancy-Impact Analysis' - OIA), the aim being to sub-divide the grid of 200 points into distinct geographic zones within which

[39] The calculation is markedly more time-consuming, and typically – if at all – yields a somewhat smaller variance estimate (and hence standard error). We tend to use this method when analysing monitoring data (i.e. changes over time) and only if sufficiently concerned about employing the more conservative standard approach (which tends to over-estimate variance) which involves treating the systematic sample as a random sample for ease. When undertaking dozens of such calculations the time involved in onerous – in the case of this baseline study it would have involved hundreds of such calculations if including the work on impacts also.

[40] http://nora.nerc.ac.uk/id/eprint/507894/1/ITE_AR_83.pdf

occupancy level varied markedly. By quantifying the level of occupancy in each zone and comparing it to the level of impact measured, it is often possible to gain a useful insight into how impacts vary with occupancy level – this data can be helpful if trying to establish how much the level of occupancy on a site might need to be reduced (e.g. by culling) to obtain a desired impact level and thus, later on, deliver a desired habitat end state[41]. In the end, the selection of final analysis zones was done by dividing the site into two groups of estates – this was for a combination of reasons:

a) The higher concentrations of deer/sheep pellet groups mainly appeared to be on Invercauld Callater, Invercauld Glenshee, Glen Prosen and Clova (south); the other estates tended to have variable but generally lower levels of accumulation on average. There were hotspots in other places, but they tended to be isolated examples (e.g. one or two high occupancy transects) as opposed to larger aggregations of high occupancy transects.

b) When the three estates were merged into one analysis zone ('Higher' occupancy level) and the remainder into another ('Lower' occupancy level) (Map 8) it was apparent that a number of additional factors favoured use of this final stratification[42] for the exploratory analysis of occupancy-impact patterns:

   i) Both areas were equally large in extent, and each contained approximately half of the total samples available. This ensured a degree of statistical power, as well as balance, in the analysis which can often be difficult to obtain in a *post-hoc* design[43].

   ii) The areas each contained broadly similar breakdowns of general habitat type, certainly as balanced as could be expected given that the study is 'observational' in nature as opposed to being a manipulative experiment of deliberate design. Each of the habitats was extensive, and there was typically some degree of spatial interspersion apparent also (albeit not even). These factors would help ensure a more robust exploratory analysis could be undertaken.

[41] Clearly, this information would be better obtained from a manipulative experiment in which mammal occupancy is deliberately varied over time and the site monitored before and after. Ideally, such knowledge would in fact be obtained from a designed experiment involving controlled trials. However, neither option is available at present for this site as (i) habitat monitoring only began in 2008 after the major density reduction had been implemented from 2005-07 and (ii) SNH is unlikely to have the funds currently to undertake a formal trial given the state of current budgets, and such a design was not possible in the time available for this project.

[42] A previous stratification was employed at an earlier stage in the project – and presented to the estates and SNH at early meetings - which employed 3 zones (Lower, Intermediate and Higher occupancy) and which had several smaller areas combined for each. Upon more detailed scrutiny, it was determined that the two zone approach was more robust because of the benefits of larger sample size and more even habitat extent and distribution.

[43] It was not possible to design this analysis *a priori* – clearly the preferable approach - as none of the critical site information on occupancy available now was available at that stage.

iii) The core areas of sheep activity recorded in the survey area tended, in general, to be in the 'Higher' zones estates. This was also the case for hare activity in general. Whilst not essential, this was potentially of use when considering the relative impacts of the different grazing species present.

OIA: sheep, hare and grouse

96. When on transects undertaking survey work and on walked routes in between, records were made on maps of where sheep were seen and how many. This was done both on the first and the second visit to sites. Maximum likely numbers of sheep present on the study site over the summer were then estimated from the composite data set. This data was used to adjust downwards the deer abundance estimate (see preceding section). Records of sheep signs (wool, scrapes, characteristically large piles of dung pellets) were also recorded by surveyors on and off transects during both survey visits.

97. On transects, signs of hare were formally quantified on a 1x1m area assessed at the 10, 20, 30, 40, 50, 60, 70 and 80m points on each transect. The number of hard faecal pellets present was recorded on the first visit (June/July) and the second visit (Sept/Oct). Pellets were not cleared off after the first visit, for budgetary reasons[44], so the second visit result was in effect an integration of losses and gains from the first visit.

98. Grouse faecal pellets were counted on each quadrat on the second visit to transects only, in case this information was of use in future analysis.

99. Zones where sheep were active on the site were identified by examining the totality of available data on their direct presence and indirect signs. It appeared from the evidence available that sheep tended, in the main, to occupy specific parts of the survey site only (Map 9). Some were scattered throughout the wider area but they seemed to be few in number. A distribution was drawn on ArcMap, in an attempt to identify 'Core sheep zones'. The approach employed to identify these was not ideal as it may have missed local areas where sheep are active (e.g. between transects), but in the circumstances it was the best approach we could deliver.

[44] The budget for the project was very limited relative to the scope of work issued at tender stage. The contractor used their best endeavours to maximise the amount of data that could be gathered on site, through changes to design and through design efficiencies, but in essence time was limited. Whilst clearance plots would have been the preferred method to use for hare accumulation this approach would have taken far longer to implement. The reasons for this include that (i) we counted ~ 5,000 hare pellets on the first visit to site, which would all need to have been cleared by hand otherwise, (ii) a buffer around each plot would also need to have been cleared at the same time, to ensure old and new pellets were not confused at the time of the second visit (a further 5,000 – 10,000 pellets), (iii) each plot would have needed to be more robustly marked for relocation on the second visit, (iv) on the second visit to site more time would have been needed to re-instate marking and (v) a parallel trail would have been needed to assess the rate of 'intermediate decomposition' of pellets between V1 and V2.

100. Hare distribution was assessed with more certainty than the sheep, as their faecal pellets were easily distinguished from deer/sheep. Their distribution was overlain on the sheep zones on ArcMap for comparison, and zones were identified in which the majority of hare activity was observed. This involved interpolating the hare dung density data (from Visit 2 to site, as it best reflected summer activity) and then identifying zones where activity signs were above average ('Core hare zones').

101. SNH and owners were keen, at the outset of the project, to understand more about the potential contributions of deer, sheep and hare to the pattern and level of impacts measured on site. Given the project budget, and timeline, this was a challenging task and so all we could do was employ our best endeavours. We chose, in the end, to use the dung count data[45] as the basis for the main comparison for a number of reasons:

a) The total density of the dung standing crop of deer/sheep[46], hare and grouse was all measured at the same time on site in autumn 2018 on the second visit to site. This dung standing crop reflected a period of accumulation of many months, and hence was a long term measure of activity.

b) The amount of faecal material was assumed, in some way, to reflect the dry matter intake of each species group on site and hence, in some way, should reflect the relative contribution of each in relation to impacts, given all groups share a fairly similar diet (see Appendix 4)[47].

[45] It would have been preferable to undertake a number of parallel studies to ensure a more robust approach. This would have included: (i) obtaining proper local weights of the faecal pellets of each species from the site in question, (ii) undertaking some controlled trials with live animals to investigate differences in the way biomass is consumed, utilised and defecated, (iii) counting hare directly and (iv) obtaining parallel data on the impact of hares versus deer, by direct field measurement, for comparison. Budgetary restrictions played the largest role in determining the final approach (i.e. to use dung dry weight). Counting hare directly would have been very time-consuming, and also likely to have produced erroneous results (biases arising from their detectability – being small and relatively cryptic – as well as due to their daily activity patterns etc). There are technical issues associated with trying to measure the impact of each species directly in field conditions. One key issue is that summer impacts will tend to be more focused on graminoids – the leaves of many species are very fine, meaning that incredibly close field observation would be needed to assess the nature of impacts on shoot tips. It is often reported that hare and deer impacts can be distinguished between by whether shoots are 'torn' or 'snipped'. However in our experience, even working with planted trees which have larger shoot diameters than the plants at Caenlochan, the differences are not always as clear cut as is reported in the literature. As importantly, much of this work was undertaken in very challenging weather conditions - on exposed hilltops at high altitude -where surveyors were already static for long periods gathering other data sets. In addition, it is entirely possible that deer may utilise the same plant shoots after hares have utilised them, and *vice versa*. The extent to which this would bias a field survey is not clear but would certainly have to be investigated in controlled conditions before being certain of the best approach to use in the field.

[46] Whilst the main data set used in the report is the FAR, it was also possible to calculate a 'standing crop' of dung present on the second visit to site. The calculation was 'total groups present on V1 - original groups decayed + new groups accumulated'. The calculation was made possible by us recording the number and fate of original groups as well as the number of new groups arriving.

[47] Clearly though, there are reasons why this assumption will not be entirely robust. For example, the digestive systems of deer/sheep and hare are different.

c) As faecal pellets were actually counted for hare and grouse, and the number could be estimated for deer/sheep given knowledge of the number of groups counted, there was the possibility to estimate the dry weight (kg or tonnes) of dung of each species present on site. This was done from information available in the scientific literature[48] which described the typical average dry weight (g) of faecal pellets of each species in Scottish conditions.

102. The approach, which relied on several assumptions, can never be expected to be entirely accurate but was nevertheless considered in the circumstances to be a useful exercise to undertake:

a) The mean density of faecal pellets of hare and of grouse per transect (with standard error) was calculated for the Higher and for the Lower zone, as well as for the study area overall. Data on the mean dry weight (g) of a typical pellet of each animal was used to estimate the total weight of dung of each species present.

b) A similar process for deer and sheep was employed, but two precursor steps were also required:

i) The number of faecal pellets had first to be estimated by assuming the average number present per defecation event (n=75 average). The data from Welch (1982), obtained in experimental conditions, matched fairly closely that gathered during the research undertaken for FC Bulletin 128 on the number of individual pellets present in freshly-defected pellet groups in natural conditions. The mean count of pellets in a group for sheep, which was lower than that reported for red deer (86) was employed to ensure the analysis was conservative in favour of mountain hare (and grouse) given the importance of ascertaining their likely impact on site condition in comparison with deer/sheep.

ii) The % of total pellets counted which was attributable to sheep and to deer had to be estimated. This was done iteratively. Firstly, we used the live sheep count data (total of 650 sheep counted on average each visit; ~450 in the Higher zone and ~200 in the Lower zone). FAR data estimated the total number of deer/sheep present, hence in turn we estimated deer numbers by deducting estimated sheep numbers. From this, we deduced the likely % of pellet groups defecated by deer and by sheep in each analysis zone and overall.

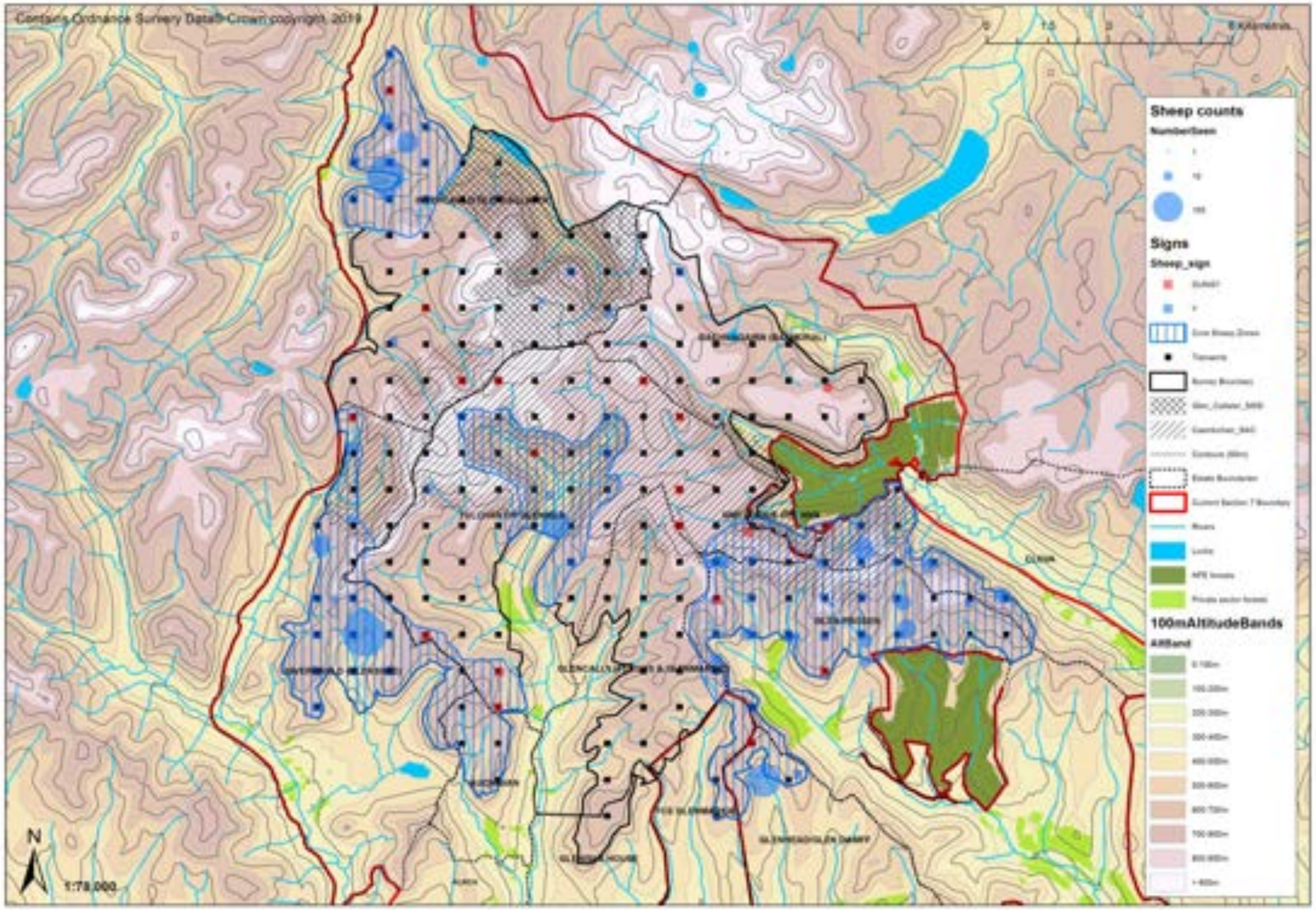
iii) Dry weight per pellet was assumed to be 0.42 g and 0.28g for deer and sheep respectively, as per Welch (1982). An estimate of the total dry weight of dung of deer and of sheep was obtained by scaling up from the transect data (with standard errors).

103. The total dry weight (kg) of dung of each species group (deer, sheep, hare and grouse) in each analysis zone, and overall, were tabulated. A measure of

---

[48] Welch (1982) Dung properties and defecation characteristics in some Scottish herbivores, with an evaluation of the dung-volume method of assessing occupance. Acta theriologica 27(15):191-212.

potential variability in the model was reflected by use of three dung density estimates for each (mean dung density, mean + 1 standard error & mean – 1 standard error). Markedly more complex analyses are possible, by incorporating variation attributable to dung pellet weight and pellet number estimates etc as per Welch (1982), but given the process was already recognised to be for broad guidance only it was not considered worthwhile to pursue further. The % contribution of each species group to the total estimated dry weight of dung present in each zone, and overall, was calculated as a potentially useful proxy for the possible contribution of each species group to the volume of material grazed on site. The outputs of this model were available to SNH and owners when later considering how each type of herbivore present might be contributing to the pattern of impacts observed on site currently, and how that might affect future management decisions for the site.



Map 9 The locations at which sheep (or their signs) were recorded during surveys, and the 'Core Sheep Zones' identified using the data.

104. A 2x1m area was assessed at the 10, 30, 50 and 70m points for the following:

a) Bog moss (*Sphagnum* spp): % cover and % of the cover that has been up-rooted, number of hoofmarks (obvious / faint).

b) Woolly-hair moss (*Racomitrium lanuginosum*): as for *Sphagnum.*

c) Dwarf willow (*Salix herbacea*): signs of trampling (Y/N), % shoots browsed (0%, 1%, 2.5%, 5%, 10%, 20% etc).

d) Lichens (*Cladonia* spp): % cover (1% increments), signs of trampling (Y/N).

e) Grass tillers: number of items uprooted (entirely, partly).

f) Other vascular plants: number of items uprooted (entirely, partly).

g) 'True grass' (combined cover of e.g. *Agrostis, Festuca, Nardus*): % leaves grazed (0%, 1%, 2.5%, 5%, 10%, 20% etc), number of flowering heads present.

h) Cottongrasses (*Eriophorum* spp): % leaves grazed (0%, 1%, 2.5%, 5%, 10%, 20% etc), number of flowering heads present.

i) Stiff sedge (*Carex bigellowii*): % leaves grazed (0%, 1%, 2.5%, 5%, 10%, 20% etc).

105. Along the entire length of the 80m transect, under the threadline, the presence and attributes of patches of bare soil were mapped (mineral or peat; patch length; % of patch actually bare; likely patch cause - vehicle, path, large mammal, frost heave etc, deer hoof marks on patch?).

106. Data were summarised on Microsoft Excel and a variety of descriptive statistics were derived (mean and standard error[49]) using the analysis zones identified from the occupancy surveys.

107. As well as stratifying the data by analysis zone (Higher and Lower occupancy) the data were split by habitat type. In order to maintain acceptable sample sizes, only four broad habitat types were employed (summit communities, peatland, heathland and grassland - derived from the wider suite of habitat types recorded on a per segment basis; some of the rarer habitat types such as flush were removed from the analysis entirely) (Map 10). The transect-specific classification was employed in preference to other available data sets (e.g. Land Cover Scotland or National Vegetation Classification) as the data were specific to the actual area being sampled.

[49] SE's were calculated by assuming samples were obtained at random, and not using the variance calculation described in Appendix 2. The chosen approach would, with all else equal, be expected to produce conservative estimates of the SE. At this stage, when examining patterns in baseline data only, this was considered a practical approach due to time constraints. In the future, if the site is ever monitored, the alternative approach could be employed should it be deemed important.

108. In order to help explore relationships between occupancy and impacts, decisions had to be made about what data to employ:

a) Only the deer/sheep FAR data were employed on the occupancy side; whilst grouse and hare are present their relative contributions (in aggregate) were established to be markedly smaller than for deer/sheep. Moreover, taking their contributions into account analytically at this exploratory stage would have involved a markedly larger amount of time being spent - the project budget precluded this, albeit options are available to do so at a later date. It is of course accepted their contribution needs to be considered in respect of any proposals for how to manage the site in the future.

b) Two types of impact data were employed in the analysis:

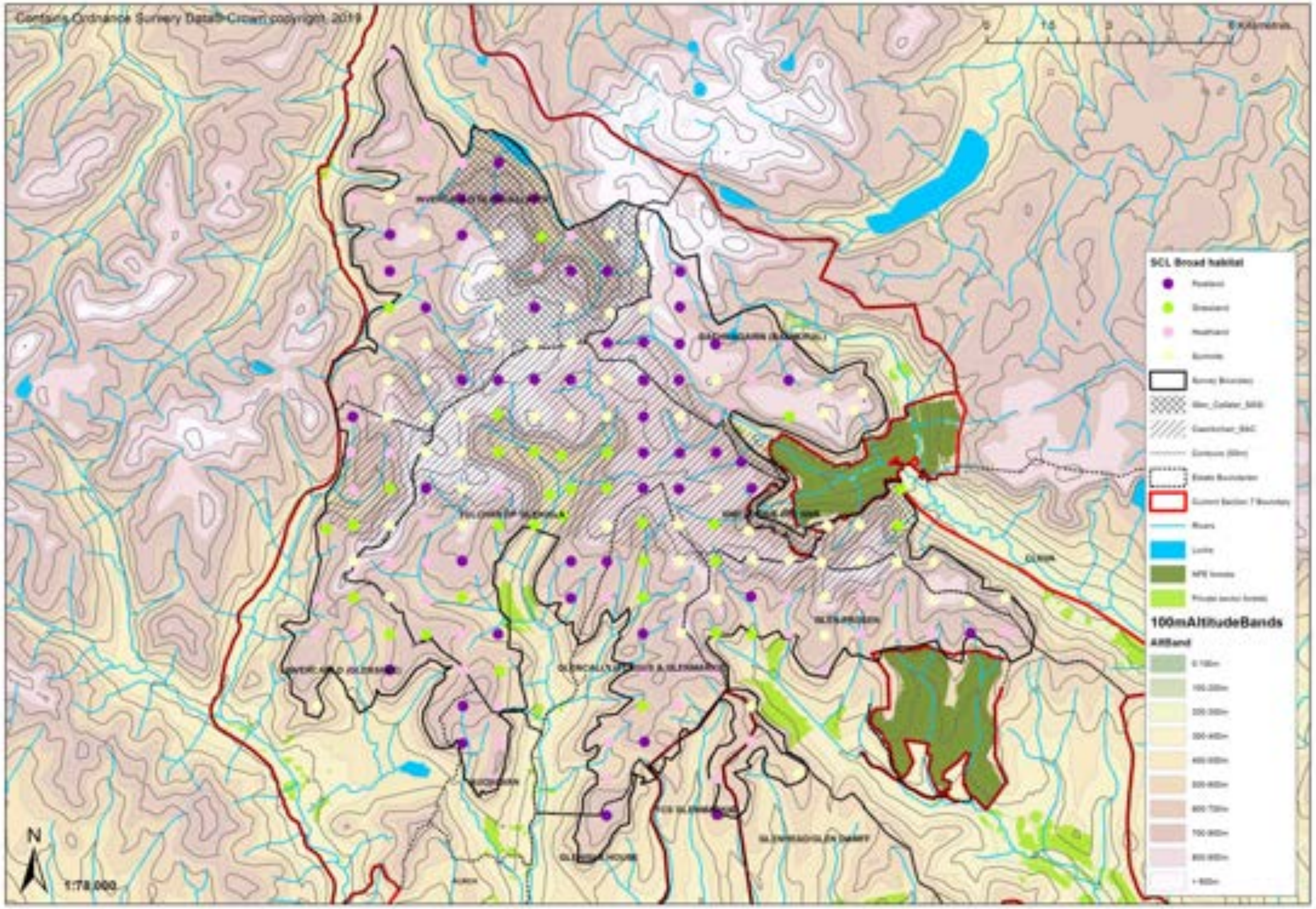
   i) The most detailed analysis involved the use of the contractor's quantitative impact survey from the transects, as this provided the widest range of variates gathered and the highest level of precision available locally (data gathered on multiple quadrats and at larger spatial scale than the single 2x2m quadrat of the SNH method).

   ii) HIA small-scale indicators were also assessed, using the single quadrats obtained on the systematic grid as these were locally matched to the occupancy data and covered the same survey extent (the original HIA baseline only covered the designated sites).

109. Data were presented in two ways:

a) The mean level of impact recorded in the Higher and Lower zones, for each of four broad habitats and overall, was presented in chart form with standard errors.

b) The relationship between occupancy level and impact level was displayed in the form of a scatter diagram. The standard errors of the occupancy and the impact data were both displayed, to help illustrate variation in the underlying data given sample sizes varied markedly and also the mean-variance relationships varied markedly. In order to help the reader examine the occupancy-impact relationships in an ecologically meaningful way, the occupancy data were converted from FAR to 'animal density' using the estimated defecation rate. However, the variance of the defecation rate was not incorporated into that of the pellet count data for this analysis. The reason for this is that the precision of the underlying FAR data is markedly higher than that of the estimated density (one source of variance not two used in the calculation) and the relationships are therefore clearer when using this data.



Map 10 The most dominant habitat type present at each of the grid-sampling locations at Caenlochan.

OIA: Detailed peatland condition assessment

110. The 80m transect also formed the basis of the detailed peatland assessment, undertaken whenever it was clear either that the transect was underlain by at least ~ 50cm of organic soil and otherwise where eroding peatland was present even if the organic horizon was shallower in places (Map 10). Data were gathered from the 0, 10, 20, 30, 40, 50, 60, 70 and 80m points, in an attempt to characterise the nature of the peatland present (extent, erosional state, specific impacts of deer etc):

a) Broad habitat type (blanket bog; eroded bog; non-bog habitats – summit heaths, grassland, flush etc) in each segment.

b) Peat depth (cm; only if bog or eroded bog present within a segment).

c) Landform (intact bog surface, peat hagg top[50], peat hagg apron, erosion gully wall, erosion gully base or bare peat flat).

d) % Bog moss (*Sphagnum)* cover (thin-branched species or thick-branched).

e) Bog water table position (visible at surface; appeared with pressure applied by the boot; no appearance even with pressure).

f) Defined deer path through the vegetation?

g) % Cover of bare peat.

h) Hoof marks visible on ground surface: Y/N.

i) Bare peat over-deepened by deer: Y/N.

j) % Bare peat recolonised with new plants (attempt made to distinguish between new plants and older plants from original mire surface).

   i) % Colonising leaves grazed.

   ii) % Colonising leaves trampled/dislodged.

111. Data were summarised on Microsoft Excel and a variety of descriptive statistics were derived (mean and standard error or SE) using the analysis zones identified from the occupancy surveys, in order to conduct exploratory analysis of the data:

a) In the first instance, data were stratified into four broad landform types for analysis as some were relatively uncommon: intact bog (I), peat hagg (H), gully walls and hagg aprons (G) and gully bases/peat flats (F).

b) The final sample size of transects where detailed bog data were gathered was relatively low, at 61. In order to ensure a sufficient sample size of transects,

---

[50] Intact bog was defined as any feature where at least 5m of intact acrotelm surface was present, where erosion if present at all was in the form of micro-erosion – features less than 0.5m deep; hagg was defined as any intact feature less than 5m in diameter.

and yet still acknowledge landform as an important variable, for an analysis of deer-related impacts in the Higher and Lower zones a second stage of analysis involved the landform data being further consolidated: broadly intact surfaces (I+H) and eroding surfaces (G+F).

SNH HERBIVORE IMPACT ASSESSMENTS & ANALYSIS

112.The Herbivore Impact Assessment (HIA) surveys undertaken at Caenlochan in 2018 were based on the methods of MacDonald et al. (1998).

113. Two pieces of work were undertaken in 2018:

a) SNH had requested at tender stage that the 2018 survey be a repeat of two original baseline surveys undertaken in 2008, which had subsequently been repeated in 2012 and 2015[51]. This survey is termed hereon in the 'repeat HIA'.

b) As a compliment to the original design, and to help provide a broader and more integrated data platform for future decision-making on site, the contractor proposed that the 200-transect sampling grid also involved HIA data gathering. In effect, this was a new baseline at much larger spatial scale based on an evenly-spread sample. This survey is termed hereon in the 'wider HIA'.

HIA: Repeat of original 2008 survey

114.The process employed during the 2008 baseline survey, and subsequent repeats in 2012 and 2015, is summarised below for sake of brevity (readers should refer to the original survey reports for a more detailed description of the methods employed).

a) The 2008 baseline survey was undertaken within three sites: the Caenlochan SAC, the Glen Callater SSSI and the Cairnwell SSSI.

i) The Caenlochan SAC baseline survey involved sampling 8 habitat types, the distribution of each having been previously mapped by SNH. The site was divided into a set of ¼ km^2 boxes on the map (termed herein 'sample squares') and some squares selected at random to facilitate field sampling of the target habitats. The habitats sampled, and the final number of sample squares employed for sampling within each in 2008, were as follows: blanket bog (n=35 sample squares), montane acid grasslands (n=15), alpine and subalpine heaths (n=32), dry heaths (n=21), flushes (n=18), species-rich grasslands (n=12) and mountain willow scrub (n=4). When a habitat was present within a sample square, up to 5 quadrats of 2x2m were to be sampled (with at least 50m between quadrats). In reality, sample sizes of quadrats varied from 1 – 5, for each habitat, due

[51] Haycock and Jay Associates Ltd. 2015. Repeat Assessment of Herbivore Impacts at the Caenlochan Special Area of Conservation, Glen Callater and Cairnwell Sites of Special Scientific Interest. Scottish Natural Heritage Commissioned Report.

to the distribution and extent of habitats present locally. A total of ~ 680 quadrats were sampled from a total of 154 sample squares in the end.

ii) The Callater SSSI baseline survey employed a similar approach. Four habitats were sampled: flushes (n= 13 sample squares), species-rich grasslands (n=9), mountain willow scrub (n=3) and tall herbs (n=2). A total of 56 quadrats were sampled from a total of 27 sample squares.

iii) The Cairnwell SSSI survey involved sampling 2 habitat types (alpine calcareous grassland and flush) and employed 15 sample plots spread across 4 sample squares.

b) In 2012, the same sampling locations were re-visited and the survey was repeated albeit fewer quadrats were assessed because of various issues encountered on site (e.g. too dangerous to re-access, habitat not present probably due to an error in grid reference recording etc).

c) In 2015, the same sampling locations were re-visited as in 2012. Again, however, some problems were experienced which meant some quadrats were not re-sampled. In 2015, SNH asked for an additional baseline survey to be completed on the blanket bog on the Glen Callater SSSI. A total of 13 sample squares were employed in the assessment, with a total of 62 new sample plots being recorded.

115.The 2018 repeat HIA survey (Map 8) involved a repeat of the 2015 field survey specification but with the following changes and exceptions:

a) SNH confirmed the following did not need to be re-assessed: all plots on the Cairnwell SSSI, the blanket bog plots on Callater SSSI[52] and the tall herbs plots on the Callater SSSI.

b) By agreement with SNH at the tender stage, in order to save time and free up budget to undertake the wider HIA within the much larger study area, the sampling intensity and approach of the 2015 survey was reduced as follows:

i) The intensity of quadrat sampling within sample squares was reduced, on a per habitat basis, in cases where 4 or 5 quadrats had been originally sampled on previous studies. The approach involved removing 1 or 2 quadrats systematically from the data set[53] prior to fieldwork being conducted, the result being that surveyors sampled no more than 3 original quadrats per habitat in any one square. This approach retained the number of independent sampling units (i.e. the sample squares), as this was considered to be the biggest determinant of statistical power within the original design. The Findings section of this report presents the

[52] The contractor erroneously sampled the Callater bog quadrat hence the report does include them for sake of completeness. Given SNH said at tender stage that blanket bog was a major focus for them, it was assumed this extra sampling was of benefit.

[53] The de-selection process for a 5 quadrat square, for example, involved the omission of quadrat numbers 2 and 4 (leaving 1, 3 and 5).

results of an analysis undertaken to illustrate the effect on habitat target assessment of reducing quadrat number in some squares.

ii) Small-scale indicators, quantitative indicators and photos were taken at each quadrat as per 2015. However, to save time it was agreed with SNH that 'trend indicators' were not assessed because the survey would by then have already been repeated 4 times over 10 years. The 'small-scale indicators' should provide an acceptable, and arguably more reliable, measure[54] of trends in impact levels over the previous decade anyway.

c) An unplanned exception to the 2018 repeat HIA survey arose as a result of a data handling error by the contractor during handover of the previous files from SNH. A large number of spreadsheets, in various formats and states of post-processing, was supplied to the contractor prior to the HIA and SCM survey work beginning. They had then to extract the data from the necessary files in order to create a combined GPS 'upload file' that surveyors would use on site to identify the myriad locations to visit. In preparing these files, a somewhat complex process, a significant part of the Montane Acid Grassland data set for Caenlochan was left un-extracted[55]. The result was that only 17/35 samples squares were included in the Montane Acid Grassland re-survey (160 original quadrats would have been reduced to 109 under the proposed sampling scheme for 2018; in fact, only 51 were extracted and reduced to 37 as part of the degrade process). This error only came to light at the analysis stage, by which time it was too late to remedy the mistake in the field due to weather issues. The potential impact of this error is considered in the Findings.

116. Analysis of the repeat HIA survey data, for small-scale indicators, involved calculation in the first instance of the mean, median and modal impact class for small-scale grazing indicators, for trampling indicators and for all indicators combined. This analysis was undertaken in order to explore how the data behaves when analysed in different ways, in case marked differences arose (see Findings). The median was employed in the final analysis because it had previously been used in 2008/2012/2015. The HIA analysis included the historic data sets (2008, 2012 and 2015) as well as the new data set from 2018. However, in the final analysis presented the quadrats not sampled in 2018 were stripped out of the old data sets to make the historic comparison consistent in terms of sample spread and sample size[56].

117. The current S7 control agreement includes a set of defined habitat impact targets for the site (see Table 1) based on the small-scale indicators. The

[54] The trend indicators are felt by many practitioners to be difficult to use in the field.

[55] The Excel sheet in question had two tables of data, stacked one on top of the other. One set of quadrats were assessed using Wind-Clipped Summit heath indicators and the other with modified Tussock Grassland indicators. When the extraction took place, the upper table (TG) was not extracted whereas the WCSH table was (each of the two tables had a similar header row, and only the lower was extracted).

[56] This included stripping out the Montane Acid Grassland quadrats omitted in error from the GPS uploads.

targets relate to the % of sampled plots which lie in specified impact classes – in most habitats, the target is for at least 90% of sampled squares to lie in the Low or Low-Moderate impact classes. The presentation of data in the main body of the report focuses on these targets, to enable the readers to easily assess whether the site meets the target levels set in 2013.

118. An additional set of data was available for analysis, namely the quantitative indicators gathered at the same time as the small-scale indicators in 2008, 2012, 2015 and 2018. The quantitative indicators assessment involves measuring and recording continuous data (e.g. % heather browsed, height in cm of heather) whereas the small-scale indicators record categorical data (e.g. % heather browsed: 0-33% = Low, 34-66% = Moderate and 67-100% = High). The range of quantitative data gathered over the years has varied somewhat, and the range also varies between habitat types as part of the methodology. The analysis undertaken for this project included all ranges of data available, presentation being in the form of time-series charts with means and standard errors. The data required a considerable degree of cleansing to make it useable (e.g. data had been recorded as "20-60% browsed", in which case a mid-point of 40% was assigned etc) and so should be treated with a degree of caution.

HIA: wider baseline survey of 2018

119. At each of the 200 transect sampling points within the wider survey area, surveyors were asked to assess the habitat types present and undertake sampling if one of the following habitats were present[57]:

a) Blanket bog (using the 'small-scale' indicators for blanket bog).

b) Dry heath ('dwarf shrub heath' indicators).

c) Alpine heath or montane acid grassland ('wind-clipped summit heath' indicators).

120. When surveyors arrived at each transect, they were asked to check the 10m point, 20m etc on the transect line until one of the three dominant habitat types had been located. Priority was given to blanket bog – as SNH has the greatest interest in the condition of this habitat currently – over the other habitats. In essence, if bog was located first on the line then it was sampled. If dry heath or summit communities were present then surveyors continued along the line checking for bog. If bog was present, this location was used in preference otherwise surveyors returned to the original habitat found.

[57] The aim of this assessment was to obtain data from the 3 main broad habitats present, as found on the grid, and to ensure sufficient sample sizes to enable a later analysis of HIA data trends within the analysis zones identified. For this reason, we chose not to gather data from the less common habitats. We also chose to use a limited number of small-scale indicator types (i.e. only 3 types of form) to simplify analysis.

121. At the selected point, a 2x2m quadrat was temporarily set up and small-scale indicators assessed along with SNH's quantitative indicators[58]. Photographs of the plot location and overhead view were taken along with a plot label.

122. The median impact score was adopted in analysing the small-scale indicator data, as per normal convention.

FENCELINE CONTRASTS

123. In order to help place measurements of short-term impact on upland habitats from survey work in context, aerial photography of the study site was checked (Google Earth) to identify any areas where deer appeared to have been excluded in the long-term.

124. Only one site was identified that was considered suitable, a woodland establishment scheme in Caenlochan Glen which had been deer-fenced in the 1990's (Map 8). In the period since, the fence had become porous but in general the habitat had experienced limited grazing for most of the time since erection. The altitude of the enclosure ran from 470m to 614m.

125. A transect line was set up on the western edge, centred on the deer fence. Temporary quadrats of 10x10m were sampled 30m either side of the fence at intervals (~ 30m) up the line of the fence (n=12 outside and n=11 inside).

126. On each quadrat, the estimated % overhead cover, mean height (average of 10 measures) and % shoot off-take (average of 10 measures) was recorded for heather, blaeberry and cross-leaved heath (*Erica cinerea*).

127. Descriptive statistics were derived (means and standard errors) for each data set ('inside' and 'outside') then data were charted in Excel.

AERIAL IMAGE COMPARISON

128. Several historic air images of the site from the 1940's were purchased online. One was of the woodland enclosure location in Caenlochan Glen. Others were obtained of mid-altitude locations in the Section 7 area more widely, with the aim of examining areas where heather cover might be expected to be dominant. Comparable images were obtained from Google Earth of the present day.

129. Images were georeferenced and then clipped so that we obtained images of the same areas from the time of World War 2 and from the present day to see if any obvious visual changes were apparent. It was felt that the findings of this exercise might be of some interest or relevance when considering trends in habitat condition on the site in the past and into the future.

---

[58] Gathered as part of a baseline but not presented herein for sake of brevity.

FINDINGS

DEER COUNTS, CULLS & POPULATION MODELLING

Deer counts

130. SNH's deer count data set, once extracted and cleansed, suggests that the deer population using the current Section 7 area increased in size from the 1960's to the early 2000's then declined markedly in the early years of the original Section 7 agreement (Table 3 & Figure 1). Since then, the winter and summer count data show somewhat differing trends in deer abundance over time. Winter counts suggest deer density remained stable for a considerable period with a rise being detected only in recent times (January 2018). The summer count data suggest a less steep decline with only a brief 'bottoming-out' before densities rose consistently back upwards[59]. If the modelled estimate for post-recruitment density in 2018 is accurate then the summer population may have reached a level comparable to that counted in summer 2006.

131. The density of deer on the site, if calculated conventionally using the *winter* counts divided by the entire area covered by the current Section 7, was relatively low in the 1960's and 1970's at 7 – 15 per km^2, but rose so that by the early 2000's the calculated density was 25-30 per km^2 prior to DCS involvement ramping up. The measured density, using winter counts, then appears to have declined to a low of 17-20 per km^2 from 2007 to 2016 before apparently rising again to 23-24 per km^2 in January 2018. Scaled up to allow for subsequent recruitment in June 2018, the population density across the entire Section 7 area in summer 2018 may have been 28-29 per km^2, a figure very similar to the peak densities measured in 2003 and 2006 by summer counts.

132. Of course, the robustness of assumptions around the summer 2018 calculation (e.g. all deer present in the winter staying on site all year round, winter count is an accurate reflection of longer-term resident population size etc) are of importance. The relationship between the winter and summer population of the Section 7 control area (and, more so, the high altitude plateau area containing most of the designated features) is therefore worthy of more detailed analysis. It is of particular importance if trying to understand more about where the majority of deer spend their time in the winter and summer seasons – this is because it might be expected that *local* deer densities, rather than overall deer densities, are more likely to be driving ecological processes on the ground.

133. Firstly, we consider the extent to which deer counted in winter are likely to remain resident all year-round. Table 4 and 5 show that on average the size of the counted summer populations in the current Section 7 area match the predictions of summer population size derived from winter counts inflated to

[59] Donald Fraser (SNH) recalls that just after the reduction culls of 2005-07 the estates to the east of Caenlochan began to fence out their land to focus on grouse. It was reported that deer were displaced towards Caenlochan in summer as a result. This may in part explain this difference in the trend between summer and winter counts.

allow for recruitment. The models used to undertake this calculation are somewhat crude, as we do not hold robust data confirming the extent to which the winter counts are biased by late-season culls or mortality, and the recruitment rate used for the inflation process is an average. Nevertheless, overall the evidence seems to point to the majority of deer counted in winter remaining the in area for the summer also.

134. Tables 6 and 7 indicate that deer distribution is very seasonal within the current Section 7 area. Between 60 and 80% of the counted herd appears to use the 2018 survey area – which contains much of the land > 600m - in summer whereas during the winter and spring that proportion appears to be much more variable (5-81%). On average, ~ 70% of deer counted in the Section 7 area in the summer were counted on the high ground whereas during winter counts only ~ 35% of the herd were counted on the high ground on average.

135. If deer densities are calculated across the entire range available in the Section 7 area, as is conventional, then densities since 2003 have varied between ~17 and 29 per km^2 (Table 8). However, there is strong evidence to suggest that deer distribution is uneven and varies markedly on a seasonal basis. If the winter counts are used to estimate deer density within their core winter range (i.e. all land < 700m; see Map 2) then the average winter range density since 2003 varied from ~23-39 per km^2. If the summer count data are used to calculate density within the core summer range (land > 500m), then the equivalent figures would be ~34-51 per km^2 over the same period. Clearly, not all deer counted in the winter will be in the winter range for the entire period hence the figures overstate – on average – the winter range density. This is the case for the summer data too. That said, these 'range densities' are averages – in reality, the actual count data show that much higher local densities of deer would be present in parts of the summer and winter range at any one time.

136. The extent to which deer herd at small scale within the area is also of interest, given that impacts will likely arise in part as a function of the intensity of local grazing and trampling. Herd size is also of relevance in terms of deer control, as the larger groups of deer can be harder to separate animals from to cull. Table 9 shows that over 50% of counted groups were in the size range 1-50 animals, in both seasons, and ~ 90% of counted groups were less than 200 animals in size. That said, the counts consistently show occasional larger herds to be present also.

Table 3 Overview of the cleansed deer count data set extracted from SNH records, by year and count type. Data for winter (left hand side of the table) and summer (right hand side) have been lined up so that it is possible to compare winter counts and subsequent summer counts in the same year. Density figures quoted relate to the entire deer range (total deer/total land area) as opposed to winter or summer range densities (see later table). The columns on the far right hand side show the % rise in numbers between winter and summer. Note 1: Most of the early count data contained unclassified groups, and a model was used to split these groups into young stags, hinds and calves as per the Methods. Note 2: The 2018 summer data are estimated using a population model (i.e. are not real count data) based on parameters as listed in the Methods, and were adjusted to allow for an assumed cull of 200 hinds following the completion of the count. Conditional formatting is used to draw out trends visually.

	Year	Stags	Hinds	Calves	ALL	Deer per km2	Stags	Hinds	Calves	ALL	Deer per km2	Diff'	% Diff'
		Winter					Summer					Winter -> summer	
Ground	1966	918	1,403	489	**2,810**	7.8							
Ground	1975	2,264	3,414	999	**6,677**	18.6							
Ground	1979	1,538	2,472	783	**4,793**	13.3							
Ground	1994	2,758	4,557	1,040	**8,355**	23.2							
Helicopter	2003						1,998	6,127	3,249	**11,374**	31.6		
Helicopter	2004												
Helicopter	2005	2,639	5,302	2,396	**10,337**	28.8							
Helicopter	2006	2,870	3,741	1,683	**8,294**	23.1	3,761	4,118	1,853	**9,732**	27.1	1,438	**17%**
Helicopter	2007	2,322	2,644	1,175	**6,141**	17.1	3,327	3,465	1,550	**8,342**	23.2	2,201	**36%**
Helicopter	2008	2,862	2,676	1,194	**6,732**	18.7	3,059	3,057	1,360	**7,476**	20.8	744	**11%**
Helicopter	2009	2,595	2,506	1,124	**6,225**	17.3	2,974	3,347	1,495	**7,816**	21.7	1,591	**26%**
Helicopter	2010						2,496	3,127	1,381	**7,004**	19.5		
Helicopter	2011	2,268	2,980	1,332	**6,580**	18.3	2,858	3,379	1,520	**7,757**	21.6	1,177	**18%**
Helicopter	2012	2,803	2,474	1,082	**6,359**	17.7	2,826	4,208	1,560	**8,594**	23.9	2,235	**35%**
Helicopter	2013						2,826	4,352	1,567	**8,745**	24.3		
Helicopter	2014												
Helicopter	2015												
Helicopter	2016	2,415	3,188	1,053	**6,656**	18.5							
Helicopter	2017												
Helicopter	2018	2,983	3,984	1,473	**8,440**	23.5	*3,720*	*4,521*	*2,034*	*10,275*	*28.6*	*1,835*	*22%*

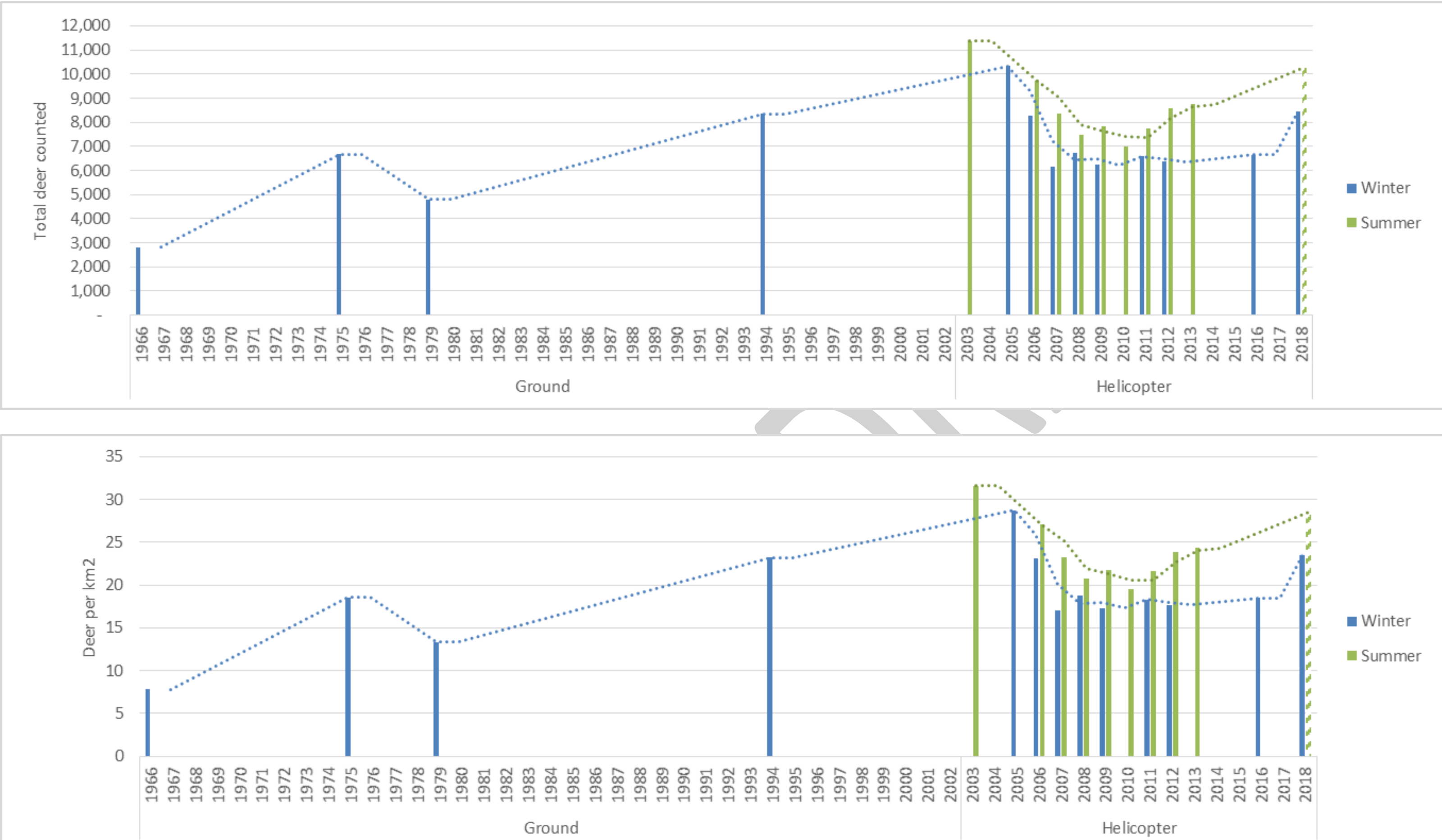


Figure 1 Compiled results from SNH deer counts (upper chart) and deer densities (lower) from within the current Section 7 Caenlochan Control Area. Count data have been omitted where they appeared not to cover all (or the vast majority) of the area in question (see Methods). Data prior to 2000 are assumed to be ground counts, and data after this date helicopter counts. The dashed lines (blue and green) are 2-year moving averages of the winter and summer count data, used as a way to identify broad underlying trends. The 2018 'summer count' was estimated by modelling; all other summer data are actual.

Table 4 Winter helicopter count data presented for the sub-set of years in which a summer helicopter count was also conducted. Winter count data are inflated up to predict the likely size of the summer population, under the assumption that no deer died after the winter count and that all deer counted in the winter remained resident the following summer. The difference between predicted summer count and actual summer count are shown. The model to inflate winter counts assumes 45 calves-at-foot, and a 1:1 birth sex ratio. Conditional formatting is used to draw out trends visually.

Year	Winter count	Actual summer count	*Predicted summer count*	Diff: Actual vs Predict
2003		11,374		
2004				
2005	10,337			
2006	8,294	9,732	*10,356*	- 624
2007	6,141	8,342	*7,595*	747
2008	6,732	7,476	*8,205*	- 729
2009	6,225	7,816	*7,606*	210
2010		7,004		
2011	6,580	7,757	*8,221*	- 464
2012	6,359	8,594	*7,716*	878
2013		8,745		
2014				
2015				
2016	6,656			
2017				
2018	8,440		*10,275*	
Mean Diff'				**3**

Table 5 The breakdown of the model presented in Table 3, showing predicted vs actual counted summer populations of stags, hinds and calves. Note that the data are derived using the model to allocate unclassified animals into three classes (young stags, hinds and calves). Conditional formatting is used to draw out trends visually.

Year	Stags expected: winter count	Stags actual: summer count	Diff: Act vs Exp	Hinds expected: winter count	Hinds actual: summer count	Diff: Act vs Exp	Calves expected: winter count	Calves actual: summer count	Diff: Act vs Exp
2003									
2004									
2005									
2006	3,712	3,761	1%	4,583	4,118	-11%	2,062	1,853	-11%
2007	2,910	3,327	13%	3,232	3,465	7%	1,454	1,550	6%
2008	3,459	3,059	-13%	3,273	3,057	-7%	1,473	1,360	-8%
2009	3,157	2,974	-6%	3,068	3,347	8%	1,381	1,495	8%
2010									
2011	2,934	2,858	-3%	3,646	3,379	-8%	1,641	1,520	-8%
2012	3,344	2,826	-18%	3,015	4,208	28%	1,357	1,560	13%
2013									
2014									
2015									
2016									
2017									
2018									
Mean	**3,253**	**3,134**	**-4%**	**3,469**	**3,596**	**4%**	**1,561**	**1,556**	**0%**

Table 6 Distribution of deer when counted in winter and summer by helicopter in the current Section 7 area, based on all cleansed data sets combined. Conditional formatting is used to draw out trends visually.

Altitude band	% Stags counted	% Hinds counted	% Calves counted	% ALL counted	% Stags counted	% Hinds counted	% Calves counted	% ALL counted
	Summer				Winter			
1. < 401m	2%	4%	5%	**3%**	6%	4%	4%	**5%**
2. 401-500m	11%	8%	8%	**9%**	30%	32%	32%	**31%**
3. 501-600m	18%	18%	18%	**18%**	37%	30%	29%	**32%**
4. 601-700m	27%	30%	30%	**29%**	19%	25%	25%	**23%**
5. 701-800m	17%	20%	19%	**19%**	5%	6%	6%	**6%**
6. 801-900m	19%	17%	17%	**18%**	2%	4%	4%	**3%**
7. > 900m	5%	3%	3%	**4%**	0%	0%	0%	**0%**
ALL	100%	100%	100%	100%	100%	100%	100%	100%

Table 7 % Deer counted each year by helicopter during summer and winter counts that were inside the study area (i.e. containing most of the land > 600m altitude in the Section 7 area). Conditional formatting is used to draw out trends visually.

Season	Year	% Counted in survey area: stags?	% Counted in survey area: hinds?	% Counted in survey area: calves?	% Counted in survey area: ALL?
Summer	2006	59%	79%	79%	71%
Summer	2007	78%	78%	78%	78%
Summer	2008	78%	71%	72%	74%
Summer	2009	41%	64%	64%	55%
Summer	2010	79%	74%	75%	76%
Summer	2011	78%	85%	86%	83%
Summer	2012	72%	78%	78%	76%
Summer	2013	63%	63%	57%	62%
Winter	2005	9%	12%	12%	12%
Winter	2006	11%	23%	23%	19%
Winter	2007	63%	88%	89%	81%
Winter	2007	11%	41%	41%	32%
Winter	2007	27%	52%	52%	43%
Winter	2008	35%	46%	47%	42%
Winter	2009	31%	59%	60%	48%
Winter	2010	9%	16%	16%	13%
Winter	2011	36%	66%	67%	56%
Winter	2012	34%	71%	72%	55%
Winter	2016	5%	5%	5%	5%
Mean summer	ALL	68%	74%	74%	72%
Mean winter	ALL	25%	41%	42%	36%
Mean ALL	ALL	**46%**	**56%**	**57%**	**53%**

Table 8 Deer density as calculated from helicopter count data using (i) winter count data divided into the entire range, (ii) winter data divided into the core winter range only (land < 700m) and (iii) using summer count data divided into the core summer range only (land > 500m). Not all deer will be present in the core winter and core summer range on any one day, so the calculated 'range densities' will lie at the extreme upper end of what might be expected. Conditional formatting is used to draw out trends visually.

Year	Winter count	Summer count	Entire range (ha)	Main winter range (land < 700m) (ha)	Main summer range (land > 500m) (ha)	Density / km2: winter count & entire range	Density / km2: winter count & winter range	Density / km2: summer count & summer range
2003		11,374	35,950	26,693	22,300			51.0
2004			35,950	26,693	22,300			
2005	10,337		35,950	26,693	22,300	28.8	38.7	
2006	8,294	9,732	35,950	26,693	22,300	23.1	31.1	43.6
2007	6,141	8,342	35,950	26,693	22,300	17.1	23.0	37.4
2008	6,732	7,476	35,950	26,693	22,300	18.7	25.2	33.5
2009	6,225	7,816	35,950	26,693	22,300	17.3	23.3	35.0
2010		7,004	35,950	26,693	22,300			31.4
2011	6,580	7,757	35,950	26,693	22,300	18.3	24.7	34.8
2012	6,359	8,594	35,950	26,693	22,300	17.7	23.8	38.5
2013		8,745	35,950	26,693	22,300			39.2
2014			35,950	26,693	22,300			
2015			35,950	26,693	22,300			
2016	6,656		35,950	26,693	22,300	18.5	24.9	
2017			35,950	26,693	22,300			
2018	8,440	*10,275*	35,950	26,693	22,300	23.5	31.6	46.1
Mean Diff'			35,950	26,693	22,300			

Table 9 Frequency distribution of the size of deer groups counted by helicopter during winter and summer counts. Conditional formatting is used to draw out trends visually.

Deer group size	No. groups counted		% Counted groups	
	Winter	Summer	Winter	Summer
1-50	605	388	61.0%	54.0%
51-100	171	131	17.3%	18.2%
101-200	134	115	13.5%	16.0%
201-300	39	43	3.9%	6.0%
301-400	18	14	1.8%	1.9%
401-500	10	10	1.0%	1.4%
501-750	10	13	1.0%	1.8%
751-1000	4	4	0.4%	0.6%
> 1000	0	1	0.0%	0.1%
All	991	719	100.0%	100.0%

Deer culls & other parameters affecting population dynamics

137. The pattern of deer culling over the period 2000-2018, as evidenced by SNH records, indicates that the total cull from the current Section 7 Control Area averaged ~ 2,000 animals per year (~ 5.5 - 6.0 per km^2) in the lead up to DCS involvement (Figure 2). Reported culls then rose to a peak of ~ 4,600 in 2005-06 (~ 12.8 per km^2) before declining rapidly in successive seasons to a low point of 1,192 in the 2011-12 season (~ 3.3 per km^2). Culls then averaged ~ 1,500 per annum (~ 4.0 - 4.5 per km^2) until 2016-17 when an increase back towards ~ 2,000 was apparent for two seasons in a row. From the start of 2004-05, until March 2018, a total of 30,190 red deer were culled (~ 9500 stags, 14,900 hinds and the balance calves).

138. Formal records have not yet all been submitted to SNH, but the DMG's involved in the current Section 7 reported that a total of 3,045 deer (~ 8.5 per km^2) were culled in the 2018-19 season (599 stags, 1902 hinds and 544 calves). This compares with typical hind culls of 500 - 1,100, and typical stag culls of 400-450, in recent years.

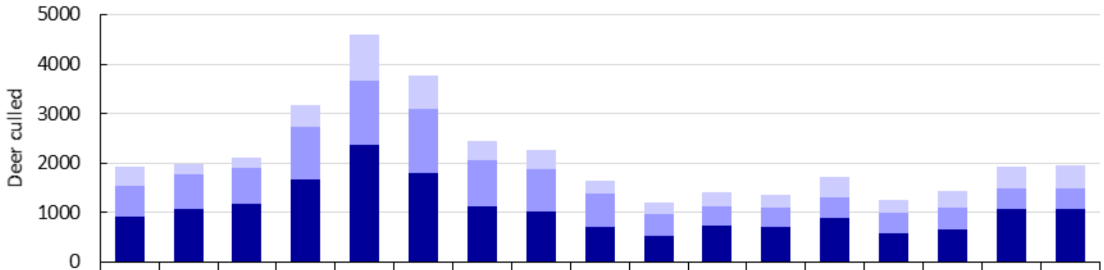
139. Culling intensity has varied markedly over time, but also varies markedly between the estates in the current Section 7 Control Area (Figure 3). Variation between estates is likely to be due to a wide range of factors which cannot easily be disentangled such as: number of stalkers available and number of days actively shooting, inherent attractiveness of the ground to deer in different weather conditions, deer numbers present 'in season' etc. Also, some properties were not part of the original Section 7 agreement, such as Clova and Glenhead/Glendamff, hence culls may have been less intensive early in the records period.

140. Recruitment rate data for modelling, when we work on the National Forest Estate (NFE) is often obtained by assessing the % of calves culled 'at foot' of hinds during the season. This approach is used because direct counts of deer cannot be undertaken in the concealing cover of a woodland. That said, the estimates of woodland recruitment from cull records are considered broadly reliable as the intensity of the cull is normally relatively high and culling is broadly unselective. The level in the Caenlochan cull records appears typically to vary between 35 and 45% but in recent years has averaged ~ 44%. For comparison, woodlands local to the Section 7 area show a noticeably higher rate (~ 55% on average). This is commonly observed across Scotland, and tends to arise through a combination of factors including better shelter and better forage alongside the fact that woodland populations are typically culled more intensively– to protect forest crops – hence their densities are normally lower relative to carrying capacity.

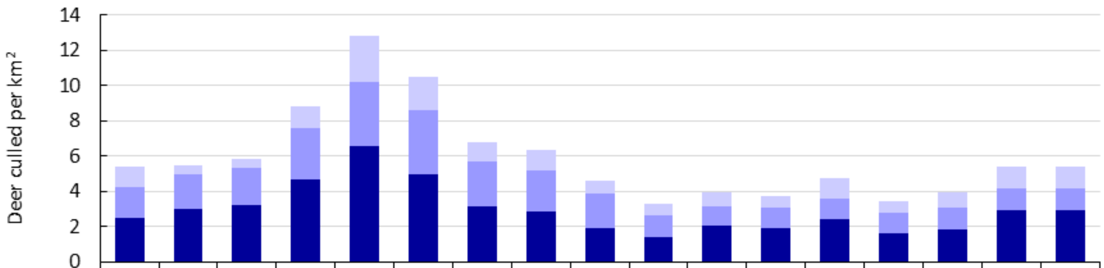
141. The high number of Caenlochan count data sets available could have afforded the opportunity to undertake a detailed analysis of recruitment rates into the population, because matched calf count data would have been available for summer and subsequent winter counts. However, most of the early surveys contained large numbers of 'unclassified' count groups and only the most recent

had all deer classified (Table 10). The few classified summer count data sets indicate % calves-at-foot to have been between 33 and 37% over a period when culled calves-at-foot varied from 36-48% and average ~ 43% annually.

142. Count data indicate that the adult sex ratio of the Caenlochan population has typically been biased towards hinds (1.3 hinds: 1 stag) on average over the past decade (Table 11). The ratio, based on count data, does however appear to have varied between years and also has varied between count types somewhat (summer vs winter). In the years following the major reduction culls, the population appeared to have to have a 1: 1 adult sex ratio, whereas prior to that and in recent years it appears to have been biased towards hinds (1.3 to 1.5: 1). Whilst it is a topic of considerable importance records when modelling, the cull data submitted to SNH does not distinguish between male and female calves shot. Therefore, it was not possible to assess whether a bias in the birth sex ratio was apparent.

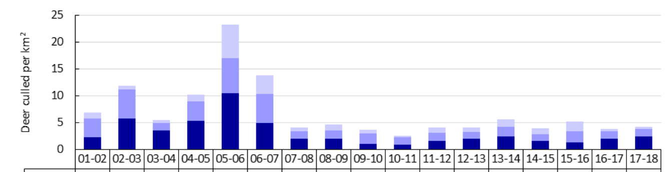


	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	1935	1973	2109	3174	4606	3770	2450	2274	1654	1192	1435	1357	1718	1246	1431	1936	1947
Calves	401	191	199	445	950	675	405	408	264	227	287	249	424	242	320	441	451
Stags	621	707	736	1052	1293	1307	922	847	690	445	389	409	410	422	444	431	426
Hinds	913	1075	1174	1677	2363	1788	1123	1019	700	520	745	699	884	582	667	1064	1070



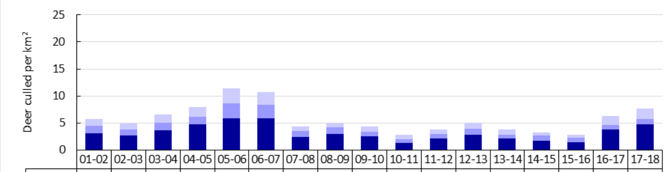
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	5.4	5.5	5.9	8.8	12.8	10.5	6.8	6.3	4.6	3.3	4.0	3.8	4.8	3.5	4.0	5.4	5.4
Calves	1.1	0.5	0.6	1.2	2.6	1.9	1.1	1.1	0.7	0.6	0.8	0.7	1.2	0.7	0.9	1.2	1.3
Stags	1.7	2.0	2.0	2.9	3.6	3.6	2.6	2.4	1.9	1.2	1.1	1.1	1.1	1.2	1.2	1.2	1.2
Hinds	2.5	3.0	3.3	4.7	6.6	5.0	3.1	2.8	1.9	1.4	2.1	1.9	2.5	1.6	1.9	3.0	3.0

Figure 2 Compiled historic cull records supplied to SNH by estates within the current Section 7 Control Area. Bachnagairn (Balmoral) cull figures are taken mainly from Deer Management Plans provided by SNH as only part of the area is included within the Section 7 area. Total cull (upper chart) and cull intensity (lower chart).



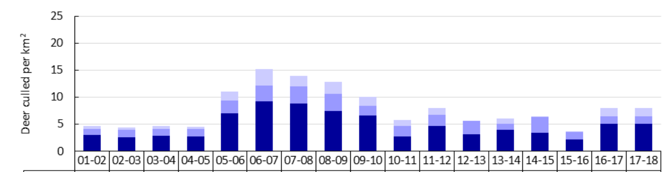
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	6.8	11.8	5.5	10.1	23.2	13.8	4.0	4.6	3.7	2.5	4.1	4.1	5.6	4.0	5.1	3.9	4.3
Calves	1.1	0.6	0.5	1.1	6.2	3.5	0.6	1.1	0.8	0.2	0.9	0.8	1.4	1.1	1.8	0.5	0.5
Stags	3.5	5.4	1.4	3.7	6.4	5.4	1.3	1.4	1.9	1.4	1.6	1.2	1.8	1.2	2.0	1.4	1.4
Hinds	2.3	5.7	3.5	5.3	10.5	4.9	2.1	2.1	1.1	0.9	1.6	2.0	2.4	1.7	1.3	2.0	2.4

Alrick & Auchavan



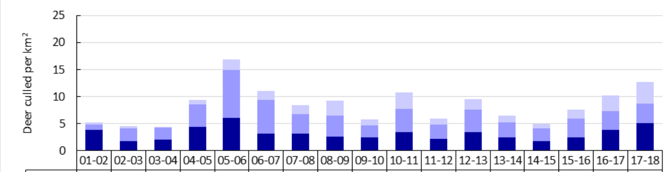
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	5.7	4.9	6.5	7.9	11.4	10.8	4.3	5.1	4.4	2.9	3.8	5.0	3.8	3.2	2.9	6.3	7.7
Calves	1.3	1.1	1.4	1.7	2.8	2.4	0.8	0.9	0.9	0.9	0.9	1.1	1.0	0.5	0.6	1.7	1.9
Stags	1.3	1.1	1.5	1.5	2.7	2.5	1.2	1.2	0.9	0.7	0.7	1.1	0.8	1.0	0.9	0.9	1.0
Hinds	3.1	2.7	3.6	4.7	5.9	5.9	2.4	3.0	2.5	1.3	2.2	2.8	2.1	1.7	1.4	3.7	4.8

Bachnagairn (Balmoral)



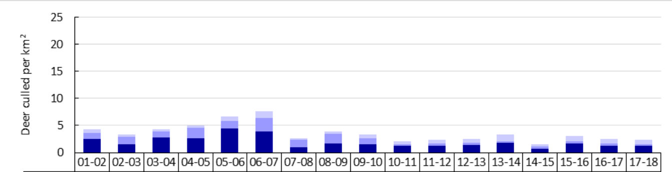
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	4.7	4.3	4.6	4.6	11.0	15.2	14.0	12.8	10.0	5.8	8.0	5.6	6.1	6.5	3.7	8.0	6.6
Calves	0.6	0.3	0.5	0.4	1.5	3.1	2.0	2.3	1.5	1.1	1.3	0.0	1.0	0.2	0.2	1.5	1.5
Stags	1.1	1.4	1.3	1.4	2.4	2.8	3.3	3.2	1.9	2.0	2.0	2.4	1.1	2.8	1.4	1.4	1.4
Hinds	3.0	2.6	2.8	2.8	7.1	9.3	8.8	7.4	6.6	2.8	4.7	3.2	4.0	3.4	2.2	5.0	5.0

Clova (South)



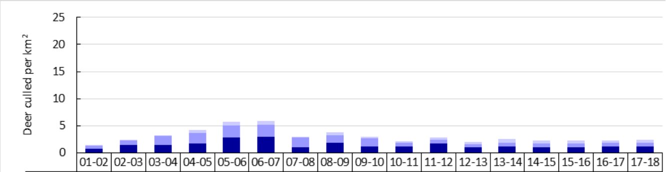
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	5.3	4.6	4.4	9.4	16.9	11.1	8.4	9.2	5.8	10.7	6.0	9.6	6.5	5.0	7.6	10.3	12.8
Calves	0.5	0.5	0.1	0.9	2.0	1.7	1.6	2.8	1.0	3.0	1.2	2.0	1.2	0.8	1.6	2.9	4.1
Stags	0.9	2.3	2.2	4.1	8.9	6.2	3.6	3.8	2.2	4.3	2.6	4.1	2.8	2.4	3.6	3.6	3.6
Hinds	3.9	1.8	2.1	4.4	6.1	3.1	3.2	2.6	2.5	3.5	2.2	3.5	2.5	1.7	2.4	3.8	5.1

FCS Glen Doll & SNH Corrie Fee



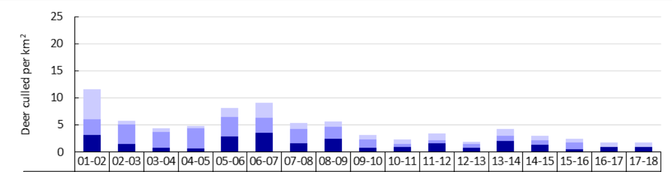
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	4.3	3.3	4.3	5.0	6.7	7.7	2.6	3.9	3.3	2.0	2.4	2.5	3.4	1.5	3.0	2.5	2.4
Calves	0.7	0.4	0.4	0.4	0.9	1.2	0.3	0.5	0.7	0.4	0.7	0.7	1.2	0.4	0.9	0.8	0.8
Stags	1.2	1.3	1.1	1.9	1.4	2.5	1.3	1.7	1.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3
Hinds	2.5	1.6	2.7	2.7	4.4	3.9	1.0	1.7	1.5	1.2	1.3	1.4	1.8	0.7	1.7	1.2	1.2

Glen Prosen



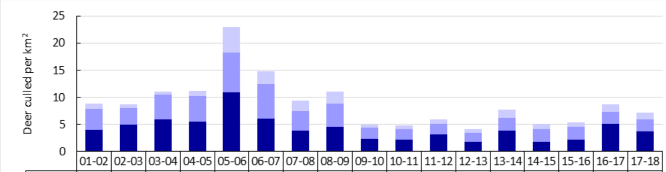
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	1.4	2.4	3.2	4.2	5.7	5.8	3.0	3.8	2.9	2.1	2.8	2.0	2.5	2.2	2.2	2.3	2.3
Calves	0.1	0.2	0.1	0.6	0.7	0.7	0.2	0.6	0.3	0.3	0.5	0.4	0.6	0.5	0.5	0.5	0.5
Stags	0.5	0.8	1.6	1.9	2.2	2.2	1.7	1.4	1.5	0.7	0.6	0.6	0.7	0.7	0.7	0.7	0.7
Hinds	0.8	1.4	1.4	1.7	2.9	3.0	1.0	1.8	1.2	1.1	1.7	1.0	1.2	1.0	1.0	1.1	1.2

Glen Callater (Invercauld)



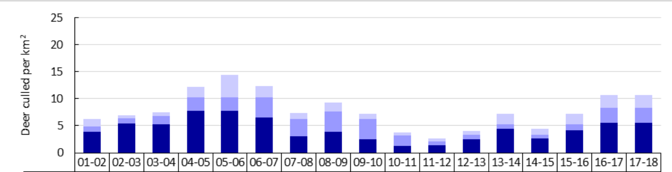
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	11.6	5.8	4.4	4.7	8.1	9.1	5.4	5.6	3.1	2.3	3.4	1.9	4.2	3.0	2.4	1.8	1.8
Calves	5.6	0.7	0.7	0.4	1.6	2.8	1.1	0.9	0.8	0.8	1.3	0.5	1.2	0.9	0.6	0.9	0.9
Stags	2.8	3.6	2.8	3.7	3.6	2.8	2.7	2.2	1.5	0.6	0.5	0.6	0.9	0.7	1.3	0.0	0.0
Hinds	3.1	1.5	0.8	0.7	2.9	3.5	1.6	2.4	0.8	1.0	1.6	0.8	2.0	1.4	0.5	0.8	0.8

Glenhead/Glen Damff



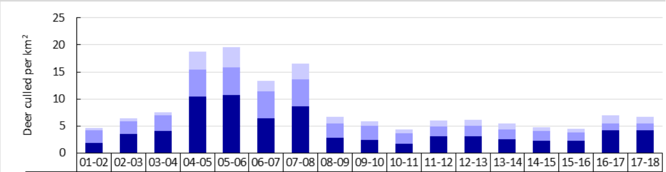
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	8.8	8.7	11.0	11.2	23.0	14.8	9.5	11.0	5.0	4.8	6.0	4.1	7.7	5.1	5.3	8.7	7.2
Calves	1.0	0.6	0.5	0.9	4.8	2.3	2.0	2.1	0.6	0.7	0.8	0.6	1.5	0.9	0.7	1.3	1.3
Stags	3.8	3.1	4.5	4.7	7.2	6.4	3.6	4.3	2.1	1.9	2.0	1.7	2.4	2.4	2.5	2.2	2.2
Hinds	4.0	4.9	6.0	5.5	11.0	6.1	3.8	4.6	2.3	2.2	3.1	1.8	3.9	1.8	2.2	5.2	3.7

Glenisla House/Glen Cally



	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	6.2	7.0	7.5	12.2	14.4	12.4	7.4	9.4	7.3	3.7	3.0	4.0	7.2	4.5	7.2	10.7	10.7
Calves	1.4	0.6	0.7	1.9	4.2	2.1	1.2	1.7	1.0	0.5	0.5	0.7	2.0	1.1	1.9	2.5	2.5
Stags	1.0	1.0	1.5	2.5	2.5	3.7	3.2	3.8	3.8	1.9	0.8	0.8	0.8	0.7	1.0	2.7	2.7
Hinds	3.8	5.4	5.3	7.8	7.8	6.6	3.1	3.8	2.5	1.3	1.3	2.5	4.4	2.6	4.2	5.6	5.6

Glenshee (Invercauld)



	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Total	4.6	6.4	7.5	18.8	19.7	13.3	16.5	6.7	5.8	4.4	5.9	6.1	5.4	4.8	4.5	6.9	6.7
Calves	0.4	0.5	0.6	3.3	3.8	1.8	2.8	1.2	0.8	0.7	1.0	1.0	1.0	0.6	0.7	1.5	1.3
Stags	2.2	2.4	2.8	5.1	5.1	5.1	5.1	2.6	2.7	2.0	1.9	2.0	1.8	1.9	1.6	1.2	1.2
Hinds	1.9	3.5	4.1	10.4	10.8	6.4	8.6	2.9	2.3	1.7	3.0	3.0	2.5	2.2	2.2	4.2	4.2

Tulchan of Glenisla

Figure 3 The intensity of cull (animals culled per km^2) taken on each estate over the period 2000-2018. Land ownership changes over the period mean that certain properties are reported jointly. Note also that some analysis zones are in fact parts of larger estates (e.g. Invercauld, Balmoral).

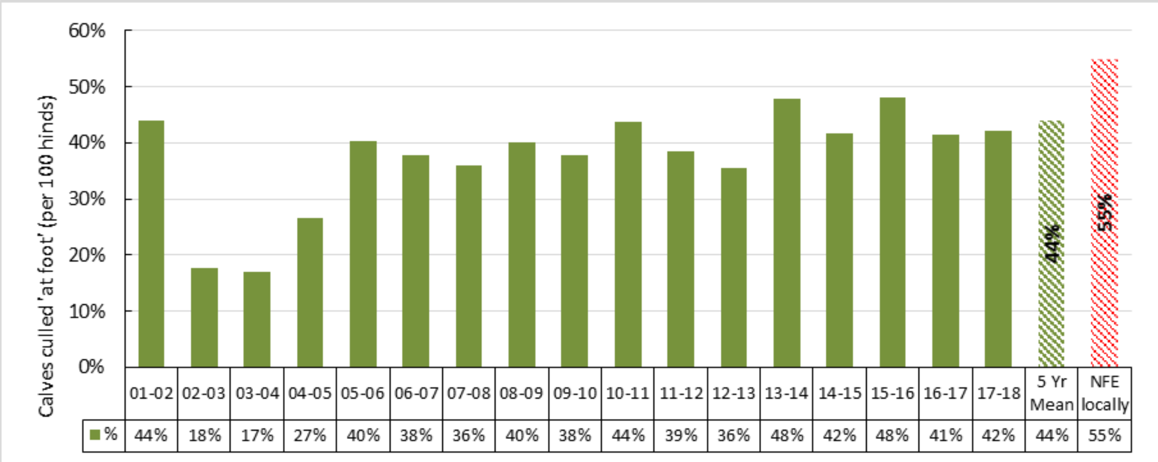


Figure 4 The % of calves culled 'at-foot' of culled hinds. The chart includes a recent 5-year average as well as the figures calculated for forested NFE properties in the vicinity of Caenlochan.

Table 10 Calves-at-foot during summer helicopter counts, matched up with equivalent data from counts undertaken the subsequent winter and compared with data obtained from culls in the lead up to the winter counts. Conditional formatting is used to draw out trends visually.

Year	% Calves at foot: from summer count that year	% Calves at foot: from count the following winter		% Calves culled at foot: from subsequent year's records
Jun-03	Unclassified			17%
Jun-04		Unclassified		27%
Jun-05		Unclassified		40%
Jun-06	Unclassified	Unclassified		38%
Jun-07	Unclassified	Unclassified		36%
Jun-08	Unclassified	Unclassified		40%
Jun-09	Unclassified			38%
Jun-10	Unclassified	Unclassified		44%
Jun-11	Unclassified	Unclassified		39%
Jun-12	37%			36%
Jun-13	36%			48%
Jun-14				42%
Jun-15		33%		48%
Jun-16				41%
Jun-17		37%		42%
Jun-18				29%
Jun-19				Not avail' yet

Table 11 The ratio of hinds: stags present in cleansed count data. Conditional formatting is used to draw out trends visually. Note: a model was used to allocate unclassified deer (see Methods).

Season	Year	Stags counted	Hinds counted	Calves counted	ALL counted		Hinds: stags
Winter	1966	918	1,403	489	2,810		153%
Winter	1975	2,264	3,414	999	6,677		151%
Winter	1979	1,538	2,472	783	4,793		161%
Winter	1994	2,758	4,557	1,040	8,355		165%
Summer	2003	1,998	6,127	3,249	11,374		307%
Winter	2005	2,639	5,302	2,396	10,337		201%
Winter	2006	2,870	3,741	1,683	8,294		130%
Summer	2006	3,761	4,118	1,853	9,732		109%
Winter	2007	2,322	2,644	1,175	6,141		114%
Summer	2007	3,327	3,465	1,550	8,342		104%
Winter	2008	2,862	2,676	1,194	6,732		94%
Summer	2008	3,059	3,057	1,360	7,476		100%
Winter	2009	2,595	2,506	1,124	6,225		97%
Summer	2009	2,974	3,347	1,495	7,816		113%
Summer	2010	2,496	3,127	1,381	7,004		125%
Winter	2011	2,268	2,980	1,332	6,580		131%
Summer	2011	2,858	3,379	1,520	7,757		118%
Winter	2012	2,803	2,474	1,082	6,359		88%
Summer	2012	2,826	4,208	1,560	8,594		149%
Summer	2013	2,826	4,352	1,567	8,745		154%
Winter	2016	2,415	3,188	1,053	6,656		132%
Winter	2018	2,983	3,984	1,473	8,440		134%

143. The retrospective population modelling exercise yielded some potentially useful results, albeit as always with such work the results need to be treated with a considerable degree of caution because some of the parameters required are not monitored by estates at all (e.g. birth sex ratio of calves) and some parameters needed to be estimated from proxy data (e.g. recruitment into the population):

a) With the core parameters fixed as described in the Methods[60], the model was firstly run with a net recruitment into the population annually of 45 calves per 100 hinds[61], and with adult natural mortality (e.g. due to exposure, starvation etc) at 0% per annum for stags and for hinds. This model failed to balance as the total number of deer present declined to zero, and therefore did not in any way 'fit' the actual count data provided by SNH.

b) Subsequent runs involved sequentially increasing the recruitment until such times as the hind model (and companion model for calves) appeared to intersect a majority of the actual count data. The logic behind this was that

[60] An accurate February 2005 count of 10,337 resident deer present; initial adult sex ratio biased 2: 1 in favour of hinds; 1: 1 juvenile sex ratio; ~ 60 deaths due to deer-vehicle collisions and poaching per annum; reported culls being accurate and complete for the area.

[61] All hinds including yearlings.

hinds tend to be more hefted, and hence even if the Section 7 Control Area experiences movement of deer across its boundaries it is more likely on average to be from stags in large numbers than hinds in large numbers. The hinds model struggled to balance at all until such times as the recruitment rate was implausibly high (~ 55 calves per 100 hinds) which, in turn, pushed to overall population implausibly high.

c) An adjustment was then made at the start of the model whereby the initial abundance was assumed to be an underestimate. The start population was increased, in the end, by 4% (to 10,755 or ~ 400 extra animals above the 2005 count). At this point, the model began to balance for hinds and calves if a 50% recruitment rate was employed in tandem. However, by this point the adult stag model failed to balance as it had much larger numbers of stags present than expected by count data.

d) Further iterations of the model involved increasing 'aggregate losses of adult stags from the system' until a semblance of stag model balance was achieved – this was reached with annual losses of 10% of stags (~300 animals per annum on average) from the system. Such 'losses' could, in effect, arise for multiple reasons:

   i) Skew in the sex ratio towards more females being born (not allowed for in the model) or in mortality rates in the first year of life.

   ii) Net difference in exposure of adult stags and hinds to natural mortality, which was not explicitly allowed for in the model, or to deer-vehicle collisions (e.g. on the Glenshee road, where many stags winter).

   iii) Permanent emigration of stags at some point after becoming yearlings.

   iv) Neighbouring estates shooting stags born or residing in Caenlochan but moving off site during the rut.

   v) Unreported stag culls from neighbouring farms and forestry, errors in estate record keeping etc.

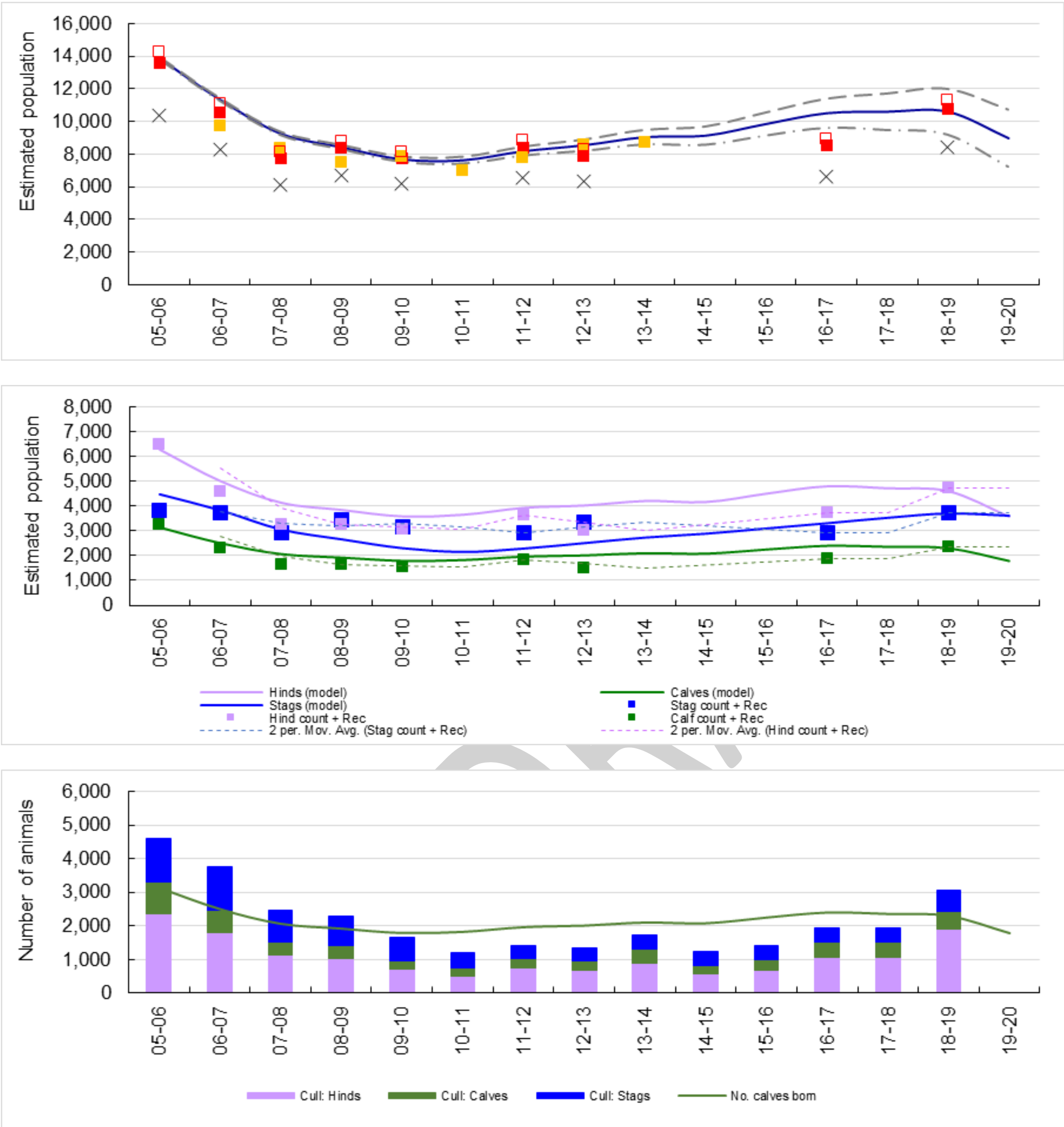


Figure 5 Key outputs from the final retrospective population model for red deer in the current Caenlochan Section 7 area. Upper chart: overall predicted trend in abundance set against count data (cross = winter count; orange square = summer count; red square = inflated winter count + white box above shows effect of 5% undercount; dashed lines show effect of 0.5% variation in model start abundance, as an illustration of the sensitivity of this type of long-term model). Middle chart: breakdown of the overall model into its 3 core strands – adult males, adult females and calves (actual winter count data – elements inflated to allow for recruitment - shown by coloured squares; dashed lines are 2-year running averages of counts). Lower chart: the size of cull taken each year, as input to the model to run it, alongside the predicted number of calves being born. In general terms, culls higher than the calf production will reduce the population (assuming a sufficiently high adult female cull) and culls below the calf production will allow the population to rise over time.

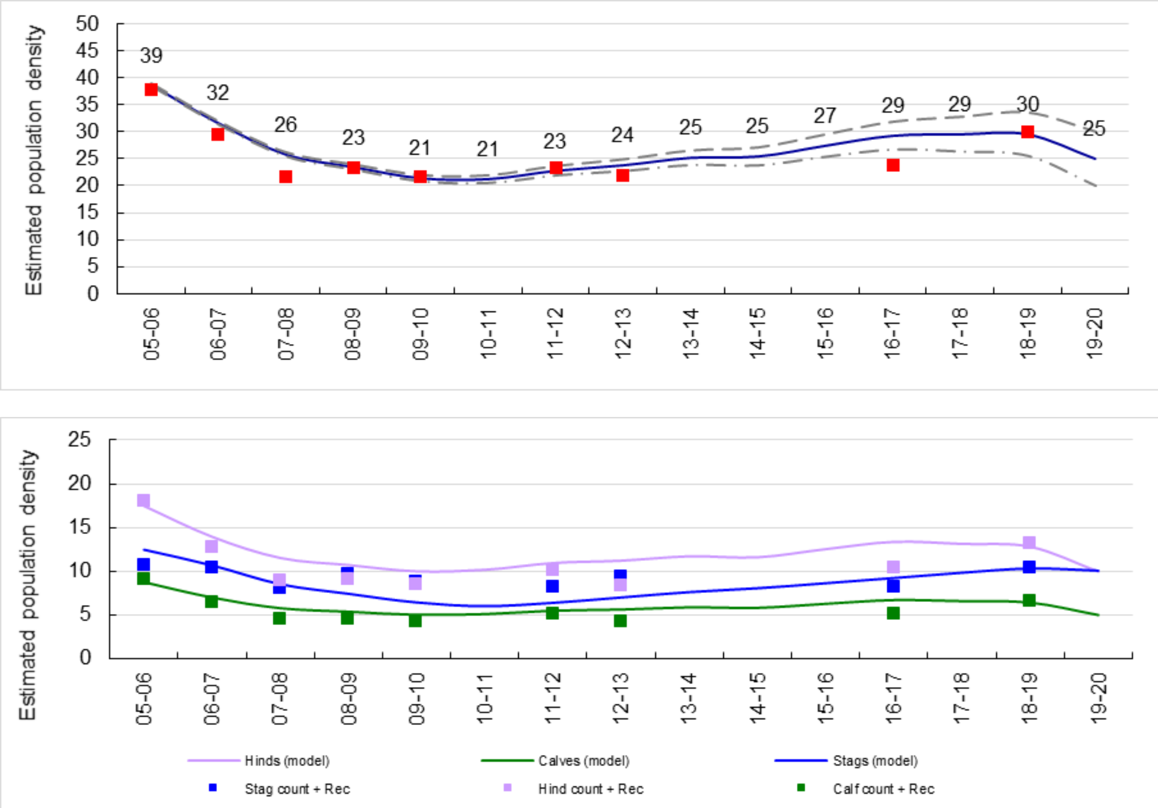


Figure 6 Key outputs from the final retrospective population model for red deer in the current Caenlochan Section, in the form of average density (Figure 5 shows the same data, but as abundance).

144. The retrospective modelling indicated that it is possible to achieve a degree of balance in the model based on parameters that lie within sensible bounds. That said, the degree of variability in the deer count data and difficulty of achieving a model which fits all the counts from the site does make it difficult to be sure whether (i) the 'final' model outputs are still not very reliable or in fact (ii) the count data themselves are unreliable (this may be due, for example, to large scale deer movements between counts, to errors in counting/count processing or some combination of the two). It is most likely that both aspects (models and counts) are somewhat unreliable, given the models undoubtedly have some known deficiencies which would make their year-to-year predictions inaccurate.

145. The main deficiency is that we know recruitment will vary from year to year, as will mortality, and yet the models use fixed rates due to a lack of reliable annual parameters. This approach inevitably means that the real detail of local population dynamics from year-to-year is inevitably 'dampened' in the model output.

146. Another possibility is that the area selected for the modelling contains a population of deer which are not resident. In other words, a considerable proportion of the deer being counted in summer or winter are not in fact resident all year round.

147. It is undoubtedly the case that some movement does occur, for example across the Glenshee road, but the results of previous 'East Grampians' and Tayside deer counts (Map 11) suggest that the populations of deer in the wider area are small, in *relative* terms, or otherwise seem to be counted some distance away from Caenlochan. The main exceptions to this seem to be (i) the south-western side of the site around Spittal of Glenshee, (ii) to the south where some smaller estates are known to harbour red deer (just outside the S7 area), (iii) the north around Callater, where deer may move in and out of the edge of Balmoral and (iv) the northern section of Glen Clova, from Glen Doll up to the watershed with Callater, where deer may move east to west and *vice-versa*.

148. The reason that problems with the integrity of the retrospective model are of interest is that building a prospective model, to use for cull setting, is made more difficult if historic data sets cannot be formed into a reliable retrospective model themselves first. This in turn is because of the preference for using a retrospective model to form up the prospective model, to improve its reliability.

149. A prospective model was formed based on the lessons learnt during the retrospective model, despite its potential deficiencies, for use in future cull setting – the outputs are presented later in this report in the chapter entitled 'Next Steps'.

OCCUPANCY-IMPACT ASSESSMENT

Faecal pellet group counts

150. Over a period of 93 days (+/- SD of 20.5 days) an average of 1,105 (SE +/- 64 or 5.8%) new pellet groups accumulated per km^2 based on the network of 200 transects deployed on site (Table 12 & Figure 7).

151. However, distinct variations were apparent in the local FAR measured on different parts of the site, and there was also variation in FAR apparent between habitat types (see Map 12, Table 12 and Figures 7 & 8).

Table 12 The faecal accumulation rate (FAR) per km^2 as measured on the survey site over the period June – October 2018 from a sample size of 200 transects. The data are stratified by broad habitat type, within each of the two main analysis zones identified using the interpolation model (see Map 12). A density estimate (deer and sheep combined) for each habitat and zone is presented, assuming a mean daily defecation rate of 20 pellet groups / day. See also Figures 7 & 8. Conditional formatting is used to draw out trends visually.

Zone	Broad habitat	Sample size (n)	Mean FAR / km^2	Sample standard deviation (SD)	Standard error (SE)	Estimate: deer/sheep per km^2
Lower	Peatland	32	647	529	94	32.4
	Heathland	23	972	793	165	48.6
	Grassland	20	934	653	146	46.7
	Summits	28	926	823	155	46.3
	Lower-ALL	103	851	706	70	42.6
Higher	Peatland	16	915	721	180	45.8
	Heathland	31	1,237	712	128	61.9
	Grassland	12	1,912	1170	338	95.6
	Summits	38	1,508	1163	189	75.4
	Higher-ALL	97	1,374	1001	102	68.7
Entire Site	**ALL**	**200**	**1,105**	**899**	**64**	**55.2**

152. For the purposes of a later analysis aiming to explore the relationship between deer occupancy and impact levels on different parts of the site, the FAR data were stratified in two ways:

a) Zones of higher than average occupancy were identified in the north-west and south-east of the study area, focused mainly on the Invercauld properties, Glen Prosen and Clova (south)[62]. These areas were combined and termed the zone of 'Higher' occupancy for further analysis (average of ~ 69 deer/sheep per km^2). The remainder of the study area was termed the 'Lower' zone as accumulation rates, whilst very high relative to many other upland sites in Scotland, were lower on average (~ 43 deer/sheep per km^2).

[62] The boundaries of these estates were used for this zone. Small other areas of land could have been added in, but for the sake of clarity and ease they were not included given that many areas in the Lower zone showed local hotspots also.

b) Within each zone, the data were further stratified by broad habitat type so that differences in impact levels between habitat types could be explored, as well as interactions between density and habitat.

153. Whilst the stratifications employed in the exploratory analysis are post-hoc, hence no control was exercised in advance on this aspect of the sampling design, the sample size of transects in the Higher and Lower zones were in the end sizeable and broadly equal; the sample sizes of transects within each habitat within each of these zones were somewhat variable, but most were at least adequately represented in most cases[63].

154. The average accumulation rate was inflated from transect scale to the scale of the entire site according to land area (15,879ha), then adjusted for known biases, in order estimate the abundance of deer/sheep present. As well as being of interest in itself, this step was necessary in order to estimate the approximate contributions of deer and sheep separately to the accumulation measured on site.

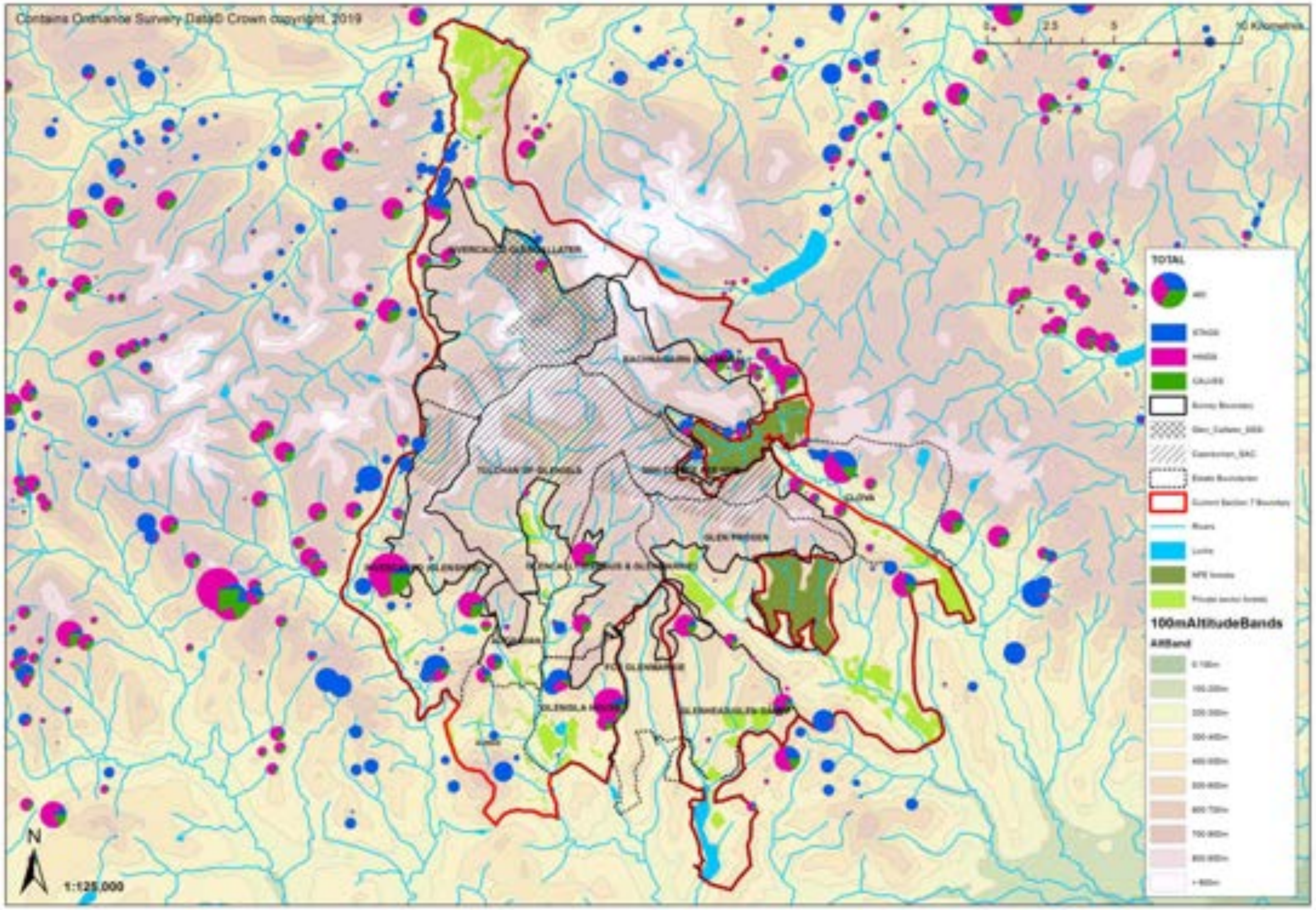
155. The adjustments to the raw FAR data allowed for the presence of ghost groups and for intermediate decomposition during the accumulation period, but overall resulted in a negligible difference (1.3% increase) in the overall estimate (Table 13).

156. The total number of pellet groups which accumulated at site scale, after adjustments for bias, was estimated to be 16,477,869 (SE +/- 959,110 or 5.8%). These data are equivalent to 8,883 (SE +/- 1,260 or 14%[64]) deer/sheep on average - or 55.9[65] animals per km^2 - having used the site over the accumulation period, assuming a mean defecation rate of 20 pellet groups per day.

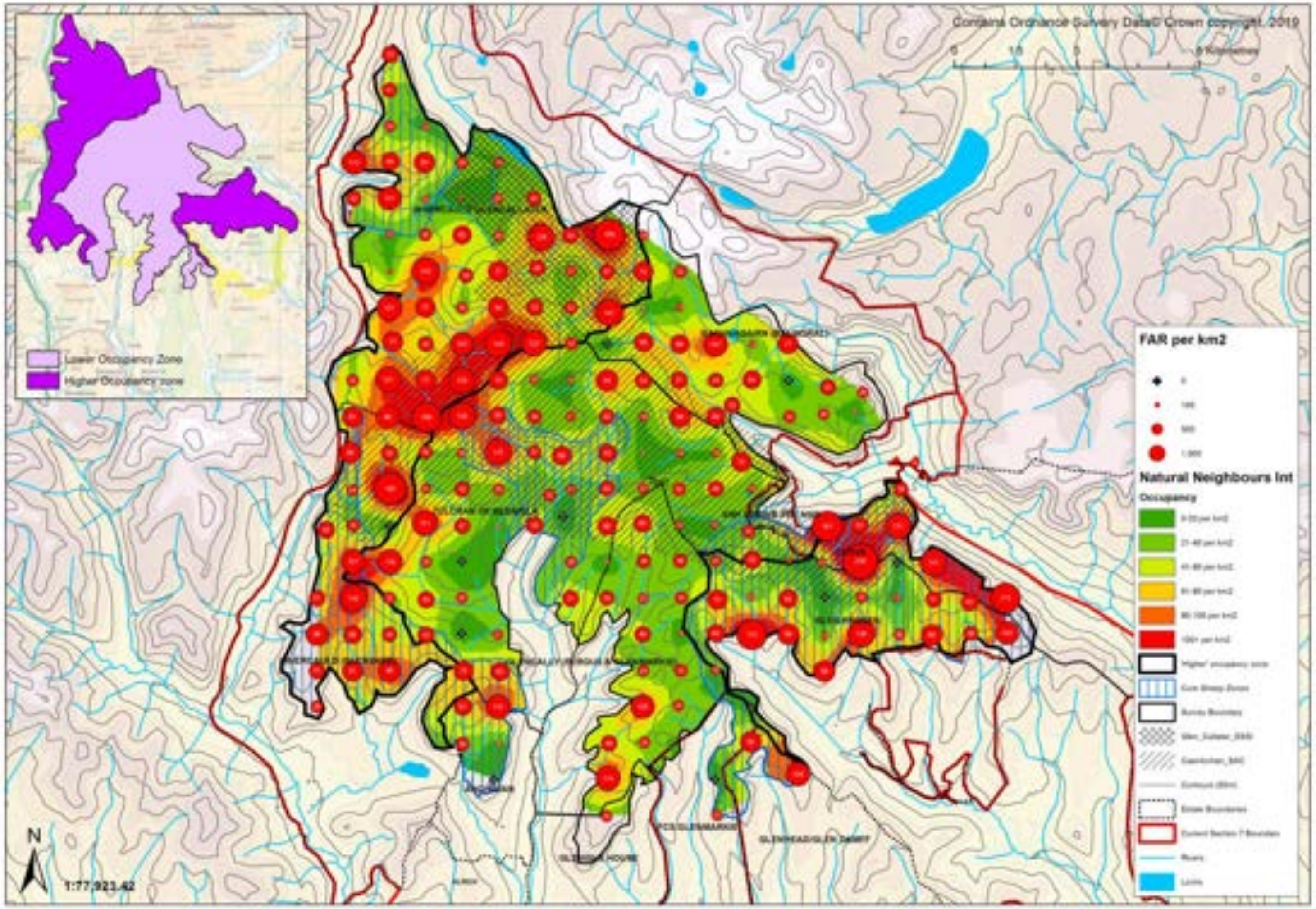
Table 13 Steps employed in adjusting the raw FAR data to allow for known biases.

Count step	Scaled-up count	% Change from Raw
1. Raw pellet group density (PGD) estimate	16,268,163	n/a
2. Amended for intermediate decomposition	16,978,046	4.4%
3. Amended for ghost groups	16,477,869	1.3%
4. Adjusted PGD estimate	16,477,869	

[63] Future studies of the site could add additional sampling locations in if deemed sufficiently important.
[64] Incorporating the variance estimates of both the pellet group density estimate and pellet group defecation rate estimate as per Forestry Commission Bulletin 128.
[65] Adjustments for known biases cannot be easily made at the scale of transects, hence why the overall density quoted in Table 12 is 55.2 per km^2 and not 55.9 per km^2



Map 11 The results of the most recent East Grampian red deer count showing the location, size and composition of each group counted in and around Caenlochan.



Map 12 The deer/sheep faecal accumulation rate per km^2 per day over the period June-October 2018, along with a 'density surface' interpolated using ArcMap.

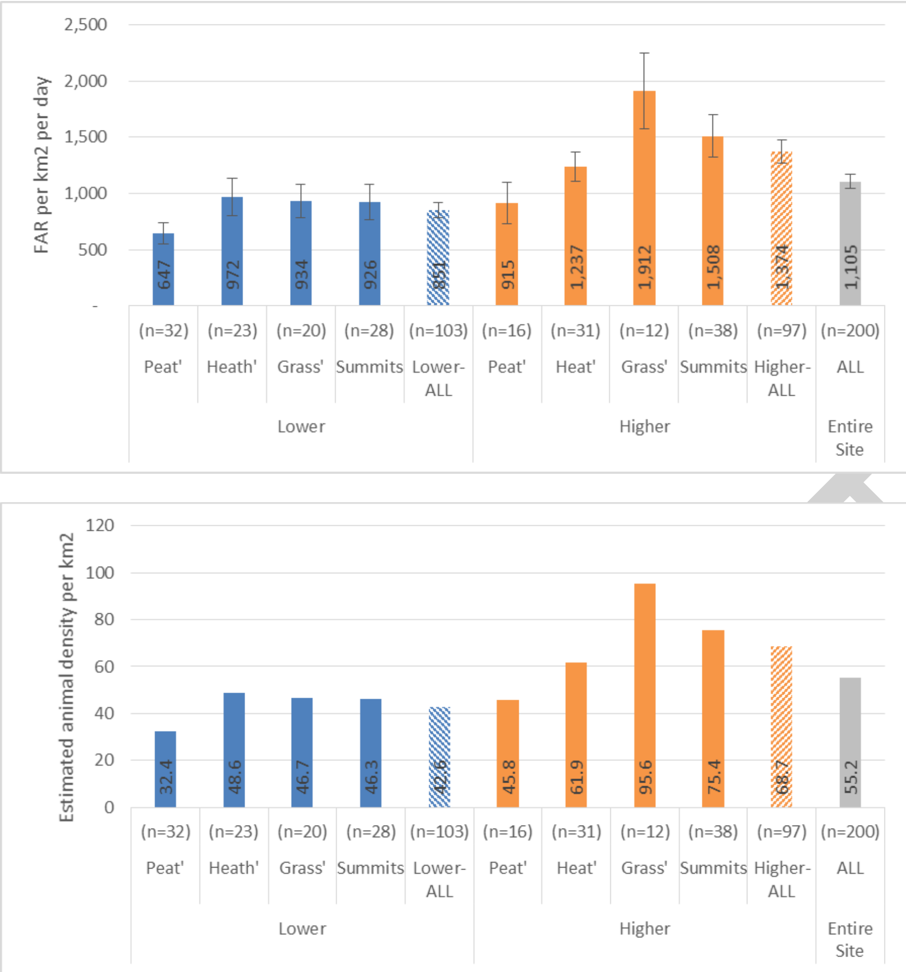


Figure 7 The faecal accumulation rate (FAR) per km^2 as measured on the survey site over the period June – October 2018 from a sample size of 200 transects (+/- 1 SE). The data are stratified by broad habitat type, within each of the two main analysis zones identified using the interpolation model (see Map 12). A density estimate (deer and sheep combined) for each habitat and zone is presented in the lower chart, assuming a mean daily defecation rate of 20 pellet groups / day.

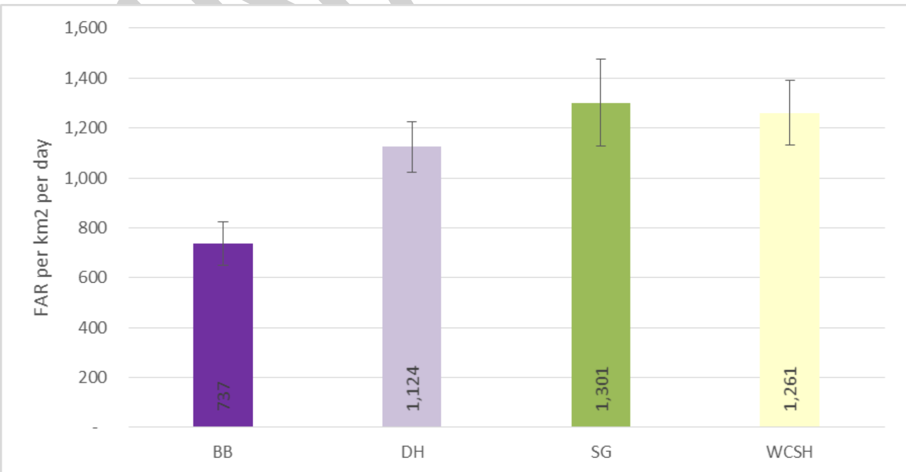


Figure 8 The faecal accumulation rate (FAR) per km^2 as measured on the survey site over the period June – October 2018 from a sample size of 200 transects (+/- 1 SE), stratified by broad habitat type.

157. Direct counts of sheep on site during the first and second visits to site (June/July, and September/October) yielded total counts of ~550 and ~750 sheep respectively, with observers trying to ensure no overlap in the data recorded but with it being inevitable that there was given the number of days active on site surveying. It is assumed the maximum likely number of sheep using the study site over the period, based on the evidence to hand, was in the order of ~ 650 sheep. Of these, approximately 200 are estimated to have been active in the Lower Zone and 450 in the Higher zone.

158. If the total estimated abundance of deer and sheep combined was 8,883 on average then in the order of 8,233 deer and 650 sheep may have been using the study site (93% and 7% of measured accumulation respectively).

159. In previous summer deer counts approximately 72% of the herd on average was located within the wider study area at the time of the count (Table 7). In broad terms, based on the deer abundance estimate obtained from the FAR study, it follows that the overall summer population in 2018 could very cautiously be inferred as ~ 139% (1/0.72) of the calculated abundance from the study area – this calculation produces a figure of ~ 11,370 deer.

160. In terms of corroboration the winter 2018 deer count data, when inflated up to allow for recruitment in early summer 2018 (Table 3), suggests a possible summer population of ~ 10,275 animals. That said, historic count records indicate that summer counts can show levels higher than expected from inflated winter count data presumably because of additional animals migrating in from a wider area around the Control Area. Depending on how the data are viewed, the two different forms of summer 2018 abundance estimate are within ~10% of each other, implying some degree of confidence might be attached to the dung count abundance estimate despite the range of variables which could affect its accuracy (e.g. sampling error, potential inaccuracy in the defecation rate employed, the potential for more sheep and less deer to have contributed to the accumulation etc). On balance, the inflated winter count is markedly more likely to be accurate.

161. A key issue in interpreting the results of the impact surveys undertaken in 2018 is to consider the contribution of each of the main herbivores present on site. The Methods section of this report describes the process used to develop a model which estimates the dry weight of dung present on the site from each species group in autumn 2018. The approach employed undoubtedly has several weaknesses, but given the inherent difficulty of the task and the lack of dedicated funds to address the question specifically, the results obtained appear to be of some use:

a) The selection of analysis zones (Higher and Lower) was driven predominantly by that pattern of deer-sheep faecal accumulation measured. However, in selecting these zones it was also apparent that the core areas of sheep activity were mainly to be found in the Higher zone. Likewise, the majority of the locations where mountain hare activity was elevated were also to be found in the Higher zone and the same was apparent for grouse (managed moorland appears to be attractive for both species; Map 13). These facts implied that the results of any habitat impact analysis from the Lower zone were likely to be relatively free of the grazing influences of sheep and hare whereas those from the Higher zone appeared more likely to be affected by them. That said, it was still considered important to try and understand more about the likely importance of their contribution to impacts in each zone.

b) The first stage in the process of quantifying contributions was to allocate a proportion of the faecal accumulation of deer and sheep to each species group (Table 14).

c) Next, the contributions of all species groups (including mountain hare and, for completeness, grouse) were assessed by estimating the dry weight (kg) of dung of each group present on the survey site in autumn 2018 (Table 15). Models were developed for the site overall, and then in turn the Lower and Higher zones.

162. The results of the modelling suggested the following:

a) At the overall site scale, it is estimated that ~ 80% of dung by dry weight relates to deer. Approximately 11% comes from hare, with the balance split equally between sheep and grouse.

b) When the models are run for each analysis zone, it appears that ~ 85% of dung by dry weight comes from deer in the Lower zone whereas in the Higher zone ~ 75% of the dung by dry weight comes from deer. Mountain hare activity appears to be markedly more important in the Higher zone (14% of dung by dry weight) compared to the Lower zone (8% by dry weight). If wishing to be more conservative in interpretation, then as much as 28-30% of dung by dry weight in the Higher zone might not have come from red deer.

163. The modelling focuses on the predicted dry weight (kg) of faeces of each key herbivore present. Dung dry weight is presented as a potentially useful proxy for the likely level of dry matter off-take by each species group. In turn, this could be a potentially useful proxy for possible contributions to the levels of impact observed on common food plants (e.g. heather) in the key habitats (e.g. peatland, heathland and summit communities). It is beyond the scope of this project to quantify the reliability of these assumptions, but Appendix 4 contains some information on the diet of each species group which should aid readers in judging the extent to which the results presented herein are useful.

Table 14 Estimated % of the FAR pellet group accumulation measured on site in autumn 2018 which relates to sheep activity. The direct counts of sheep made on site – and the breakdown between zones – are employed in the calculation.

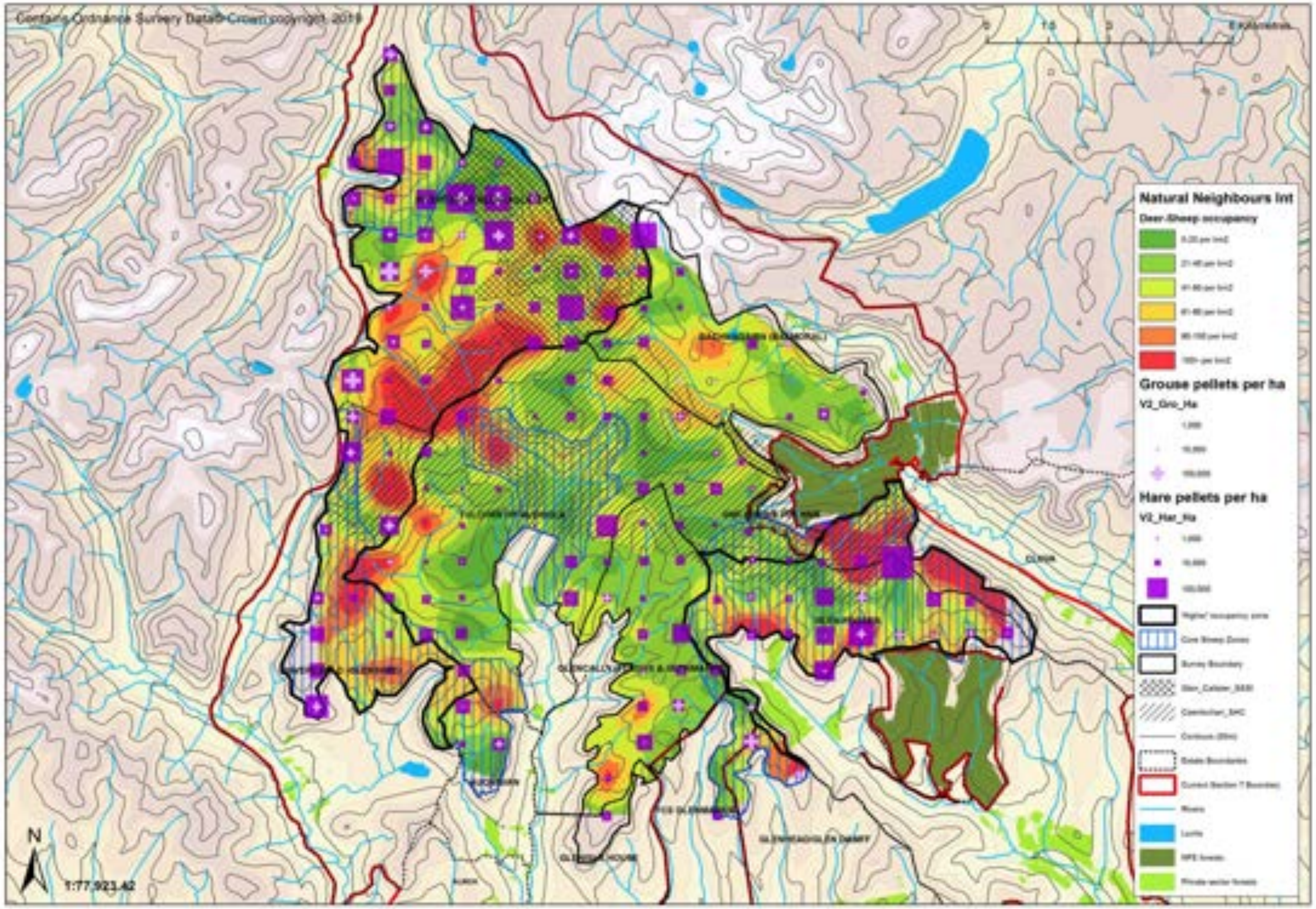
Zone	Area (ha)	Estimated average sheep number	Sheep per km^2 (live count)	Deer+sheep per km^2 (FAR dung count)	-> Deer per km^2 (inferred)	Estimated % accumulation that is sheep
Lower	8,454	200	2.4	43.0	40.6	6%
Higher	7,425	450	6.1	69.0	62.9	9%
ALL	15,879	650	4.1	55.0	50.9	7%

Table 15 Outputs of a simple model which estimates the total dry weight (kg) of faecal matter (by dry weight) present on the study site in autumn 2018, and provides a breakdown of the % contribution by weight of each of the main herbivores present. Markedly more sophisticated analysis of the data is possible, which would better represent the interplay between the different forms of sampling error evident, but given the complexity of doing so this was considered out with the current scope of work. In place of this, in order to illustrate the potential for error in the predictions, the model runs with 3 different scenarios for each species (estimated faecal dry weight based on the mean faecal pellet count, mean + 1 SE and mean – 1 SE). Similar models (not shown here) were created using the main site model to produce the same calculations for the Lower and the Higher occupancy zones separately – see outcomes in Table 16. Conditional formatting is used to draw out trends visually.

Species	Occupancy estimate type	Data type	Timing	Faecal pellets / ha	Faecal pellets / km2	Pellet group density / km2	Mean weight (g) of a faecal pellet	Total dry weight (g) of faeces per km2	Total dry matter (kg) of faeces per km2	Estimated % contribution to total dry weight
Red grouse	Mean - SE	FSC	Sept/Oct (V2)	6,772	677,200	N/A	0.29	196,388	196	3%
	Mean	FSC	Sept/Oct (V2)	9,941	994,100	N/A	0.29	288,289	**288**	**4%**
	Mean + SE	FSC	Sept/Oct (V2)	13,110	1,311,000	N/A	0.29	380,190	380	5%
Hare	Mean - SE	FSC	Sept/Oct (V2)	24,551	2,455,100	N/A	0.24	589,224	589	10%
	Mean	FSC	Sept/Oct (V2)	30,416	3,041,600	N/A	0.24	729,984	**730**	**11%**
	Mean + SE	FSC	Sept/Oct (V2)	36,281	3,628,100	N/A	0.24	870,744	871	12%
Sheep	Mean - SE	FSC	Sept/Oct (V2)	8,275	827,508	N/A	0.28	231,702	232	4%
	Mean	FSC	Sept/Oct (V2)	9,217	921,703	N/A	0.28	258,077	**258**	**4%**
	Mean + SE	FSC	Sept/Oct (V2)	10,159	1,015,899	N/A	0.28	284,452	284	4%
Deer	Mean - SE	FSC	Sept/Oct (V2)		10,994,030	N/A	0.42	4,617,493	4,617	82%
	Mean	FSC	Sept/Oct (V2)		12,245,484	N/A	0.42	5,143,103	**5,143**	**80%**
	Mean + SE	FSC	Sept/Oct (V2)		13,496,939	N/A	0.42	5,668,714	5,669	79%
ALL	Mean - SE	FSC							5,635	
ALL	Mean	FSC							**6,419**	
ALL	Mean + SE	FSC							7,204	
Deer/sheep	*Mean - SE*	*FSC*	*Sept/Oct (V2)*		*11,821,538*	*157,621*				
	Mean	*FSC*	*Sept/Oct (V2)*		*13,167,188*	***175,563***				
	Mean + SE	*FSC*	*Sept/Oct (V2)*		*14,512,838*	*193,505*				

Table 16 Outcomes from the modelling of relative contributions to total faecal dry weight (kg) in each analysis zone. Results are shown for the site overall, and then in the right hand side of the table for the Lower and Higher zones. At the base of the table, the contributions of all 'non-deer' species are summed and a conservative rounding ('Pessimistic') applied. Conditional formatting is used to draw out trends visually.

Species	Occupancy estimate type	% Contribution to total dry weight	% Contribution to total dry weight	% Contribution to total dry weight
	ZONE --->	OVERALL	LOWER	HIGHER
Red grouse	Mean - SE	3%	2%	5%
	Mean	**4%**	**3%**	**6%**
	Mean + SE	5%	3%	6%
Hare	Mean - SE	10%	7%	13%
	Mean	**11%**	**8%**	**14%**
	Mean + SE	12%	8%	14%
Sheep	Mean - SE	4%	4%	6%
	Mean	**4%**	**4%**	**6%**
	Mean + SE	4%	4%	5%
Deer	Mean - SE	82%	87%	76%
	Mean	**80%**	**86%**	**75%**
	Mean + SE	79%	85%	74%
% 'Not deer'	Averages	**20%**	**14%**	**25%**
	'Pessimistic'	**25%**	**17%**	**28%**



Map 13 The density of hare dung pellets and red grouse dung pellets recorded in September/October 2018 at Caenlochan

Impact-occupancy patterns: all habitats

164. The results obtained from quantitative impact surveys undertaken on transects showed the following:

a) The level of off-take of heather long shoots which grew in summer 2017 and were assessed in autumn 2018 (i.e. last season's growth) varied between the occupancy zones with elevated levels present, on average, in the Higher zone (Figure 9a). In most of the habitat types assessed, impact levels were elevated in the Higher zone compared to the Lower zone. A broad relationship between off-take and occupancy was apparent within and between habitats and zones. Impacts appeared lowest in peatland within the Lower zone and highest within grassland in the Higher zone. Rates of off-take overall were sufficiently high to be causing severe suppression of the heather cover in many places, and shrinkage in some[66].

b) Off-take patterns on the heather shoots that grew in summer 2018 were broadly similar to those from growing season 2017, in that they were generally elevated in the Higher zone and also varied broadly in line with occupancy at the scale of individual habitat types. However, as expected, levels of off-take were lower than the level measured on the previous season's shoots. That said, summer off-take of fresh-grown heather is normally only seen at low levels on comparable sites studied – the levels were noticeably higher on the Caenlochan study site than have been seen elsewhere.

c) The proportion of heather plant canopies in flower in autumn 2018 was higher in the zone of Lower occupancy, and in broad terms the % of plant canopies in flower varied inversely with occupancy at the habitat scale.

d) Signs of breakage on live heather plant stems in quadrats appeared to be elevated in the Higher zone (Figure 9b). Patterns of impact varied between habitat types, in line with occupancy in some cases. The data for grassland showed no sign of trampling, but plant cover levels were very low. Dead stems were markedly more prevalent in quadrats in the Higher zone (64% of quadrats on average) than in the Lower zone (28%) (no Figure).

e) There was a trend towards somewhat shorter plant height in the Higher zone compared to the Lower, and also in some habitats sampled, whereas for heather cover the data did not in general show any obvious trend between the main zones.

---

[66] Pakeman, R. J. & Nolan, A. J. (2009) Setting sustainable grazing levels for heather moorland: a multi-site analysis. Journal of Applied Ecology, 46, 363-368.

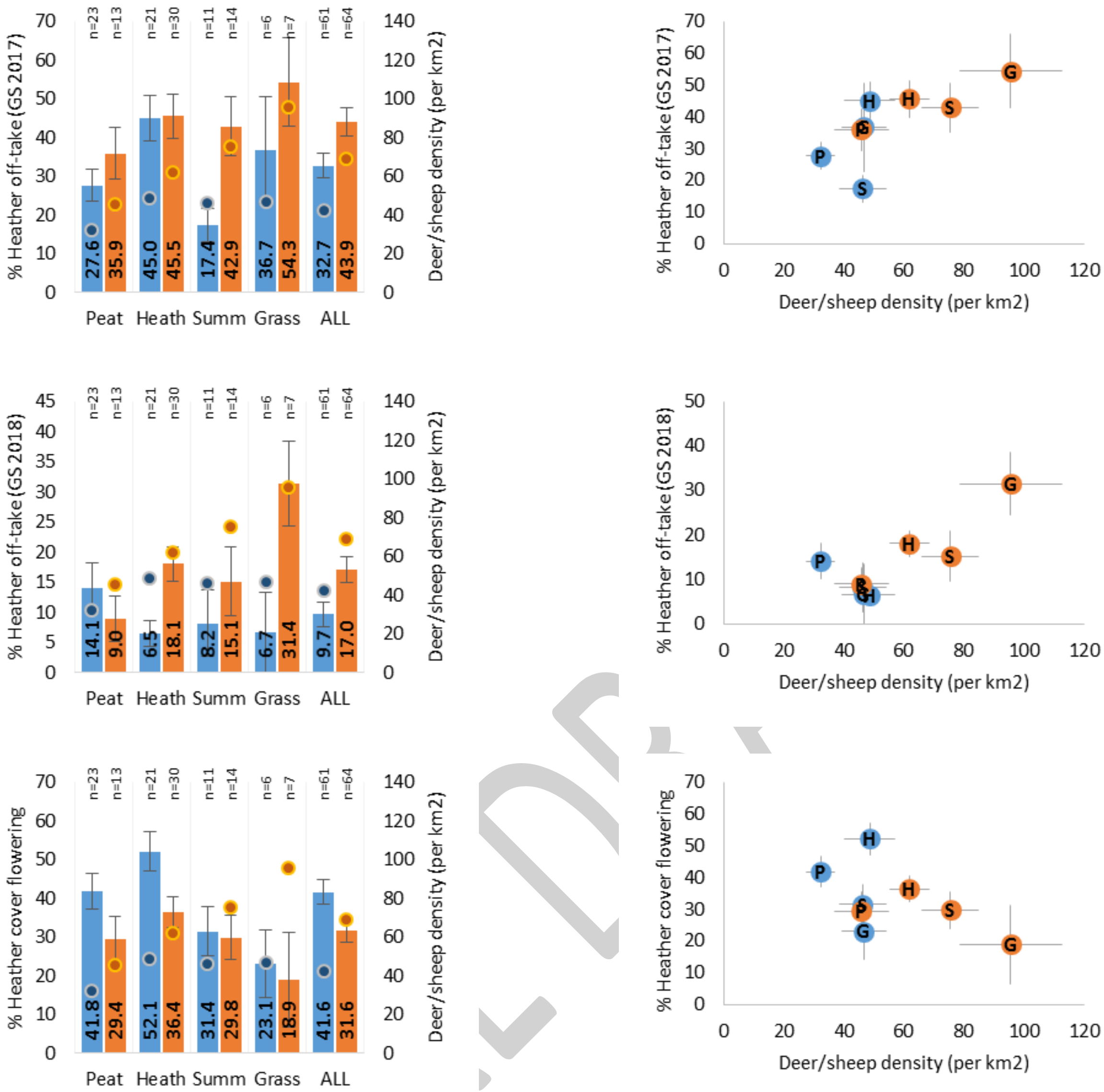


Figure 9a Impacts on heather: mean % off-take of long shoots from the 2017 growing season (upper graphs), for growing season 2018 to date (middle graphs) and mean % plant canopy in flower in autumn 2018 (lower graphs). Blue = Lower zone and orange = higher zone.

Left-hand column: bars display the main variate (+/- 1 SE), the dots show the deer-sheep occupancy level and upper labels confirm the sample size of transects in the analysis. Right-hand column: scatter diagram showing relationship between the variate measured (+/- 1 SE) and the deer-sheep occupancy level (+/- 1 SE) in that habitat/zone combination. Peatland = P, Heathland = H, Summit communities = S and Grassland = G. Standard errors (SE) shown for deer-sheep occupancy in the right-hand column relate to pellet group density and not animal density. General note: sample sizes for Grassland are small so the results obtained should be treated with considerable caution.

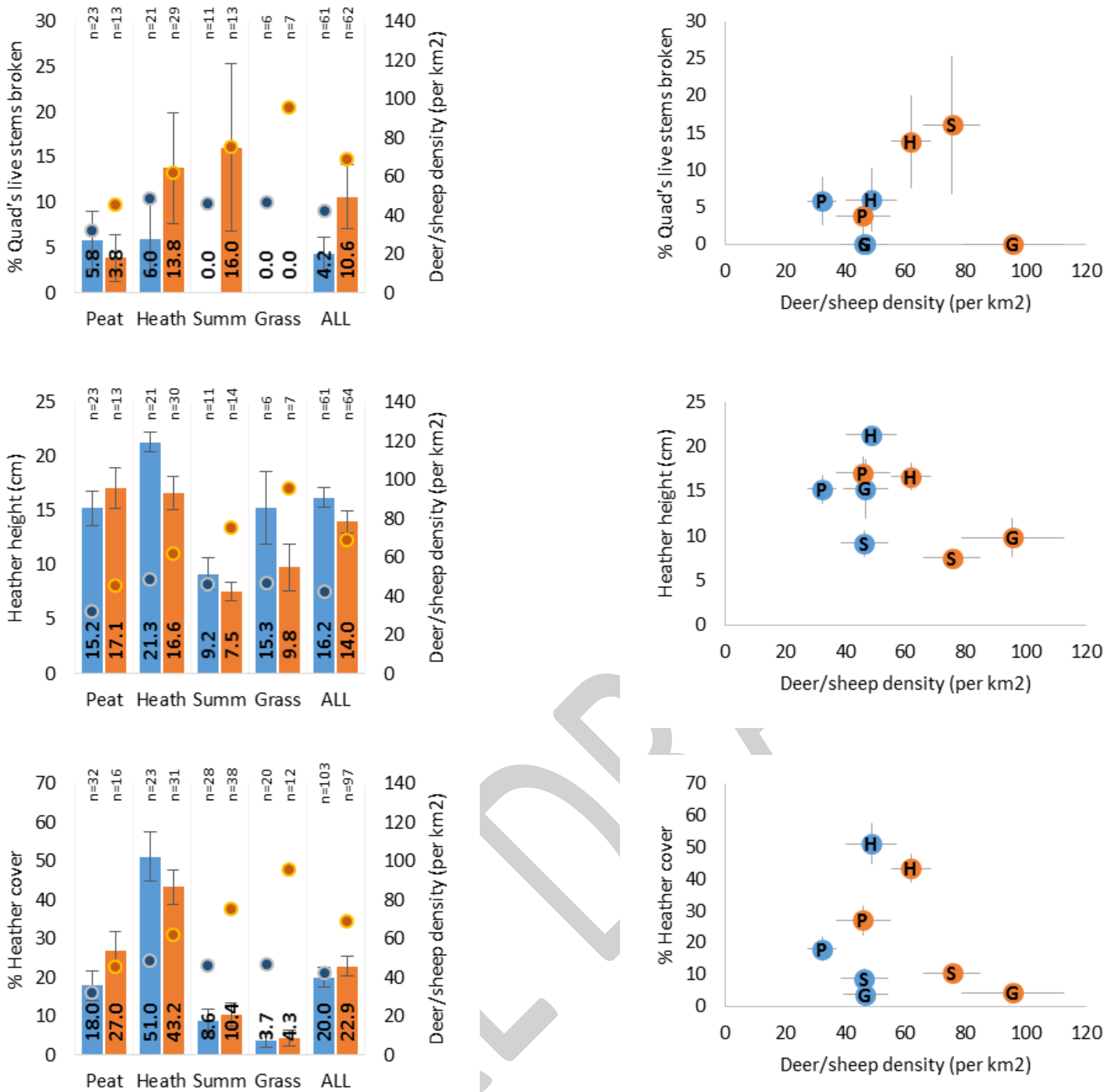


Figure 9b Impacts on heather: mean % live stems broken (upper), mean height of plants in cm (middle) and mean % cover (lower). Blue = Lower zone and orange = higher zone.

Left-hand column: bars display the main variate (+/- 1 SE), the dots show the deer-sheep occupancy level and upper labels confirm the sample size of transects in the analysis. Right-hand column: scatter diagram showing relationship between the variate measured (+/- 1 SE) and the deer-sheep occupancy level (+/- 1 SE) in that habitat/zone combination. Peatland = P, Heathland = H, Summit communities = S and Grassland = G. Standard errors (SE) shown for deer-sheep occupancy in the right-hand column relate to pellet group density and not animal density. General note: sample sizes for Grassland are small so the results obtained should be treated with considerable caution.

165. The results for Blaeberry (Figure 10) show that off-take levels were typically elevated in the Higher zone, and varied in line with occupancy between and within habitat types much in the same way as for heather. However, the level of off-take was on average higher than it was for heather. As for heather, there was a trend towards reduced plant stature in the Higher zone, even though the analysis zones have broadly comparable ranges of altitudes (Figure 10b).

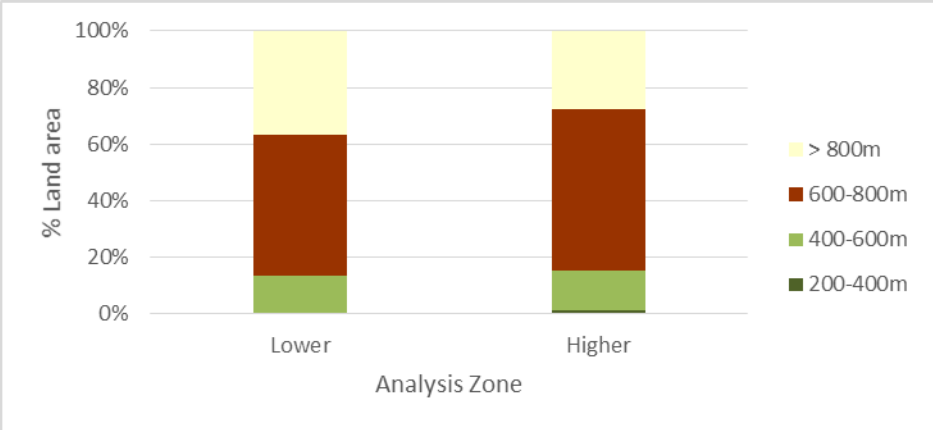


Figure 10b % Sampled transects falling in different altitude zones within the Lower and Higher occupancy zones.

166. Patterns of occupancy and impact for Crowberry broadly mirrored the other dwarf shrubs, in terms of off-take (Figure 11) albeit the average level was markedly lower than for heather and much lower than for Blaeberry. However, there was no trend towards lower plant height at site scale.

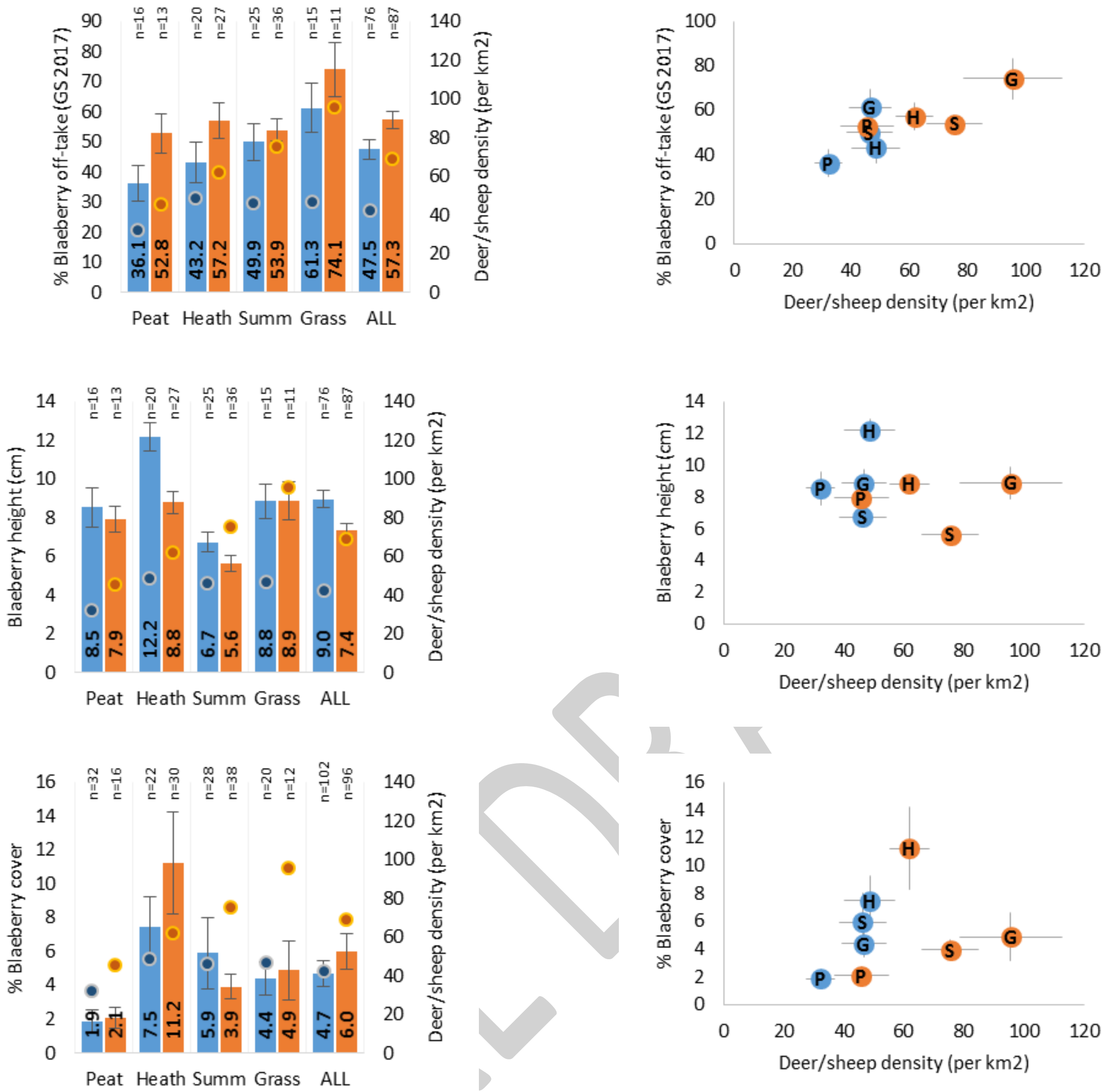


Figure 10a Impacts on Blaeberry: mean % off-take of long shoots (mix of growing season 2017 and 2018, as was sometimes difficult to distinguish in the field) (upper), mean plant height in cm (middle) and mean % cover in autumn 2018 (lower). Blue = Lower zone and orange = higher zone.

Left-hand column: bars display the main variate (+/- 1 SE), the dots show the deer-sheep occupancy level and upper labels confirm the sample size of transects in the analysis. Right-hand column: scatter diagram showing relationship between the variate measured (+/- 1 SE) and the deer-sheep occupancy level (+/- 1 SE) in that habitat/zone combination. Peatland = P, Heathland = H, Summit communities = S and Grassland = G. Standard errors (SE) shown for deer-sheep occupancy in the right-hand column relate to pellet group density and not animal density. General note: sample sizes for Grassland are small so the results obtained should be treated with considerable caution.

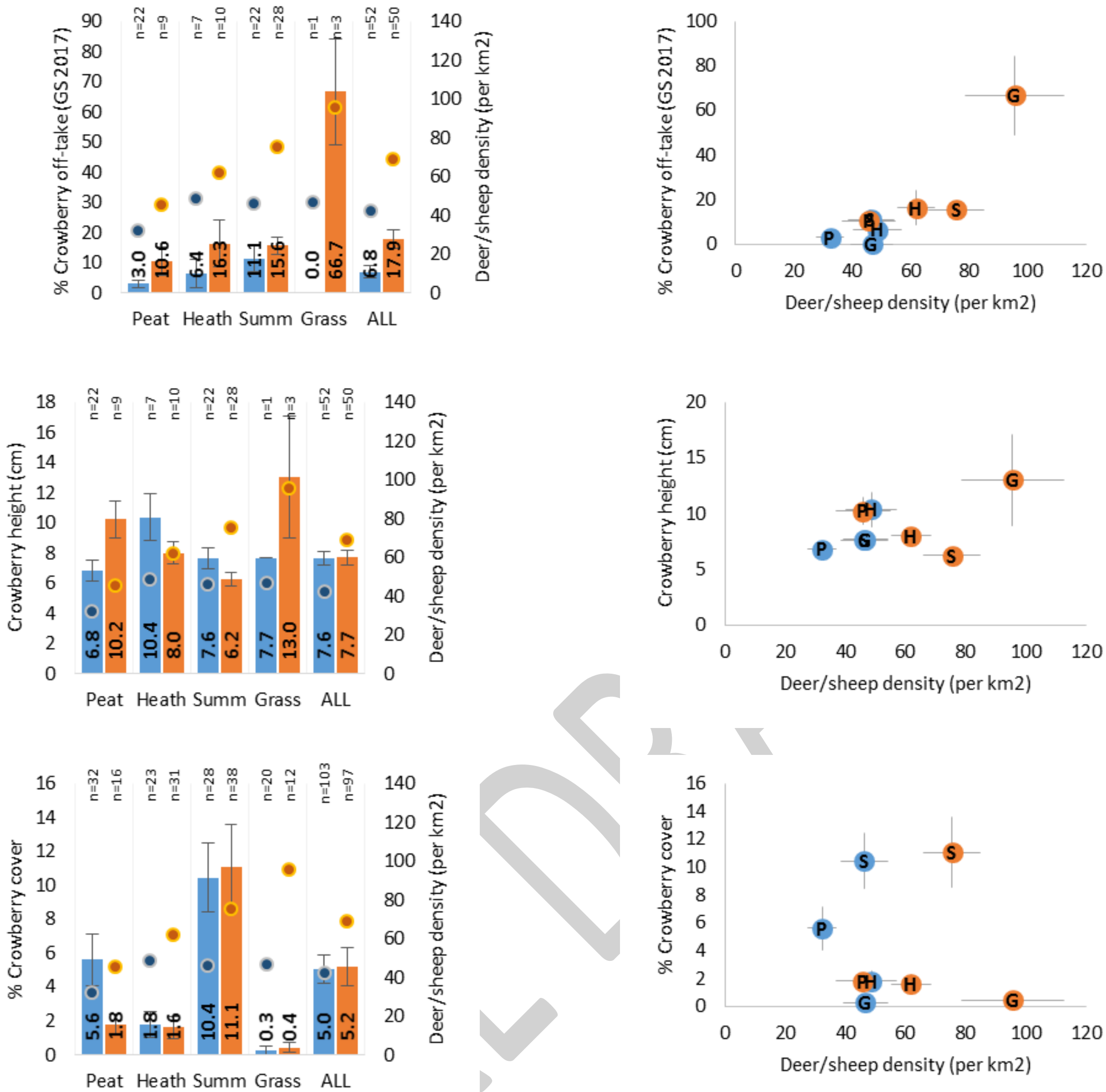


Figure 11 Impacts on Crowberry: mean % off-take of long shoots (mix of growing season 2017 and 2018, as was sometimes difficult to distinguish in the field) (upper), mean plant height in cm (middle) and mean % cover in autumn 2018 (lower). Blue = Lower zone and orange = higher zone.

Left-hand column: bars display the main variate (+/- 1 SE), the dots show the deer-sheep occupancy level and upper labels confirm the sample size of transects in the analysis. Right-hand column: scatter diagram showing relationship between the variate measured (+/- 1 SE) and the deer-sheep occupancy level (+/- 1 SE) in that habitat/zone combination. Peatland = P, Heathland = H, Summit communities = S and Grassland = G. Standard errors (SE) shown for deer-sheep occupancy in the right-hand column relate to pellet group density and not animal density. General note: sample sizes for Grassland are small so the results obtained should be treated with considerable caution.

167. Overall, the level of grazing off-take on ‘true grasses’ was similar between zones (Figure 12) and averaged ~ 10% of total leaves available. There was little evidence of a relationship with occupancy.

168. An average of ~ 0.75 tillers per quadrat were uprooted, with no mean difference apparent between the occupancy zones in the level recorded.

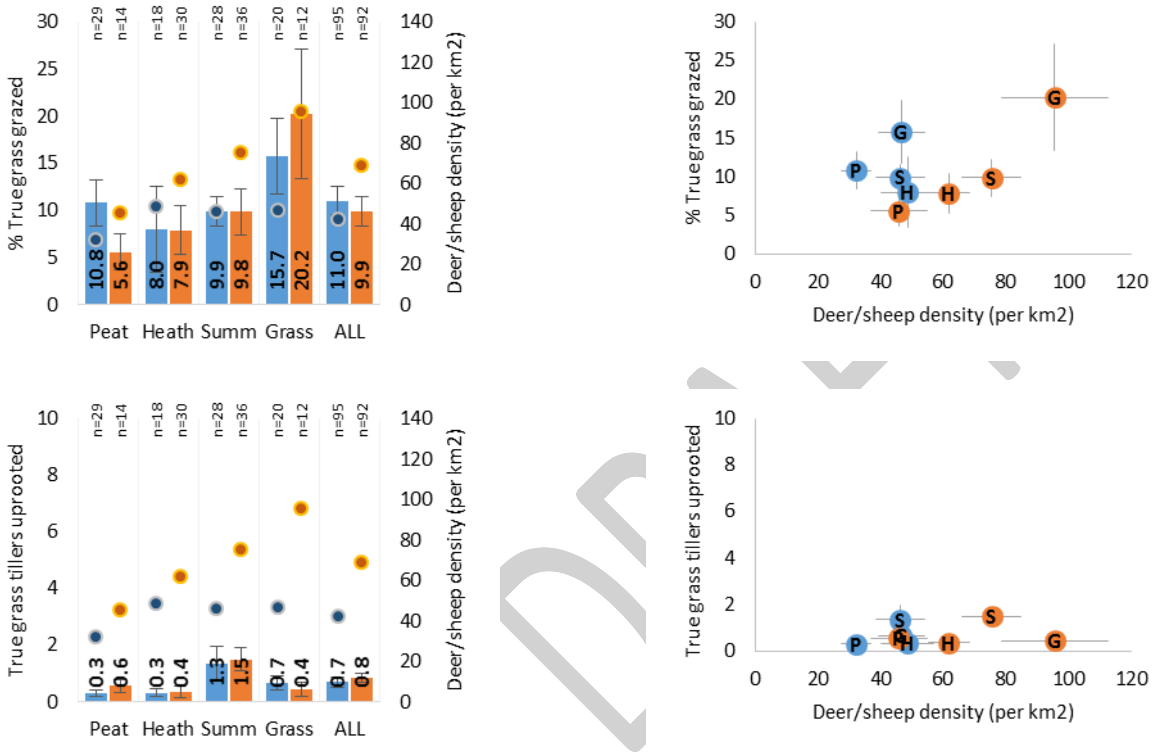


Figure 12 Mean % of ‘true grass’ leaves grazed (upper) and the mean number of tillers uprooted per quadrat (lower). True grasses were classified as all grasses other than Cottongrasses. Blue = Lower zone and orange = higher zone.

Left-hand column: bars display the main variate (+/- 1 SE), the dots show the deer-sheep occupancy level and upper labels confirm the sample size of transects in the analysis. Right-hand column: scatter diagram showing relationship between the variate measured (+/- 1 SE) and the deer-sheep occupancy level (+/- 1 SE) in that habitat/zone combination. Peatland = P, Heathland = H, Summit communities = S and Grassland = G. Standard errors (SE) shown for deer-sheep occupancy in the right-hand column relate to pellet group density and not animal density. General note: sample sizes for Grassland are small so the results obtained should be treated with considerable caution.

169. Uprooting impacts on Stiff sedge, Woolly-fringe moss and Bog moss were generally very low across all zones and habitats (Figure 13). On average around a third of quadrats sampled had trampled lichens in them, potentially a relatively high frequency, but the level did not vary between the Lower and Higher zones.

170. The recorded % of the transect line that comprised bare soil was generally very low at < 1% ground cover (Figure 13) other than on peatland where the level was elevated (more so in the Lower zone) at 2-8% cover.

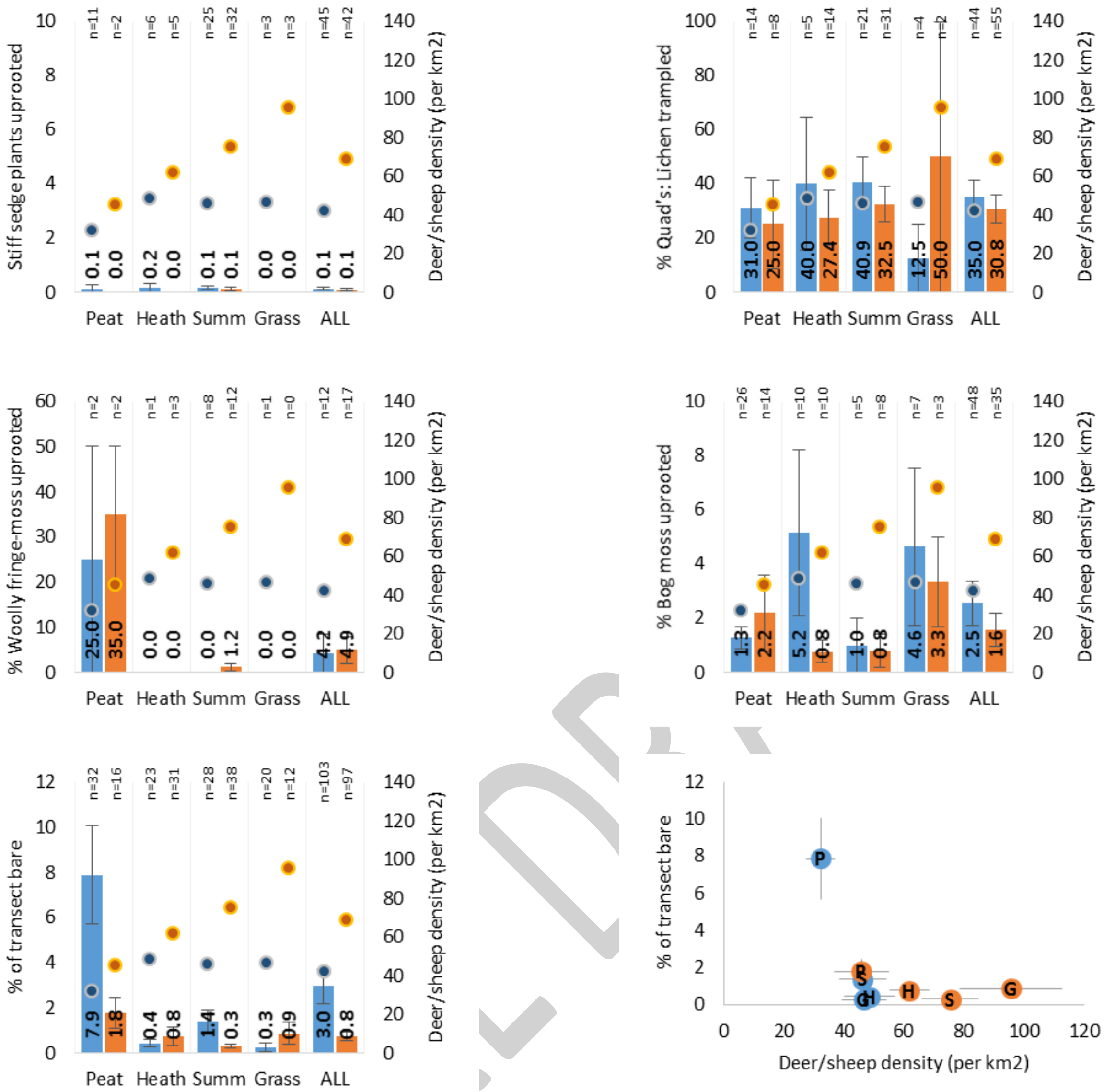


Figure 13 The mean number of Stiff sedge plants uprooted (upper left), the % quadrats with trampled lichen (upper right), the % cover Woolly-fringe moss uprooted (middle left), % of Bog moss cover uprooted (middle right), % transect sampled that comprised bare peat (lower left) with associated scatter diagram (lower right). Blue = Lower zone and orange = higher zone.

Impact-occupancy patterns: focus on peatlands

171. An additional survey was undertaken on all transects which partly or wholly fell on peatland habitat (61 / 200 transects qualified; 30.5%). On these transects, an average of 20.5% was judged to comprise intact bog and a further 37.4% was judged to comprise eroding bog surface or eroded (i.e. loss of peat, replaced now with other habitats); a total of 57.9% (Figure 14). The findings imply that ~ 17.7% of the land surface within the survey area once comprised functioning blanket bog, whereas now the figure is no more than ~ 6% based on the survey results obtained. That said, the areas included in the 'intact bog' category within the survey often comprised islands or strips of habitat set within a matrix of heavily eroded features. Given the strong drawdown effects experienced by the bog water table on the edges of these features, which typically extend well inwards from hagg edges to their interiors the extent of 'active bog', stable in the long-term and resistant to ongoing oxidative loss - is likely to be much smaller again (perhaps 1-3%).

172. The land classified as blanket bog comprises 100% intact 'acrotelm' (other than where micro-erosion was acting) whereas in the eroding bog a mix of 4 main landforms are apparent, including hagg tops (22.4%), gully walls and hagg aprons (22.1%), gully bases (34.2%) and peat flats (21.2%).

173. Peat depth varies between the landforms, with progressively less frequent deposits of deeper peat arising across a gradient from intact/haggs, through gully walls to gully bases. Peat flats tended to have some deeper deposits present, as their location is frequently at cols where peat deposits are deeper whereas erosion gullies tend more often to be on sloping ground. The mean peat depth[67] is typically less than 1m even where the bog is relatively intact, dropping to as little as 41cm (gully bases).

174. The cover of bare peat was very variable, with the highest levels of cover on peat flats (35.7%) followed by gully walls (28.6%) and bases (22.2%). Intact bog had the lowest level of cover (~ 1%).

175. Signs of colonisation of the bare peat with new plants were very variable, with the highest level on intact bog (~ 50% of bare peat had new colonising plants present) and the lowest was on gully walls (~ 17% of peat had colonising plants present).

176. Bog moss was generally most prevalent on intact bog surfaces (combined average of 29.6% cover) whereas in the more severely eroding features (gully walls and bases) the average cover was typically in the order of 17-18%. Peat flats were intermediate between the two. The cover of thick-branched species (e.g. *Sphagnum papillosum* and *S. magellanicum* etc) was lowest on gully walls where drought stresses would be expected to be most severe.

[67] Occasional depths of > 2m were detected, but probes were only 2m long hence this figure will be a slight underestimate.

177. Bog water tables at the time of the survey (although rainfall was somewhat variable over the course of the autumn visit, which was spread over several weeks) varied markedly. Bog water tables were detected least frequently on gully walls (~ 30% of quadrats) and were detected most frequently on peat flats (61.1% of quadrats). This mirrors the pattern of Bog moss cover.

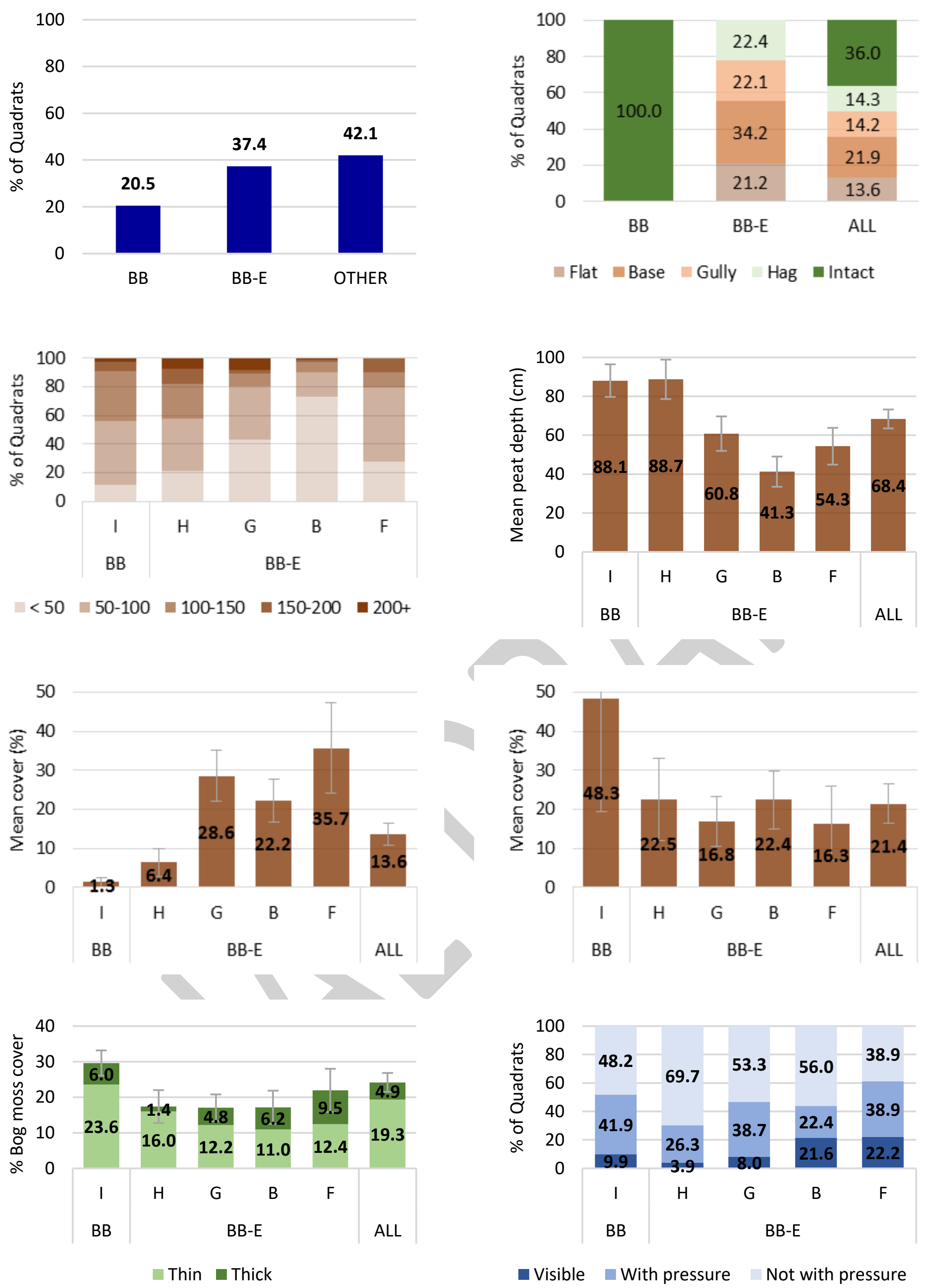


Figure 14 The prevalence of peatland habitat types (upper left), the prevalence of key landform types (upper right), peat depth variation in cm classes (upper middle left), mean peat depth with SE (upper middle right), % cover of bare peat (lower middle left), % bare peat re-colonising (lower middle right), % cover of thin and thick branched bog moss (lower left) and relative proximity of bog water to ground surface at time of survey (lower right; visible water table, appears with boot pressure or no sign). BB = blanket bog, BB-E = eroding bog and OTHER = non bog habitats. I = intact bog, H = peat hagg top, G = erosion gully wall or hagg side, B = gully base, F = peat flat.

178. The frequency of quadrats with identifiable deer paths was elevated in the Higher zone on the eroding landforms (~ 25%), whereas on the intact landforms the prevalence was similar (~ 15%) (Figure 15). Hoofmarks tended to be more prevalent on landforms in the Lower zone (60% of quadrats vs 40%). Over-deepened path features seem equally prevalent (~ 60% of quadrats). Signs of grazing on colonising plants were relatively infrequent, albeit somewhat higher in the Lower zone; a similar situation was apparent in terms of trampling.

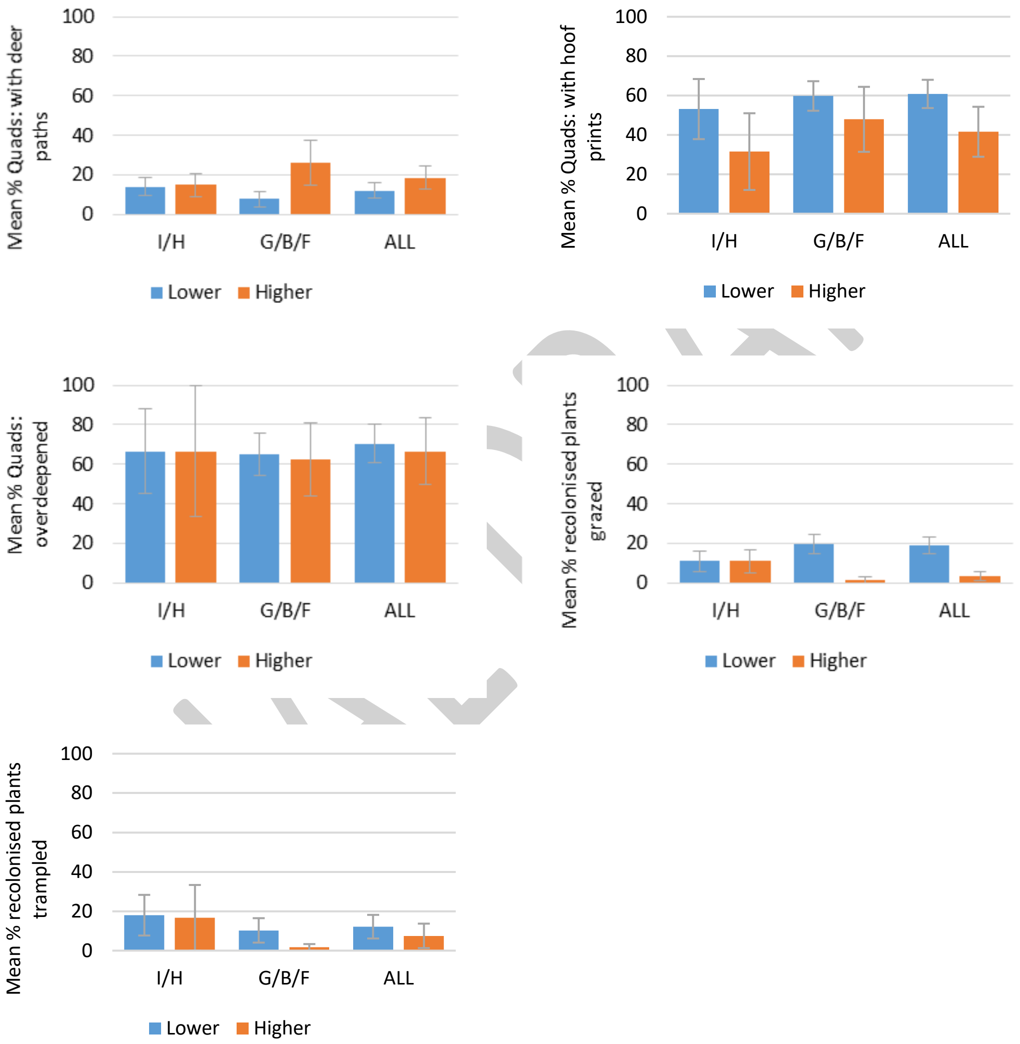


Figure 15 The prevalence of deer/sheep impacts specific to peatland: % quadrats with a visible deer path (upper left), % quadrats with visible deer prints (upper right), % quadrats where an over-deepened path feature was present (middle left), % quadrats on which re-colonising plants had been grazed (middle right) and % re-colonising plant cover that had been trampled (lower left). Data were stratified into two broad landform types: (i) Intact bog + peat hagg tops and (ii) eroding features e.g. gully walls and bases. Data are analysed in the two zones (Higher and Lower occupancy, plus at overall site scale = ALL). Error bars are +/- 1 standard error.

SNH HERBIVORE IMPACT ASSESSMENT

Grid-based assessment: 2018

179. An Herbivore Impact Assessment (HIA) was undertaken at each transect grid point, if one of three main habitat types were present. A total of 171 transect locations had an HIA quadrat installed (the other 29 locations had less common habitats present – e.g. flush or species rich grassland - hence were not sampled). Final sample sizes were: blanket bog n=57 quadrats, dwarf shrub heath n=55 and summit heath n=59.

180. The impact class (Low L, Low-Moderate LM, Moderate M, Moderate-High MH or High H) for each quadrat was calculated from the median of the small-scale indicators. Quadrat data for each of the three habitat types were then allocated to one of the two occupancy analysis zones (the 'Higher' occupancy zone – which had a summer density of 69 deer/sheep per km^2 - or the 'Lower' occupancy zone with 43 per km^2). Data were analysed in three ways: grazing indicators only (Figure 16), trampling indicators only (Figure 17) and all indicators combined (Figure 18; see also Map 14).

181. On the basis of the target levels set by SNH for blanket bog, dwarf shrub heath and summit heath on the designated sites at Caenlochan - at least 90% of sampled quadrats need to fall in the L or LM impact class - all habitat types sampled in the wider 2018 study area failed to reach the target in both the Higher occupancy zone and the Lower occupancy zone (Figure 16-18).

a) Grazing indicators:

   i) 13.5% of blanket bog quadrats scored L or LM in the Lower occupancy zone (5% of quadrats in the Higher occupancy zone), as compared to a target of 90%.

   ii) 26.9% of summit heath quadrats scored L or LM in the Lower occupancy zone (24.2% of quadrats in the Higher occupancy zone).

   iii) 47.3% of dwarf shrub heath quadrats scored L or LM in the Lower occupancy zone (31.5% of quadrats in the Higher occupancy zone).

b) Trampling indicators:

   i) 40.5% of blanket bog quadrats scored L or LM in the Lower occupancy zone (45% of quadrats in the Higher occupancy zone).

   ii) 57.7% of summit heath quadrats scored L or LM in the Lower occupancy zone (60.6% of quadrats in the Higher occupancy zone).

   iii) 57.9% of dwarf shrub heath quadrats scored L or LM in the Lower occupancy zone (33.3% of quadrats in the Higher occupancy zone).

182. The % of quadrats in the L or LM impact classes was plotted against the average level of deer-sheep occupancy (calculated from the FAR data) for each habitat within each zone (and for all habitats combined). The objective of this analysis

was to establish whether there was a relationship apparent between occupancy level and the % plots in the L / LM impact class. If a strong relationship was apparent, at habitat scale or overall, then a prediction might usefully be made of how low the occupancy level on the 2018 study site might need to be pushed for the SNH target of >90% to be achieved with certainty in each habitat type (and thus overall) in future. Although established at the larger spatial scale of the 2018 survey area, any relationships apparent might also – with all else equal - be expected to hold broadly at the somewhat smaller scale of the designated sites themselves.

183. Several noteworthy points are evident from the scatter-diagrams in Figures 16 and 17 (grazing and trampling results):

a) Grazing indicators: the % L / LM quadrats was larger in the Lower occupancy zone than in the Higher, across all habitats, for grazing indicators. However, the form of the relationship appeared to vary somewhat between habitat types. For example, if extrapolated out beyond the bounds of the available observations under an assumption of linearity the data for dwarf shrub heath suggested that the target of 90% might be met if occupancy levels were reduced to ~ 10 per km^2. However, for blanket bog the data if extrapolated out linearly suggest that the target would not be met even if occupancy levels were reduced to 0. In large part, these differences are likely to be due to sampling error given (i) the small sample size overall, (ii) quadrat numbers varied between habitats and zones and (iii) the variation in habitat distribution and patch size between and within zones. In essence, the results were obtained from an observational study and not from a deliberately design trial. Of course, some of the difference may be related to HIA methodology (e.g. an assessment of a patch of blanket bog and a patch of dwarf shrub heath with the same occupancy levels may yield differing HIA impact scores[68]). Also, there may be a genuine difference in the form of the relationship (i.e. the characteristics of bog structure and functioning might be adversely affected by a lower occupancy level than heath, or the relationships may be non-linear).

b) Trampling indicators: the % L / LM plots in the Lower and Higher occupancy zones varied for dwarf shrub heath in line with expectations (i.e. a larger % was recorded in the Lower zone). However the values recorded in each occupancy zone for summit heath were very similar as they were for blanket bog. The lack of difference in these two habitats might in part be explained by sampling error, as described for the grazing indicators. However it is probably, in part, explained by methodological reasons. For example, there are only 2 trampling indicators for summit heaths so the system is likely to lack sensitivity given the analysis employs medians (see Methods; also see next section on random-quadrat HIA). The trampling indicators generally also have fewer category options to select from during the assessment (normally

[68] We do not know if occupancy level was taken into consideration when the methods were being field calibrated in the 1990's.

only 2 options are given for a score – L or High H) whereas in the grazing indicators there are often 3 options provided – L, Moderate M or H).

c) The number of quadrats sampled in any given habitat type and zone was fixed. Given that the density of deer on the site is known to be at the upper end of the spectrum for upland sites in Scotland, the majority of sampled quadrats unsurprisingly fell in the M or H impact classes. As a result, few could fall into the L or LM class. Given the relatively small sample sizes of quadrats available in each habitat-zone combination, each quadrat counts for a sizeable proportion of the calculated %. We might expect in such cases that the % L / LM quadrats is a relatively coarse and unresponsive variate. An alternative analysis was therefore undertaken to examine the nature of the relationship between occupancy level and the % H plots recorded:

   i) The same problems are apparent with the % H plots analysis as with the % L/LM (e.g. low sample sizes in general, imbalanced analytical structure arising from the observational study design etc). Nevertheless, the results produce a more defined relationship overall when using the grazing indicators. All 3 habitat types display a similar trend, with a markedly reduced % H plots present in the Lower zone than in the Higher zone.

      (1) For dwarf shrub heath, the results if extrapolated suggest that the % H plots might be expected to decline towards 0 at a summer occupancy level of ~30 per km^2.

      (2) For blanket bog, the equivalent value is ~ 15 per km^2.

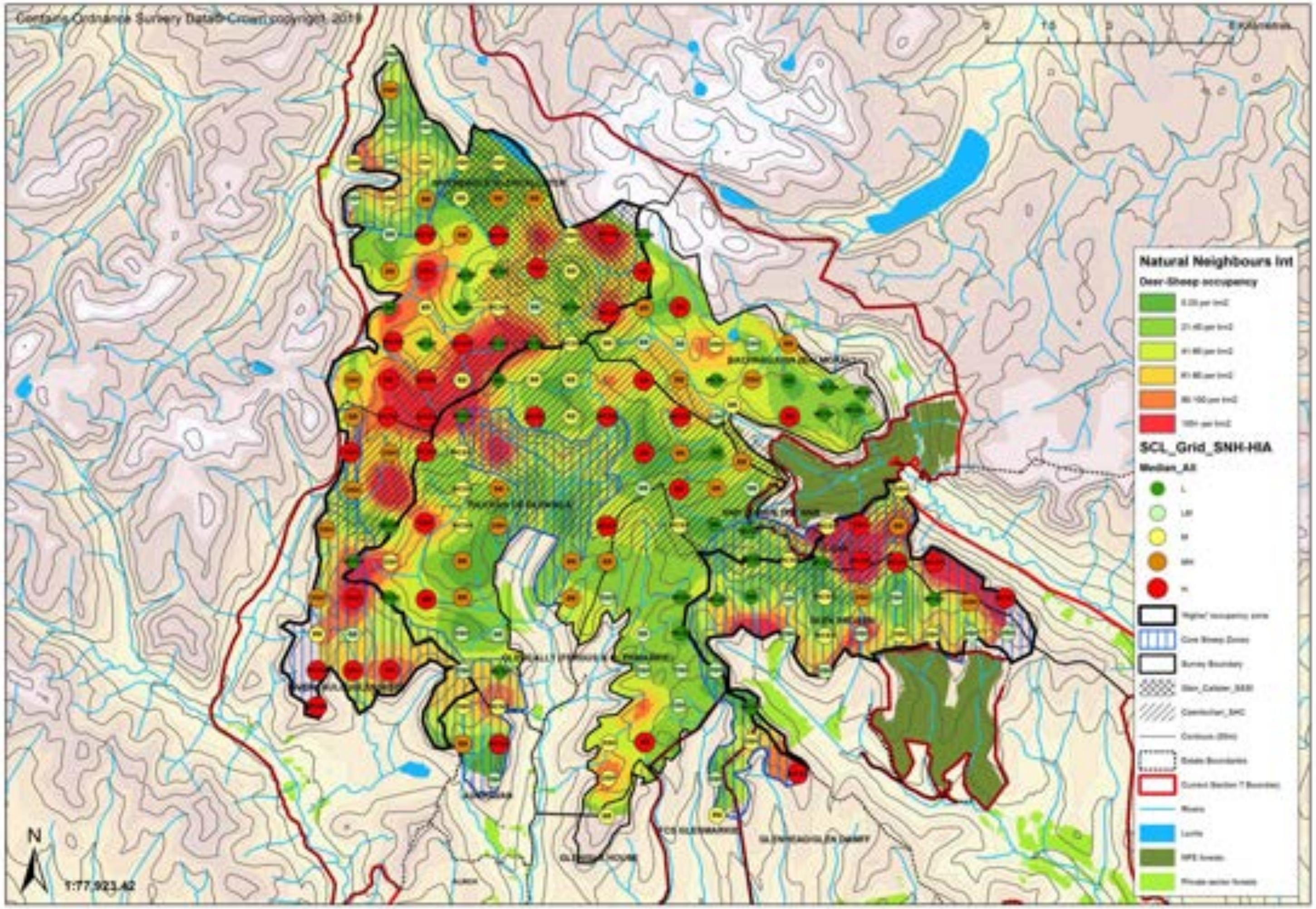
      (3) For summit heath the equivalent value is ~ 0 per km^2.

      (4) For all 3 habitats combined, the value is ~ 10 per km^2.

   ii) Given that the target level for the designated sites is 90% L / LM plots, it is clear that no more than 10% of quadrats sampled during a 'successful assessment' could score M or H. Given that M plots might normally be expected to be more commonplace than H in such situations - with all else equal - it could be argued that the tolerable % H plots would be less than 5% and realistically no more than 1-3% in an assessment. On this basis, it could be argued that local occupancy levels greater than 10-15 per km^2 in the summer range at Caenlochan are *unlikely* to produce the desired assessment outcome.

   iii) A target occupancy level would of course have to be agreed in respect of the site's objectives. If, for example, recovery of blanket bog to favourable condition is considered the most important issue then the target occupancy level might have to be set lower than if it were set with the primary focus being on dwarf shrub heath. If, however, it were set in relation to montane willow scrub – which is arguably the most sensitive of the habitats present on the site – then it is likely the target occupancy level would have to be set much lower.

184. The analysis of systematic-grid HIA data presented has acknowledged weaknesses relating to study design. However, the absence of a strong gradient in deer density across the site – from very low to very high – is, in reality, the factor that most hampered efforts to define robust local relationships between occupancy and impacts using HIA data. For this reason, we present HIA results later in this chapter from other upland sites across Scotland with low-moderate deer densities help place the Caenlochan site data in context.



Map 14 The median impact class (grazing & trampling indicators) recorded on the survey grid for blanket bog, dwarf shrub heath and summit heaths at Caenlochan

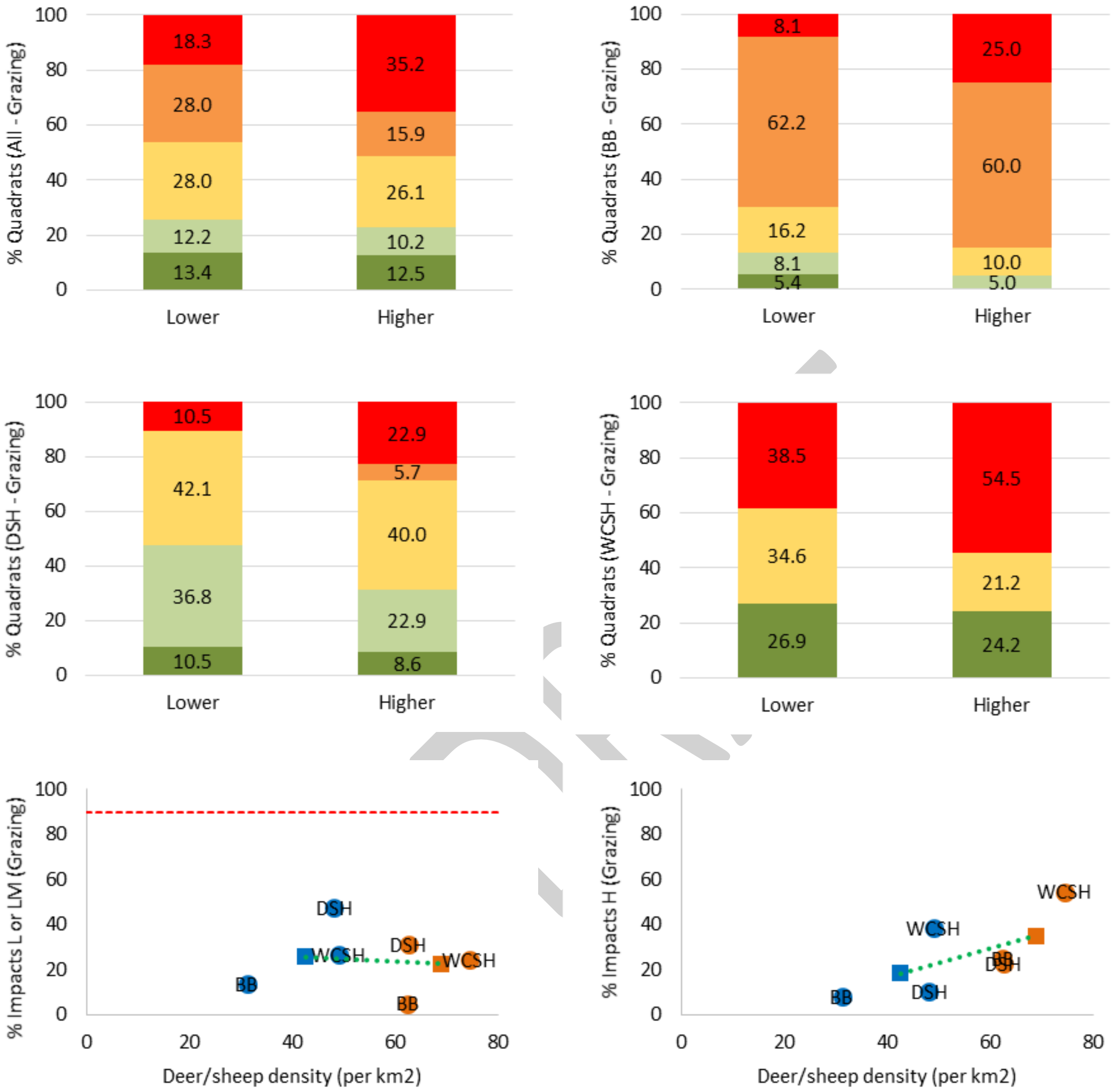


Figure 16 The % sampled quadrats falling in each HIA impact class (*grazing indicators only*) on the grid-based survey: all habitats (upper left), quadrats sampled with blanket bog indicators (upper right), dwarf shrub heath indicators (middle left), and wind-clipped summit heath indicators (middle right). Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. Scatter diagrams show the relationship between the % sampled plots in the Low or Low-Moderate category (target 90%) and the measured occupancy (lower left) and the % sampled plots in the High category compared to occupancy (lower right). Blue = Lower zone and orange = Higher zone. Circles = habitats-specific results and squares = overall results for all samples combined. The red dashed line is the target level set by SNH for the designated sites, for reference. The green trend line has been added to help readers visually track relationships evident between occupancy and impact level (only presented for all data combined - this masks habitat-specific trends but uses a larger sample size). Ideally, these charts would be generated from a larger sample size of observations obtained from multiple study sites all with a wider range of occupancy levels present. Presently, only the limited data displayed above are held for Caenlochan. Extrapolation beyond the limits of these data points (i.e. to infer what result might be obtained at a lower occupancy level) is not ideal but in the circumstances is the best option available. That said, see Table 17 which presents the findings of similar studies from other Scottish sites – these data help place the Caenlochan data in context.

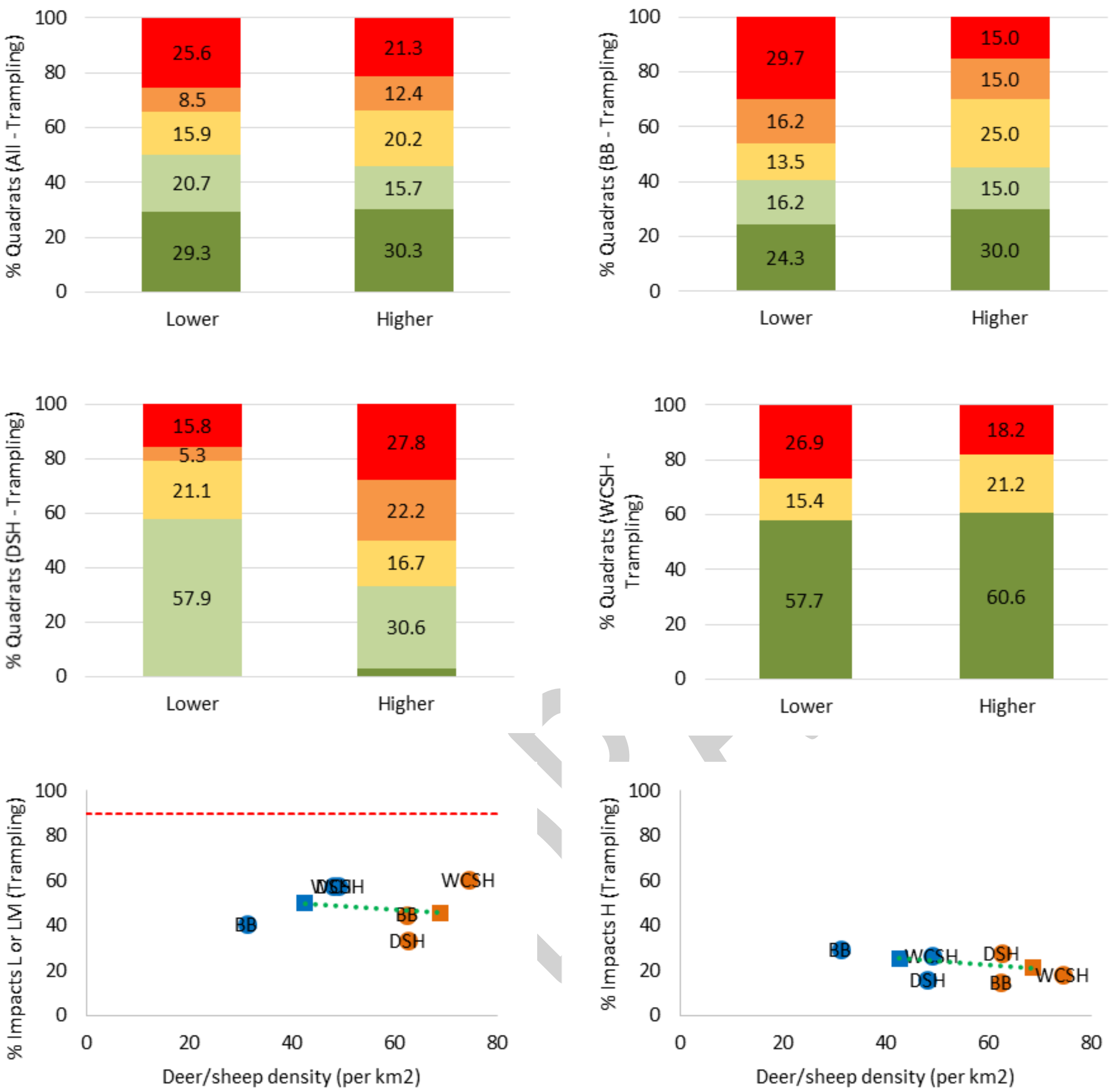


Figure 17 The % sampled quadrats falling in each HIA impact class (*trampling indicators only*) on the grid-based survey: all habitats (upper left), quadrats sampled with blanket bog indicators (upper right), dwarf shrub heath indicators (middle left), and wind-clipped summit heath indicators (middle right). Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. Scatter diagrams show the relationship between the % sampled plots in the Low or Low-Moderate category (target 90%) and the measured occupancy (lower left) and the % sampled plots in the High category compared to occupancy (lower right). Blue = Lower zone and orange = Higher zone. Circles = habitats-specific results and squares = overall results for all samples combined. The red dashed line is the target level set by SNH for the designated sites, for reference. The green trend line has been added to help readers visually track relationships evident between occupancy and impact level (only presented for all data combined - this masks habitat-specific trends but uses a larger sample size). Ideally, these charts would be generated from a larger sample size of observations obtained from multiple study sites all with a wider range of occupancy levels present. Presently, only the limited data displayed above are held for Caenlochan. Extrapolation beyond the limits of these data points (i.e. to infer what result might be obtained at a lower occupancy level) is not ideal but in the circumstances is the best option available. That said, see Table 17 which presents the findings of similar studies from other Scottish sites – these data help place the Caenlochan data in context.

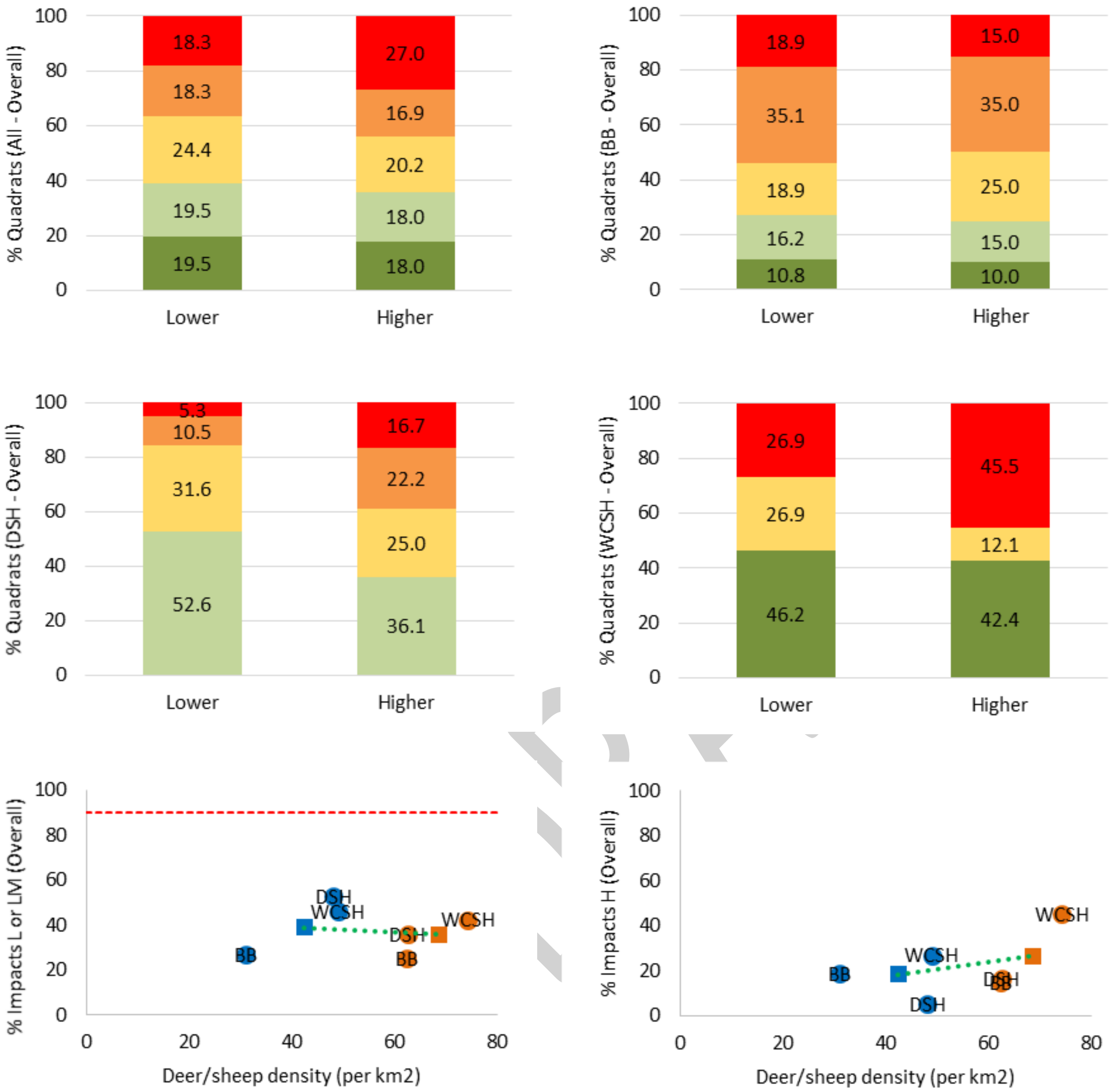


Figure 18 The % sampled quadrats falling in each HIA impact class (grazing & trampling indicators combined) on the grid-based survey: all habitats (upper left), quadrats sampled with blanket bog indicators (upper right), dwarf shrub heath indicators (middle left), and wind-clipped summit heath indicators (middle right). Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. Scatter diagrams show the relationship between the % sampled plots in the Low or Low-Moderate category (target 90%) and the measured occupancy (lower left) and the % sampled plots in the High category compared to occupancy (lower right). Blue = Lower zone and orange = Higher zone. Circles = habitats-specific results and squares = overall results for all samples combined. The red dashed line is the target level set by SNH for the designated sites, for reference. The green trend line has been added to help readers visually track relationships evident between occupancy and impact level (only presented for all data combined - this masks habitat-specific trends but uses a larger sample size). Ideally, these charts would be generated from a larger sample size of observations obtained from multiple study sites all with a wider range of occupancy levels present. Presently, only the limited data displayed above are held for Caenlochan. Extrapolation beyond the limits of these data points (i.e. to infer what result might be obtained at a lower occupancy level) is not ideal but in the circumstances is the best option available. That said, see Table 17 which presents the findings of similar studies from other Scottish sites – these data help place the Caenlochan data in context.

185. Given the findings of the grid-based HIA survey it would seem that deer/sheep occupancy levels would need to be reduced markedly for the % of sampled plots in the L and LM categories to reach a minimum value of 90%. In turn, deer occupancy of the *designated sites* in summer is strongly related to the size of the overall herd in the wider Section 7 control area - it follows that for targets to be achieved on the designated sites deer density in the wider control area would need to be reduced markedly too.

186. On the basis of evidence available[69], it would appear unlikely that the % H plots would fall to negligible levels across all 3 main habitat types until local occupancy levels fell to within the range ~10-30 per km^2 (perhaps 20 per km^2 on average). Presumably, even at this stage, a considerable proportion of plots could still remain in the Moderate category in some habitats implying that the local deer/sheep occupancy level may need to be reduced below this level (to say 15 per km^2, and perhaps lower e.g. 10 per km^2).

187. The average density of deer-sheep in summer 2018 within the survey site was estimated at ~ 55 per km^2 (corresponding with 43 per km^2 in the Lower zone and 69 per km^2 in the Higher zone). Were current average survey site occupancy levels (Figure 19; red bars) able to be reduced by approximately half, to ~27.5 per km^2 overall, based crudely on a halving of the overall Section 7 population for ease of thinking, this would presumably still leave many areas with high occupancy levels (Figure 19; orange bars).

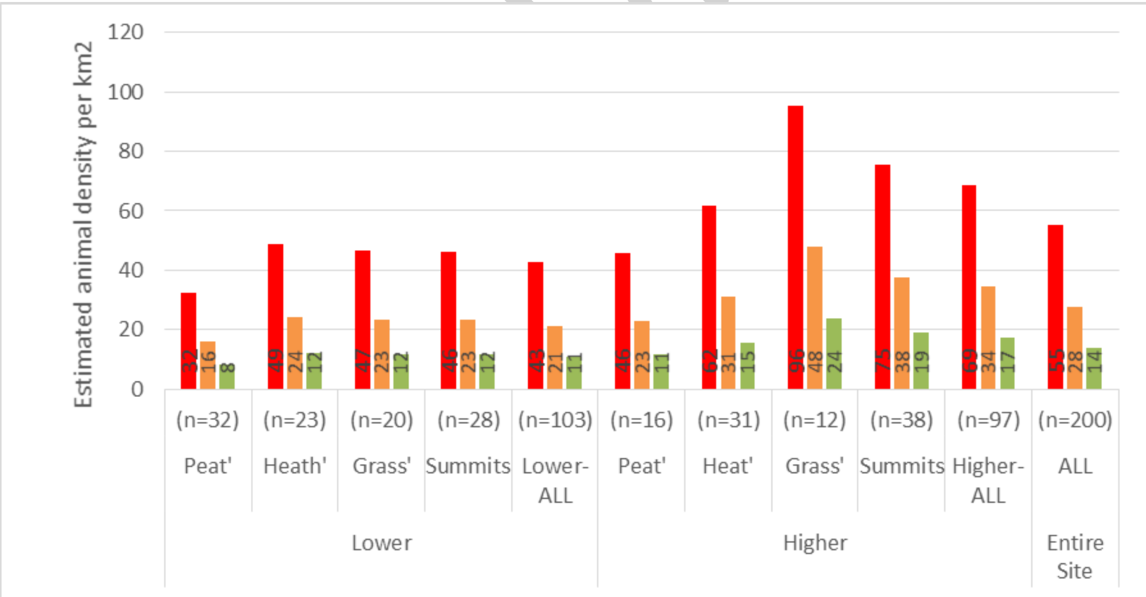


Figure 19 The mean FAR per km^2 as measured (i) in summer 2018 (red), (ii) as predicted if overall deer densities in the current Section 7 area were reduced by 50% (orange) and (iii) if reduced by 75% (green). Model assumes a linear response across all areas and habitats, which of course is unlikely to arise.

[69] The sampling design employed is not balanced, in terms of the sample sizes in each zone and habitat. Moreover, the sampling intensity per habitat and zone was not set *a priori* hence the predictive power of these charts is inevitably limited.

188.Perhaps by reducing current deer/sheep densities at overall site scale - and in turn at the scale of the current Section 7 area - by 75% the local occupancy levels on the 2019 study area may reach a level (8-24 per km^2, with an average of 14 per km^2 over the whole study site) whereby the habitat condition targets are more likely to be met albeit this could not be guaranteed (Figure 19; green bars). Of course, in reducing the occupancy level the current distribution of the deer on site may change hence the zone- and habitat-specific responses shown in the model in Figure 19 may vary somewhat. That said, deer seem to show a strong preference for parts of the Higher zone – and for certain habitats therein – hence any future shift in relative distribution may not be overly-marked.

189. SNH presumably hold data sets from other upland sites in Scotland that might be used to help obtain a clearer understanding of the likely occupancy levels at which key habitats might reach their targets. We understand that SNH is currently working on a meta-analysis of their national HIA data sets which could help in this regard, but it was not published at the time of writing[70]. In the meantime, the contractor chose to examine records held for a selection of other sites in an attempt to corroborate the predictions arising from the grid-based HIA survey of Caenlochan in 2018 (Table 17).

190.On the basis of other HIA data evidence held, only the Invereshie NNR site and the Beinn Eighe NNR/Torridon SSSI site pass most of the SNH targets set for Caenlochan. That said, blanket bog did not pass on either of these sites despite there being a very low average density of deer present on each.

Table 17 Outcomes of HIA surveys on a range of upland sites for government agencies, which included the 3 main habitat types assessed in 2018 on the grid-based survey at Caenlochan. Sites vary in size, but are typically at least 3,000-4,000 ha. Most of them lie within a broader altitude range than the Caenlochan site as they include more low ground (down to sea-level in the case of Beinn Eighe-Torridon). The deer densities quoted in the table are winter densities, calculated in the main from helicopter count data, rather than local 'range densities' (i.e. where count data adjusted so that they better reflect the local occupancy level of deer in the areas where – and at the times of year when - impacts were actually occurring).

Site	Deer per km^2 Winter count, entire range		% Plots = L or LM: WCSH	% Plots = L or LM: DH	% Plots = L or LM: BB	HIA Year	Count Year	HIA survey comments	Count comments
Invereshie NNR	3.0		100%	95%	88%	2019	2019		Dung count
Beinn Eighe NNR / Torridon SSSI	4.2		100%	94%	83%	2012	2017		Heli count
Drumochter Hills SAC	10.3		82%	80%	42%	2013	2012		Heli count
NFE South Affric	20.0		91%	17%	21%	2014	2014	WCSH very localised	Dung count
Caenlochan S7	23.5		44%	42%	26%	2018	2018		Heli count

191. The Drumochter Hills SAC was next closest to passing, but in reality was still relatively far away from target compliance across all 3 habitat types. The South Affric study site was far more similar to Caenlochan, the exception being on the summit heath communities which met the target. That said, this habitat is very uncommon on the South Affric study area (it is typical of the West Highlands, in that only the narrow summit ridges contain alpine heaths / montane grasslands).

[70] Jenny Bryce, SNH Wildlife Ecologist - personal communication.

192.Other useful information which could potentially help predict the likely level of deer-sheep occupancy needed to enable habitat targets to be met at Caenlochan is available. The OIA method employed at Caenlochan has been employed at a wide range of other sites across Scotland owned by SNH (NNR's and some designated sites) as well as on many parts of the the National Forest Estate. To date the results of all these studies have not been compiled, as they were all gathered as part of separate projects commissioned by different clients and designed to underpin operational decision-making. However, given the aims of the Caenlochan study it seemed worthwhile undertaking some initial compilation work. The results were compiled from a selection of agency-owned sites to explore the relationship between deer occupancy levels (as measured in late spring or early summer) and the % annual off-take of heather off-shoots from the previous growing season (Figure 20).

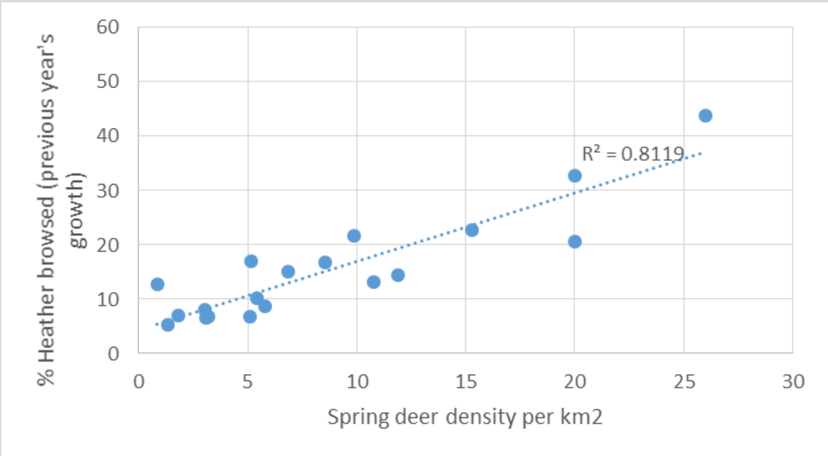


Figure 20 Results from a compilation of data arising from select OIA studies undertaken across the Scottish uplands where a range of typical habitat types (e.g. peatland, dwarf shrub heath and summit communities) were present. 7 separate sites are included, within which 1 - 7 analysis zones were assessed separately, including Caenlochan (the two highest browsing data points on the chart). A wide range of other variates were also recorded, but for the purposes of this report only % heather off-take is presented. Sites were sampled with two different types of pellet group count study (some FAR, and some using faecal standing crop or FSC) and at somewhat differing times from May to July; the 'deer density' figures have not at this stage been adjusted to a common date to reduce related bias, due to a shortage of time, but nevertheless it was felt that presenting this compiled data was still of some use given its uniqueness. The Caenlochan density data were calculated from the June 2018 FSC data, as opposed to the over-summer FAR data, to pull the data in line with other studies. The analysis presented is for exploratory purposes only and is acknowledged to be very rudimentary – a scatter diagram of data through which for ease of reference a linear trend line has been fitted and R^2 value calculated in Microsoft Excel[71]. The data ideally need a more sophisticated treatment (e.g. taking into account site and sub-site sampling design elements, altitude, habitat types, other herbivores present etc) but this was not possible within the project budget constraints imposed.

[71] R^2 of 82%. 0% indicates that the model explains none of the variability of the response data around its mean. 100% indicates that the model explains all the variability of the response data around its mean. In general, the higher the R-squared, the better the model fits." https://blog.minitab.com/blog

193.In order to attain a minimal level of heather off-take on most upland sites, which is arguably necessary if highly suppressed heather cover is to be able to recover over a period of 10 years or so, even at lower altitudes, it seems that deer occupancy levels across the Section 7 area as whole would need to be reduced to ~ 10 per km^2 and ideally to 5 per km^2 or below. Even with such low densities present, most of the other OIA study sites still register a degree of background browsing which could hamper rapid habitat recovery. In most cases this background level is assumed to arise from the combined effects of mountain hare, grouse, roe deer, goats etc.

194.Another consideration is that the Beinn-Eighe-Torridon site reported on in Table 17, which had some of the most favourable HIA results of all sites presented, had few or no mountain hare present. Invereshie NNR, the other low impact site, did have hare present but with hare pellet densities that were 10-fold lower than at Caenlochan. A key reason that the site condition targets might not be met at Caenlochan - even if a 75% reduction or more in deer/sheep occupancy was delivered - is that our analysis of the grid-based data so far ignores entirely the potential contribution of hare to the present pattern and level of impacts.

195.We have indicated, albeit through somewhat crude modelling using the estimated dry weight of dung present on site as a proxy, that mountain hares might conceivably contribute ~ 10% to the measured level of dry matter off-take across the site as a whole (and more locally, say 15% overall, for example in the Higher occupancy zone) assuming that dry matter intake and output ratios are similar across species. Of course, it is conceivable that hare could contribute disproportionately more given that they are assumed to live on site all year round whereas the red deer appear to use the high ground less in the winter and spring. Also, the dung of each species may have experienced differential levels of decomposition in the lead up to the autumn 2018 study – this is another form of potential bias[72]. Moreover, relative rates of intake / digestion / output may vary between species. That said, on the balance of evidence available from the dry weight modelling it would still seem sensible to assume that deer and sheep produce the majority, and presumably the vast majority overall, of impact measured given the outcomes of the dry weight modelling.

196. Moreover, hare population density is reported to vary considerably within the course of a typical year in the Grampian mountains because of the effects of changing food supply and seasonal weather patterns in determining survival[73]. In fact, their density late in the calendar year normally represents a distinct peak – densities in the spring tend to be markedly lower, by as much as ~ 50%, implying our model with all else equal could conceivably overstate the contribution of

[72] This could have been dealt with had the hare dung survey involved clearance and re-marking. Due to shortage of time we chose not to do this albeit we did measure standing crop density twice. The densities were similar, implying a degree of turnover in the system between visits. If anything, the turnover rate was higher than that for deer.

[73] Flux, J (1970) Life history of the Mountain hare (*Lepus timidus scoticus*) in north-east Scotland. Journal of Zoology, 161, 1, 75-123. Populations can comprise 30-50% juveniles, and 70-90% of them can die before the age of 1. Adult mortality produces an additional pressure on numbers.

hare over the course of the year leading to the assessment. Furthermore, mountain hare populations reportedly experience population cycling (see Figure 21). The 2018 survey was conducted in a single year only, implying that hare occupancy as measured on site in autumn 2018 might as easily reflect the upper or lower end of the typical cycle as the mid-point. However, on the basis of the national 'game bag' analysis (Figure 21) it would appear that – if the hare population is indeed cycling in this area, which we cannot say for sure without more detailed study – then it may well have reached a peak around 2016, and therefore have only just been starting a declining phase, in summer 2018, towards the next trough in density. This further re-inforces the likelihood that the 2018 survey probably captured hare activity (via dung pellets) towards the upper end of their natural levels.

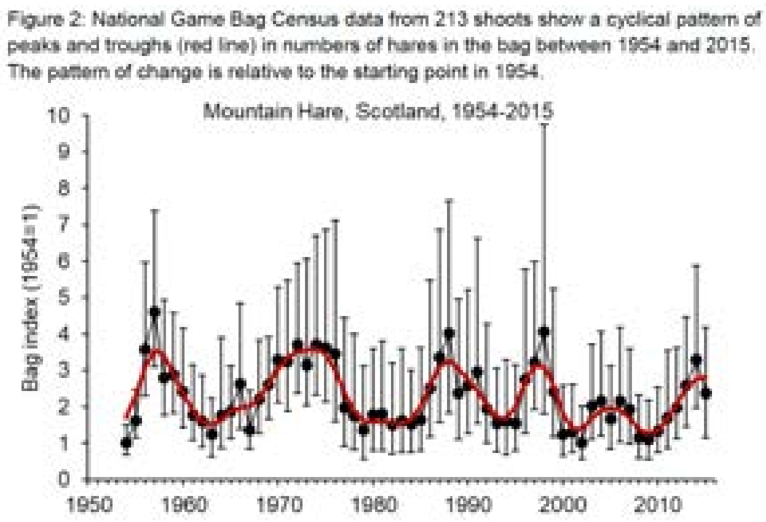


Figure 21 Extract of a submission by the Game Conservancy & Wildlife Trust to the Scottish Parliament in October 2017 which includes an up to date analysis of the 'gamebag' of mountain hares in Scotland. The chart (labelled Figure 2 – original chart title preserved) plots the cull returns since the 1950's and shows the cyclic nature of the gamebag. Copyright of GCWT ©.

197. Whilst a more complex analysis of the deer/sheep/hare data gathered on site might yield some additional insights, we were restricted by budget and time to an exploratory analysis at this juncture. In essence, due to the wide-ranging complexities and unknowns apparent, if the relative importance of deer/sheep and hare is to be investigated further it would be best done via a manipulative experiment in which the key variable of interest (i.e. deer / sheep occupancy) is reduced and the effects measured.

Random quadrats: small-scale indicators - 2008-2018

198. The evidence contained within the historic HIA data set for the designated sites is important to assess for two main reasons:

a) Firstly, and most importantly, it will help inform the various parties whether the core targets set for the site under the current Section 7 agreement are being met in advance of the agreement ending in autumn 2019.

b) Secondly, as the data set includes a time-series - and we also now have developed a clearer understanding through modelling of the likely trajectory of the deer population using the Section 7 area since before the baseline HIA in 2008 - it has the potential to yield useful additional insights into occupancy-impact relationships apparent on site over time.

199. In terms of the formal targets set for the site, their current status in 2018 (Map 15) and trend in the years leading to 2018 appears to be as follows (Figures 22-27):

a) Alpine heath (grazing; 90% L or LM): **fail** (9.7% of squares met the target, with a variable trend preceding the 2018 assessment whereby in most years the target was far away from being met other than in 2015 when it came closer).

b) Dry heath (grazing; 90% L or LM): **fail** (26.3% of squares met the target, with little or no sign in preceding assessments this was likely to change).

c) Montane acid grassland (grazing; 90% L or LM): **fail** (20.0% of squares met the target, with a declining trend apparent from preceding assessments implying an improvement was unlikely to be seen).

d) Species-rich *Nardus* grassland (grazing; 90% LM or M or MH): **fail** (9.6% of squares met the target, with a variable trend albeit typically far away from being compliant - preceding assessments implied an improvement was unlikely to be seen). *Note: the results imply the habitat is in many places being under-grazed*[74].

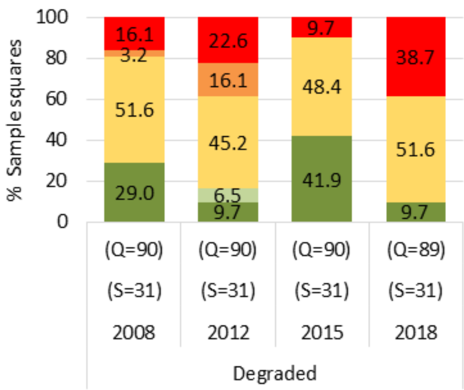
e) Willow (grazing; 90% L): **fail** (33.3% of squares met the target, with a declining trend apparent from preceding assessments implying an improvement was unlikely to be seen).

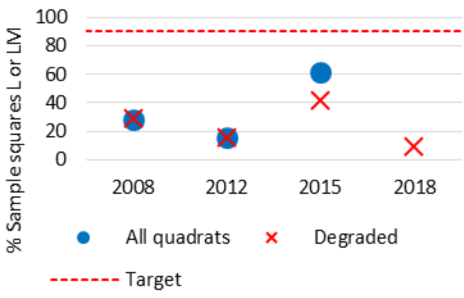
f) Bog (trampling; 90% L or LM): **fail** (25.0% of squares met the target, with a variable trend preceding the 2018 assessment whereby in most years the target was far away from being met other than in 2015 when it came closer).

g) Flush (trampling; 75% L or LM): **pass** (79.3% of squares met the target, with an improving trend apparent from the historic data set for preceding years).

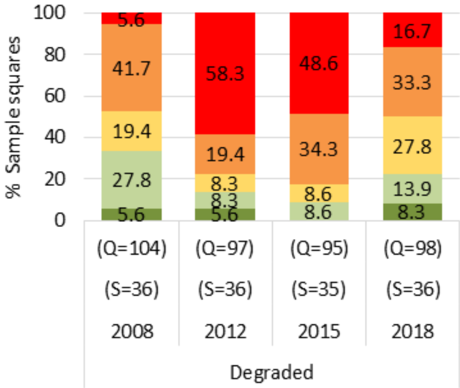
h) Montane acid grassland (trampling; 90% L or LM): **pass** (100.0% of squares met the target, with an improving trend apparent from the historic data set for preceding years).

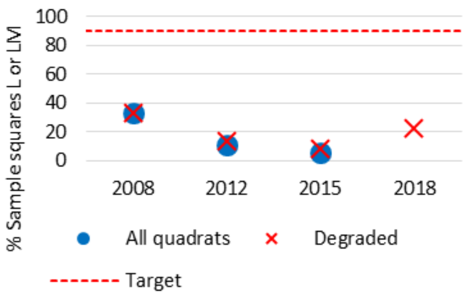
[74] According to the HIA methodology which, for example, requires the surveyor to flag up quadrats which have a noticeable depth of leaf litter indicative of grasslands with lower grazing pressure. Most of the deer spend their time on the higher tops in summer, when most grass growth arises. However, much of the species-rich grassland studied lies on the lower slopes of the study area (e.g. Caenlochan Glen) where the soils are more fertile and better-drained.



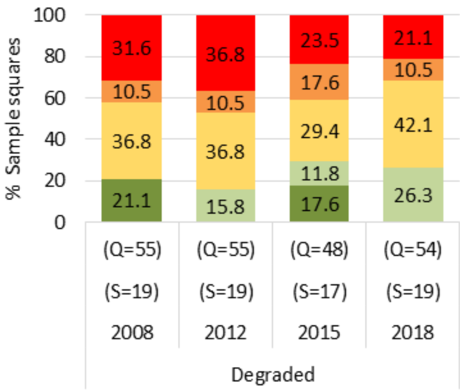


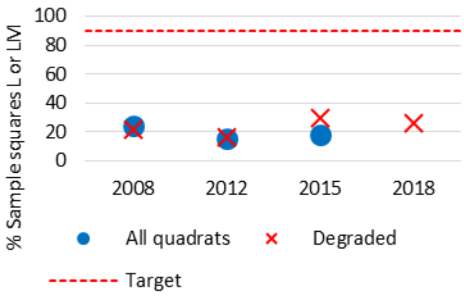
Alpine heath – grazing (official S7 target)





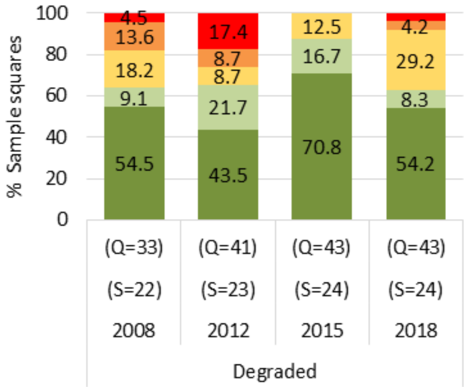
Blanket bog - grazing

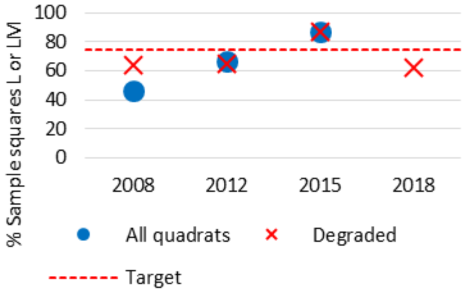




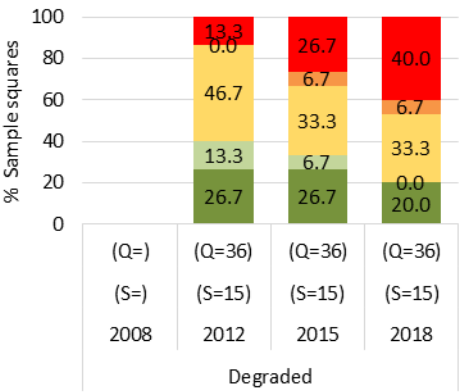
Dry heath – grazing (official S7 target)

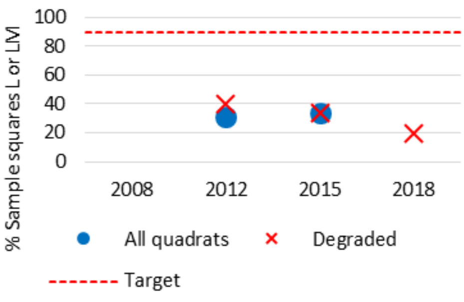
Figure 22 Left hand column: the % sampled quadrats falling in each impact class for the randomly-sampled HIA plots within the designated sites in 2008, 2012, 2015 and 2018 based on grazing indicators alone. Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. The sample size of quadrats (Q) and of sample squares (S) are both shown for reference. The outputs presented are for the degraded sample, as employed in 2018 (i.e. results for 2008, 2012 and 2015 have been stripped back to be comparable). Right hand column: shows the impact of the degrade process on the % of sample squares in the Low and Low-Moderate categories (as per the SNH site condition targets). Blue circles are the original, full results; red crosses are the results based on the degraded sample size (i.e. where the number of quadrats was reduced). Features with formal Section 7 targets (as per the current agreement) have their chart titles highlighted in blue and the target level indicated (red dashed line). Other charts also have a target level shown, but they are for reference only and do not form part of the current agreement. Note: most target thresholds are set at ‘a minimum of 90% sample squares falling in the Low or Low-Moderate impact class’ but some differ as per the axis titles (refer to Table 1 for a breakdown of target levels).



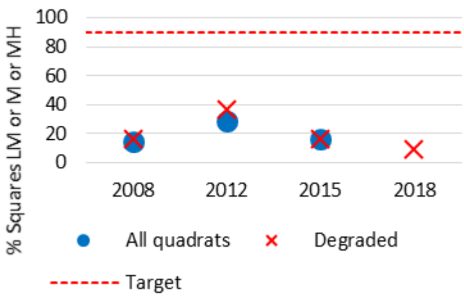


Flush – grazing



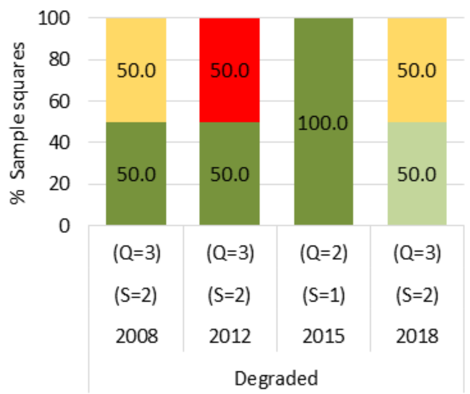


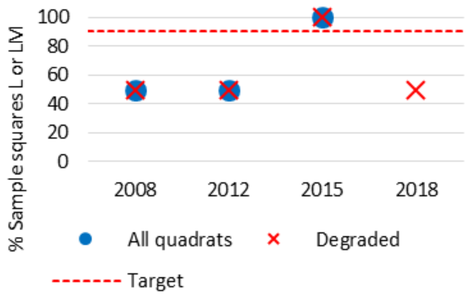
Montane acid grassland – grazing (official S7 target)



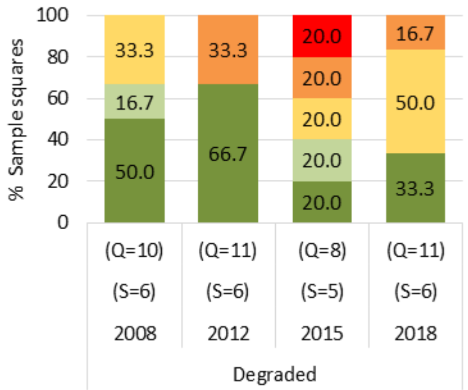
Species-rich grassland – grazing (official S7 target)

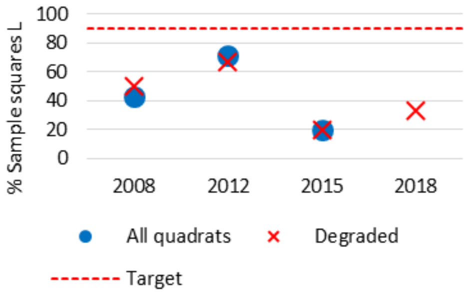
Figure 23 Left hand column: the % sampled quadrats falling in each impact class for the randomly-sampled HIA plots within the designated sites in 2008, 2012, 2015 and 2018 based on grazing indicators alone. Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. The sample size of quadrats (Q) and of sample squares (S) are both shown for reference. The outputs presented are for the degraded sample, as employed in 2018 (i.e. results for 2008, 2012 and 2015 have been stripped back to be comparable). Right hand column: shows the impact of the degrade process on the % of sample squares in the Low and Low-Moderate categories (as per the SNH site condition targets). Blue circles are the original, full results; red crosses are the results based on the degraded sample size (i.e. where the number of quadrats was reduced). Features with formal Section 7 targets (as per the current agreement) have their chart titles highlighted in blue and the target level indicated (red dashed line). Other charts also have a target level shown, but they are for reference only and do not form part of the current agreement. Note: most target thresholds are set at ‘a minimum of 90% sample squares falling in the Low or Low-Moderate impact class’ but some differ as per the axis titles (refer to Table 1 for a breakdown of target levels).



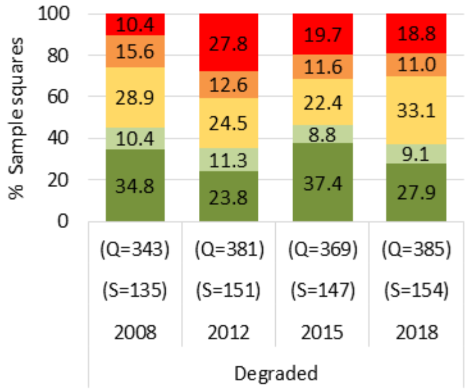


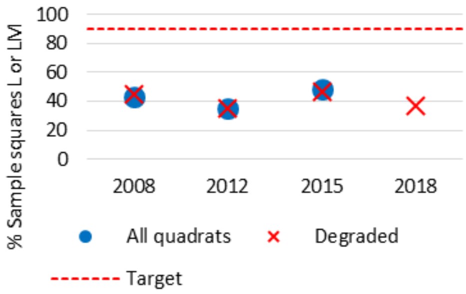
Tall herbs - grazing





Willow – grazing (official S7 target)

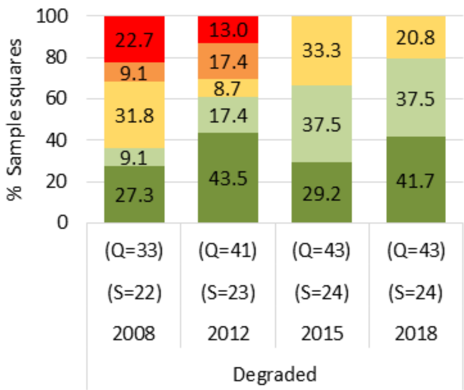


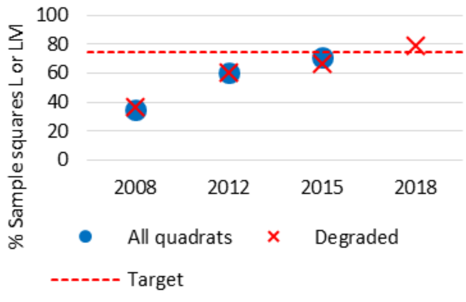


All habitats combined - grazing

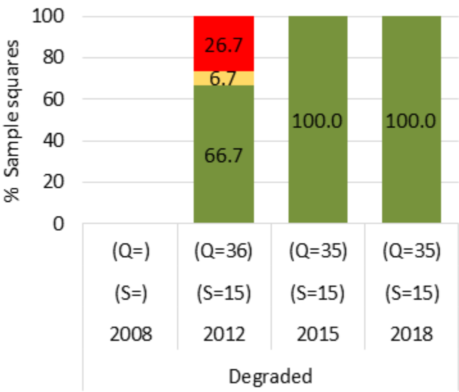
Figure 24 Left hand column: the % sampled quadrats falling in each impact class for the randomly-sampled HIA plots within the designated sites in 2008, 2012, 2015 and 2018 based on grazing indicators alone. Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. The sample size of quadrats (Q) and of sample squares (S) are both shown for reference. The outputs presented are for the degraded sample, as employed in 2018 (i.e. results for 2008, 2012 and 2015 have been stripped back to be comparable). Right hand column: shows the impact of the degrade process on the % of sample squares in the Low and Low-Moderate categories (as per the SNH site condition targets). Blue circles are the original, full results; red crosses are the results based on the degraded sample size (i.e. where the number of quadrats was reduced). Features with formal Section 7 targets (as per the current agreement) have their chart titles highlighted in blue and the target level indicated (red dashed line). Other charts also have a target level shown, but they are for reference only and do not form part of the current agreement. Note: most target thresholds are set at ‘a minimum of 90% sample squares falling in the Low or Low-Moderate impact class’ but some differ as per the axis titles (refer to Table 1 for a breakdown of target levels).

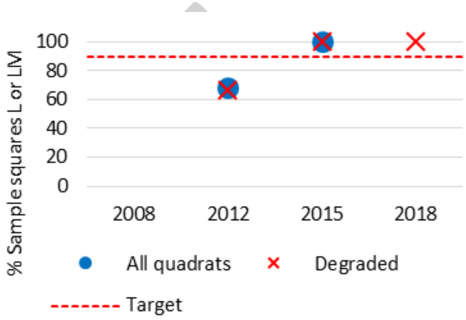
Figure 25 Left hand column: the % sampled quadrats falling in each impact class for the randomly-sampled HIA plots within the designated sites in 2008, 2012, 2015 and 2018 based on grazing indicators alone. Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. The sample size of quadrats (Q) and of sample squares (S) are both shown for reference. The outputs presented are for the degraded sample, as employed in 2018 (i.e. results for 2008, 2012 and 2015 have been stripped back to be comparable). Right hand column: shows the impact of the degrade process on the % of sample squares in the Low and Low-Moderate categories (as per the SNH site condition targets). Blue circles are the original, full results; red crosses are the results based on the degraded sample size (i.e. where the number of quadrats was reduced). Features with formal Section 7 targets (as per the current agreement) have their chart titles highlighted in blue and the target level indicated (red dashed line). Other charts also have a target level shown, but they are for reference only and do not form part of the current agreement. Note: most target thresholds are set at 'a minimum of 90% sample squares falling in the Low or Low-Moderate impact class' but some differ as per the axis titles (refer to Table 1 for a breakdown of target levels).



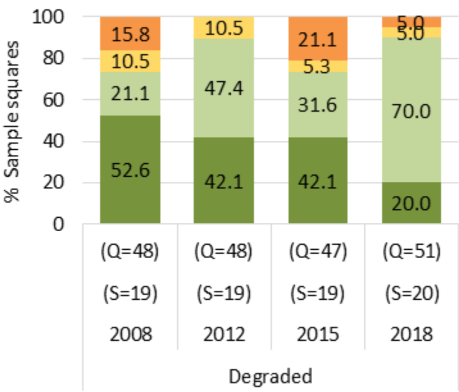


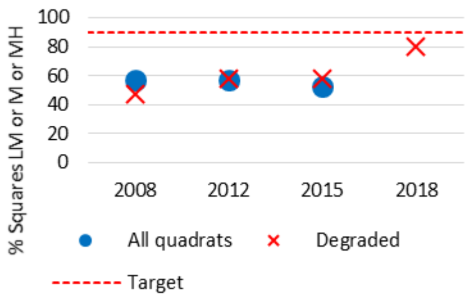
Flush – trampling (official S7 target)





Montane acid grass – trampling (official S7 target)





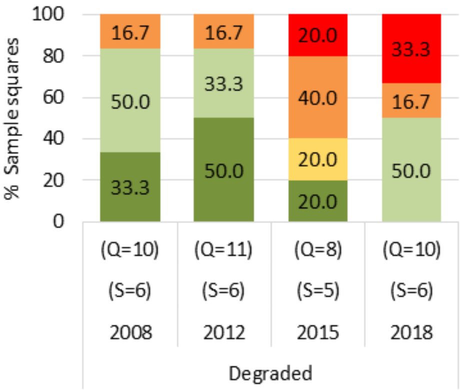
Species-rich Nardus grassland – trampling

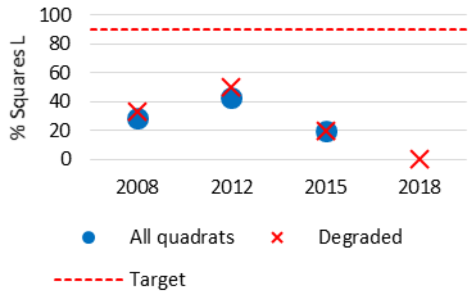
Figure 26 Left hand column: the % sampled quadrats falling in each impact class for the randomly-sampled HIA plots within the designated sites in 2008, 2012, 2015 and 2018 based on grazing indicators alone. Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. The sample size of quadrats (Q) and of sample squares (S) are both shown for reference. The outputs presented are for the degraded sample, as employed in 2018 (i.e. results for 2008, 2012 and 2015 have been stripped back to be comparable). Right hand column: shows the impact of the degrade process on the % of sample squares in the Low and Low-Moderate categories (as per the SNH site condition targets). Blue circles are the original, full results; red crosses are the results based on the degraded sample size (i.e. where the number of quadrats was reduced). Features with formal Section 7 targets (as per the current agreement) have their chart titles highlighted in blue and the target level indicated (red dashed line). Other charts also have a target level shown, but they are for reference only and do not form part of the current agreement. Note: most target thresholds are set at ‘a minimum of 90% sample squares falling in the Low or Low-Moderate impact class’ but some differ as per the axis titles (refer to Table 1 for a breakdown of target levels).

No data

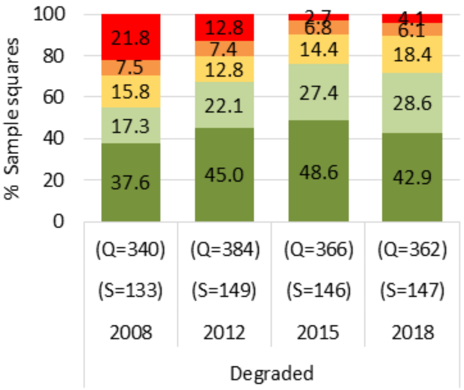
No data

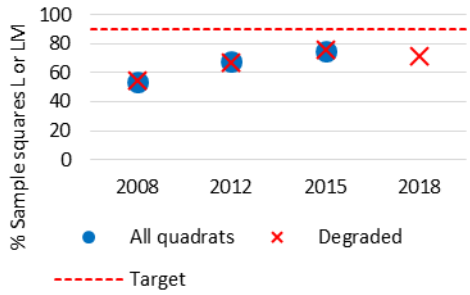
Tall herbs - trampling





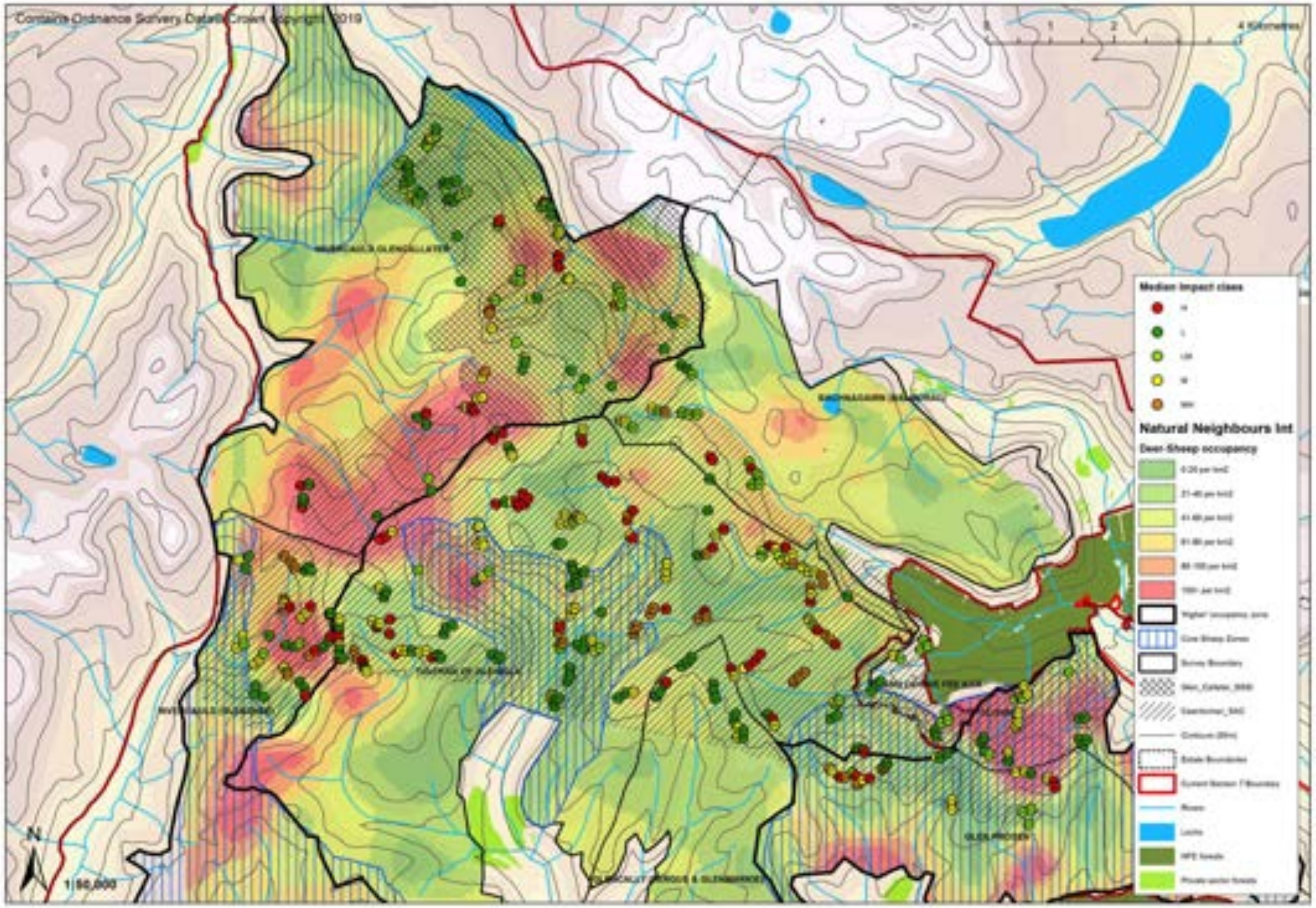
Willow – trampling





All habitats combined - trampling

Figure 27 Left hand column: the % sampled quadrats falling in each impact class for the randomly-sampled HIA plots within the designated sites in 2008, 2012, 2015 and 2018 based on grazing indicators alone. Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red. The sample size of quadrats (Q) and of sample squares (S) are both shown for reference. The outputs presented are for the degraded sample, as employed in 2018 (i.e. results for 2008, 2012 and 2015 have been stripped back to be comparable). Right hand column: shows the impact of the degrade process on the % of sample squares in the Low and Low-Moderate categories (as per the SNH site condition targets). Blue circles are the original, full results; red crosses are the results based on the degraded sample size (i.e. where the number of quadrats was reduced). Features with formal Section 7 targets (as per the current agreement) have their chart titles highlighted in blue and the target level indicated (red dashed line). Other charts also have a target level shown, but they are for reference only and do not form part of the current agreement. Note: most target thresholds are set at ‘a minimum of 90% sample squares falling in the Low or Low-Moderate impact class’ but some differ as per the axis titles (refer to Table 1 for a breakdown of target levels).



Map 15 The median impact class recorded in autumn 2018 at each of the random HIA quadrats located within the designated sites at Caenlochan

200. The results of the random HIA survey for each feature follow a similar pattern, in the main, for the grazing indicators. Levels of impact were very high at the outset of the period in 2008 and have remained similarly high – with a few exceptions in 2015 – throughout the monitoring period to date. These findings seem to be in broad agreement with the other data presented earlier in this report.

201. However, the results for trampling – other than for bog which are in line - show a considerable departure. Levels in both flush and montane acid grassland register as very low and hence pass the targets set. This is somewhat unexpected given the densities of deer present on site. The most plausible explanation is that the trampling assessments generally – and specifically for these feature types – involve very few indicators (Table 18). In the case of MAG, one indicator involves assessing bare soil features associated with terraces but if absent then the indicator is not applicable (hence the assessment has 1 indicator). In the case of flush, the indicators relate to disturbance which as we have seen from other data can be very low on site despite occupancy levels being very high.

Table 18 The inherent ability of the random-plot HIA monitoring scheme to detect change (left hand table) and the inherent sensitivity of the HIA method when assessing the impact class in each feature type (right hand table). In the left hand table, we show the contribution of each sampled square to the target assessment (e.g. for Alpine Heath each sample square represents a 3.2% increment for target assessment whereas in willow scrub each square represents a 25% increment hence is much less able to detect change on site). In the right hand table, we show how the number of indicators varies between feature types and impact types – for example, calculating the median grazing impact class in Blanket bog involves only 4 indicators whereas in species-rich grassland it involves 11. Conditional formatting is used to draw out trends visually. AH = Alpine heath, BB = blanket bog, DH = dry heath, FL = flush, MAG = montane acid grassland, SG = species-rich *Nardus* grassland, WL = willow scrub and TH = tall herb ledges. MAG in the left hand table has the actual sample size of squares sampled in 2018 (the sample size in 2008, 2012 and 2015 was higher) due to an error in grid reference extraction – see Figure 29.

Feature	Squares	Sens +/- %
AH	31	3.2
BB	36	2.8
DH	19	5.3
FL	22	4.5
MAG	17	5.9
SG	19	5.3
WL	4	25.0
TH	2	50.0

Feature	Grazing	Trampling
AH	4	2
BB	4	5
DH	6	3
FL	7	2
MAG	4	2
SG	11	3
WL	7	2
TH	4	N/A

202. A related consideration is that the design of the original scheme varies markedly in its sensitivity between habitat types and within sample squares:

a) The number of sample squares in each feature design varies, the lowest being 2 and the highest being 36 (Table 18). In assessing the % of sample squares in a particular median impact class to inform target compliance, features vary markedly in inherent sensitivity.

b) In calculating a median impact class, this operation is firstly conducted for each quadrat in a feature (and hence there is variation in sensitivity because of variability in the number of indicators available *per se* as well as applicable). Then a median is calculated for quadrats within a square, but this varies from 1 – 5 depending on the square involved. In cases where a small number of indicators are available (e.g. AH) and a small number of quadrats was installed, the calculation of median impact class will introduce a considerable degree of insensitivity in comparison with other situations.

203. In terms of analysis, a final substantive consideration relates to the choice of method to calculate impact class. Previous studies at Caenlochan have employed the median, and this is commonly used in other areas, whereas on some sites mean is sometimes used and occasionally the mode. Each produces markedly different outcomes in terms of the assessment (Figure 28). This issue, as well as the others mentioned, are worthy of consideration when interpreting the results of the random HIA data given all outputs are obtained from the same 'raw data'.

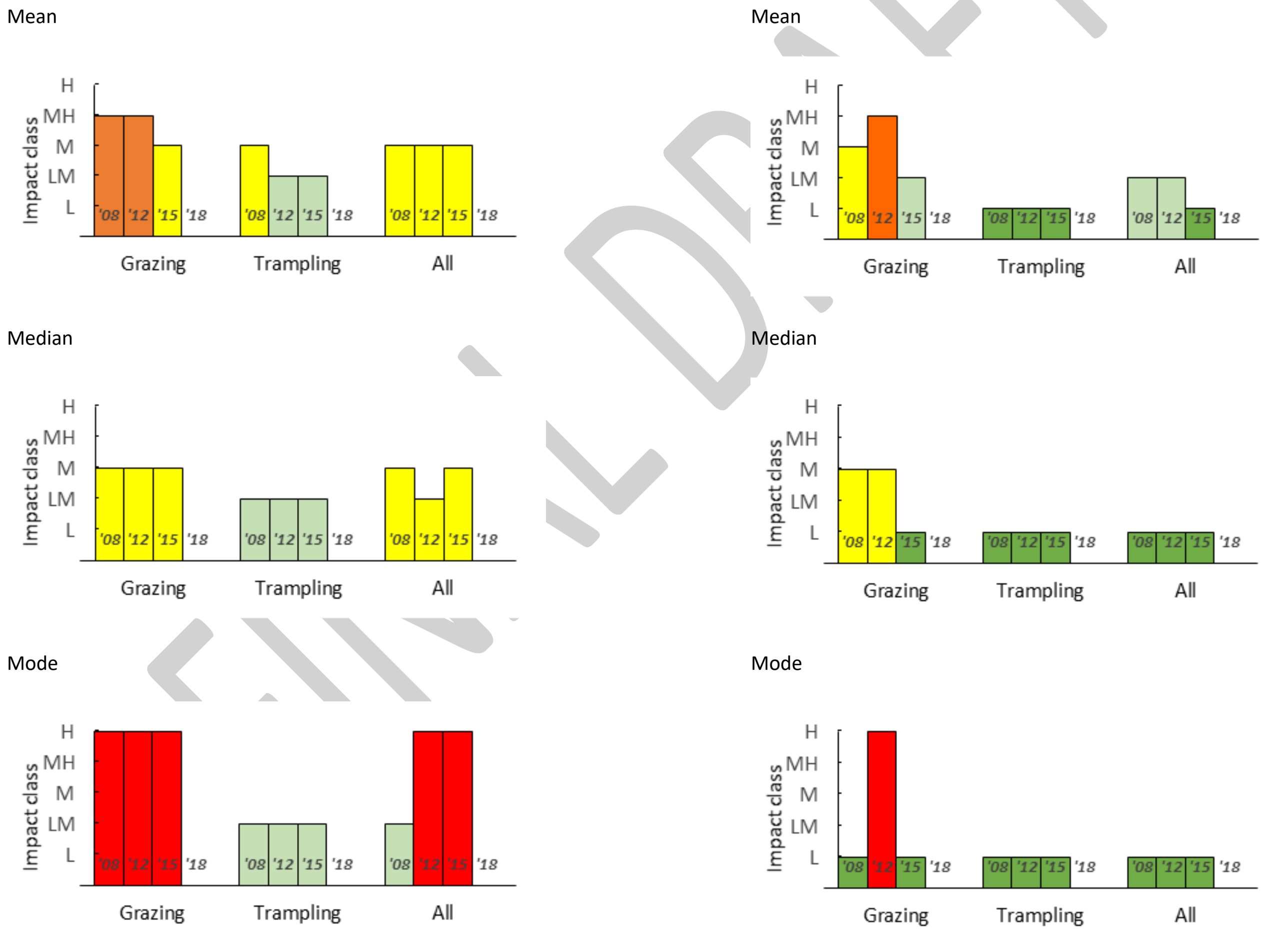
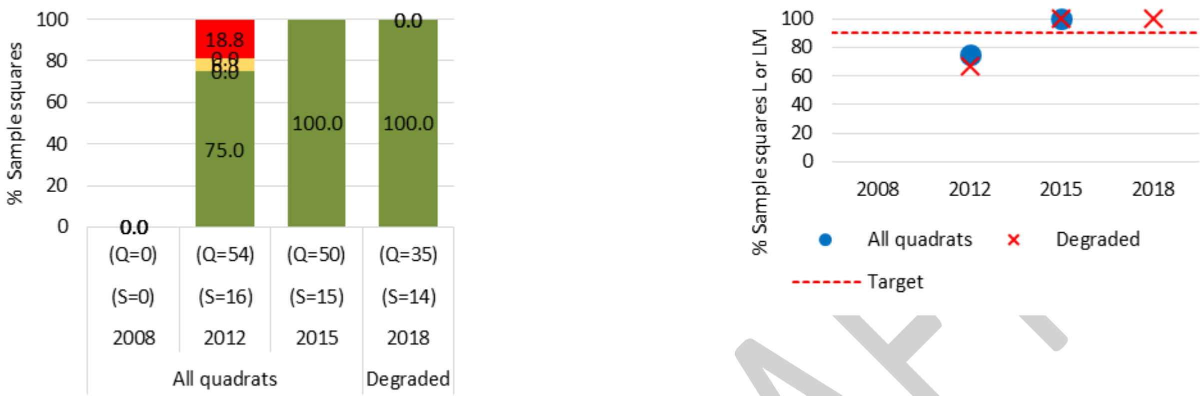


Figure 28 The results of analysing the dry heath data (left hand column) and alpine heath data (right hand column) for the Caenlochan SAC using 3 different approaches at the *quadrat* scale: mean, median and mode. Low = dark green, Low-Moderate = light green, Moderate = yellow, Moderate-High = orange and High = red.

204. One final issue relates to Montane Acid Grassland. It was not sampled in 2008, but was in 2012 and 2015 as well as 2018. The Methods section of this report describes a situation which arose during preparation for the 2018 fieldwork

whereby a considerable proportion of the sampling locations from 2015 were not extracted into the upload file for the 2018 survey – this error was not noticed until long after the survey ended. An analysis was therefore conducted to assess the impact of this error on the assessment of targets for the current Section 7 (Figure 29). The results suggest that the implications are minimal.

MAG – plots sampled with wind clipped heath indicators



MAG – plots sampled with modified tussock grassland indicators

MAG – all

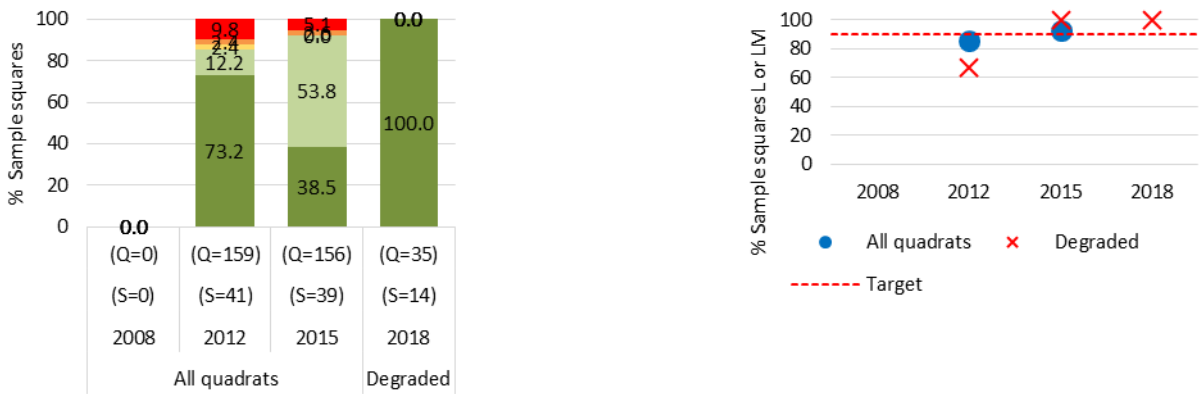


Figure 29 The outcome of assessing the targets for montane acid grassland at Caenlochan SAC using the full complement of quadrats (as per 2012 and 2015), involving quadrats with wind-clipped summit heath indicators and modified tussock grassland indicators, as opposed to assessing the targets with only plots that used 'wind-clipped summit heath' indicators (due to an error by the contractor at the

outset of the study, which ended up meaning quadrats with tussock grassland were not included in the 2018 survey). The effects of degrading the wind-clipped summit heath indicators are also included for reference because in 2018 only a degraded sampling design was employed.

Random quadrats: quantitative indicators - 2008-2018

205. SNH asks that surveyors gather a range of quantitative data from 2x2m quadrats at the same time as assessing small-scale indicators. To some extent, this has been done in all 4 years at Caenlochan albeit with a degree of variation over time as, for example certain indicators were introduced.

206. A wide range of data have been gathered, in some cases involving the same variate gathered in multiple habitat types and in other cases a variate being gathered in only one habitat type. The results have been compiled into a time series, and colour coded on a per habitat basis, to help readers interpret them (Figures 30 & 31). There are a multitude of results, arguably too many to go through individually here for sake of brevity in the report as well as clarity. Therefore, we restrict this section to key observations only. The available data indicate the following:

a) Vegetation height: data on mean vegetation height indicate a stable to rising trend, in particular in recent years. Tall herb and willow heights remain stable on average. However, consecutively later survey dates suggest much or all of this difference may be due to methodology.

b) Browsing levels: browsing levels on all dwarf shrubs appear to be declining albeit they remain high on average (having been exceptional in the past). That said, there is a suspicion that in the early years browsing off-take may have been somewhat overstated (probably by cursory examination being undertaken rather than detailed examination, because of the exceptional density of deer present and because off-take levels at the upper end of the scale can be harder to distinguish between without a lot of time being taken; perhaps also due to a lack of clarity about whether older shoots or current year's growth is being assessed). Willow browsing appears to be rising.

c) Grazing levels: a variety of trends is apparent in relation to grazing, which when averaged out indicate a broadly stable trend (see caveats below).

d) Dunging levels: we believe that methodological issues in relation to fieldwork mean these data are unlikely to be reliable, with trends in the data appearing to be highly variable between years and indicator types.

e) Disturbance levels: a variable trend is apparent between indicator types and years. In broad terms levels on average are either stable or rising slightly.

207. The gathering of this data, whilst in theory a more precise exercise than the HIA small-scale assessment because direct measurements are being made and recorded, may have a number of potential issues associated with it in reality. The most obvious one is that there is no detailed protocol for how to undertake the work, meaning that different surveyors and surveying teams may employ different definitions or approaches on site. This is particularly relevant to the dunging and disturbance measures. Timing is also an issue - surveys have become progressively later over the years thus confounding measures of plant height for example.

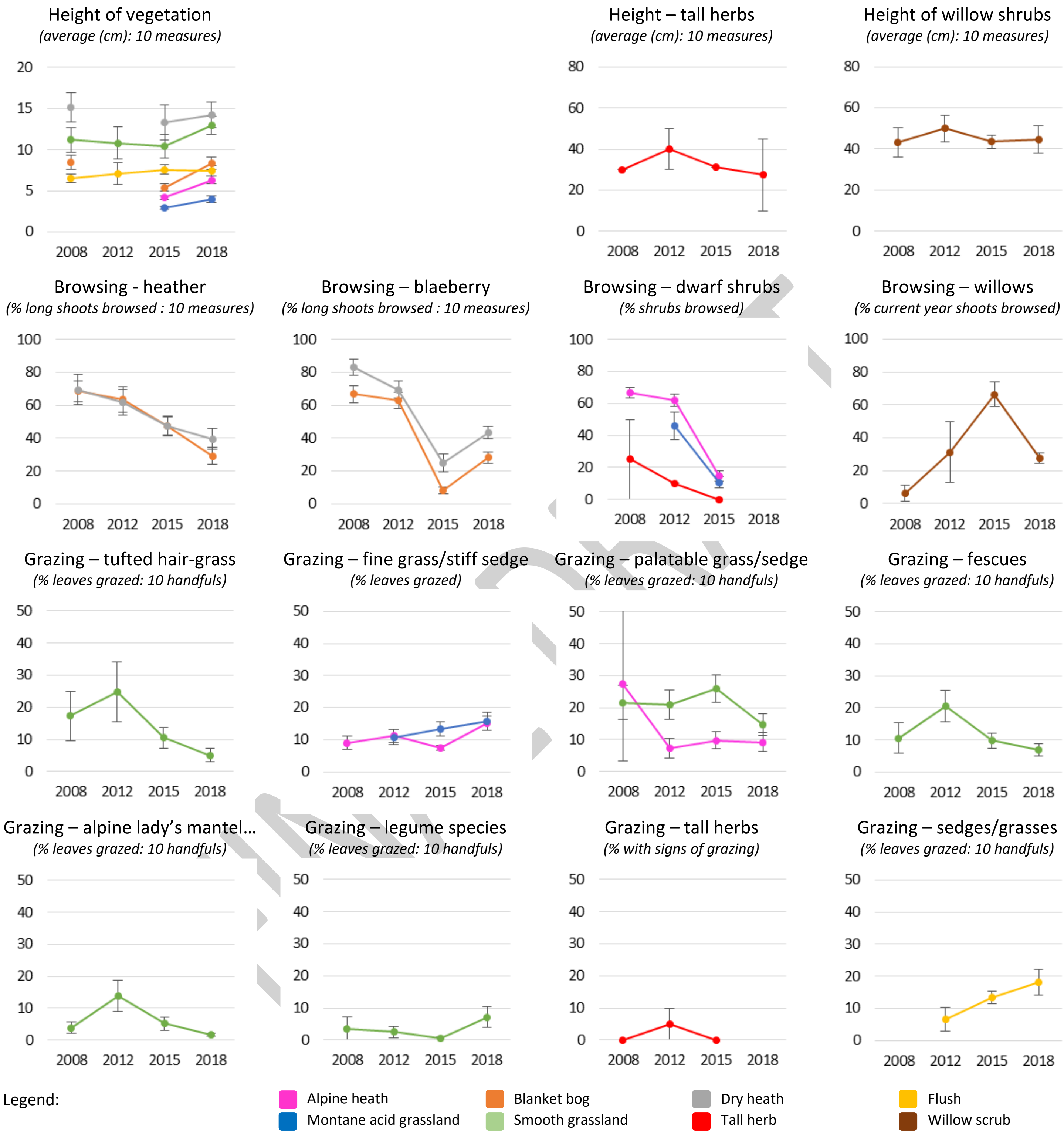


Figure 30: Average values for quantitative condition measures within each habitat in 2008 (months 6,7,8), 2012 (months 7,8,9), 2015 (months 7,8,9) and 2018 (months 8,9,10) in the Caenlochan Section 7 area (Glen Callater SSSI and Caenlochan SAC combined).

- Notes regarding the analysis and presentation of this data can be found at the foot of the next page.

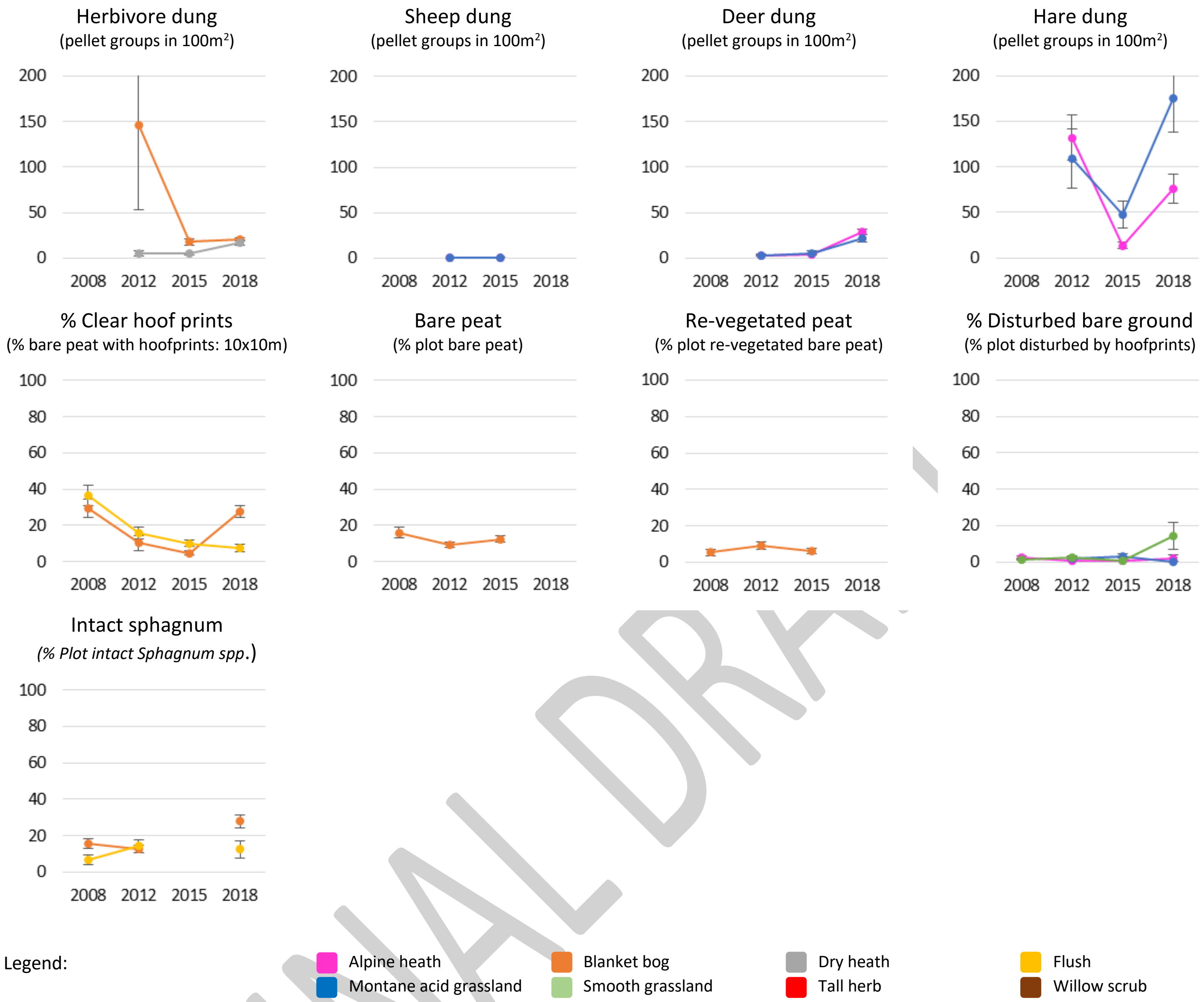


Figure 31: Average values for quantitative condition measures within each habitat in 2008 (months 6,7,8), 2012 (months 7,8,9), 2015 (months 7,8,9) and 2018 (months 8,9,10) in the Caenlochan Section 7 area (Glen Callater SSSI and Caenlochan SAC combined).

Note 1: In some years (2008, 2012 and 2015) quantitative data was not gathered at all, or was not included in the handover from SNH to the contractor, or was not in a compliant format, or was clearly incorrect e.g. typos - these data could not be included in this analysis. The remaining data were checked and, when required, changed into a "usable" format, in order to preserve the largest sample size. Mid-point data values were used where data was provided as a range of values. "Less than" or "Greater than" data were also changed to a numeric value e.g. <5% = 2.5%. It is recognised that this process may have some deficiencies. It is also felt that there may have been some differences in methodology each year which also may also effect the validity of some of the results, however the extent of this is not possible to quantify.
Note 2: In 2018, part of the survey proposal specification was to reduce the number of underlying quadrats, used to calculate the average of each condition measure for each sample square, from up to 5 to no more than 3. Analysis of the effect of the degraded sample size showed that the reduced number of quadrats did not produce a different result for the earlier years. The data for all years have therefore been analysed using a matched, reduced sample size.
Note 3: The average for each condition measure is calculated by first averaging the data for each sample square and then using those averages to calculate a mean and standard error for each habitat (presented in the charts above).
Note 4: Blanket bog measures in Glen Callater SSSI were not gathered in 2008 and 2012. The matched sample for 2015 and 2018 for this habitat therefore excludes Glen Callater SSSI data.
Note 5: In 2018, the SoR required heather and blaeberry browsing to be recorded in Alpine Heath, Montane Grassland and Tall Herbs. However, from the data submitted for 2008, 2012 and 2015 it appears that browsing data was recorded as % of dwarf shrubs browsed. It was felt that the data gathered in 2018 could not therefore be used to monitor this indicator reliably for these habitats.
Note 6: Grazing of tall herbs was not specified in the 2018 SoR hence no data was gathered.
Note 7: Herbivore dunging data is felt to be unreliable. The ability to gather dung data from different species e.g. individual hare pellet counts and deer pellet group counts cannot be added together to form "herbivore dung". Likewise it is not possible to reliably distinguish between sheep and deer dung groups in the field. Evidence in the underlying data would indicate that this has been problematic in all survey years, therefore it is likely to be misleading in this form.

FENCELINE CONTRASTS

208. The findings of the assessment of dwarf shrub stature within the woodland enclosure fence at Caenlochan Glen (Figure 32) showed that the cover of heather (and blaeberry) was markedly lower outside the fence, as was the stature of heather plants. The recent level of browsing was very much higher outside the fence

209. Results for Bell heather (no data shown) were very similar. Mean cover was 1.7% inside (1.3% outside), mean height was 24cm inside (6cm outside) and off-take from the 2017 growing season was 15% inside (43% outside).

210.An image obtained from GoogleEarth provides a useful visual contrast (Image 1).

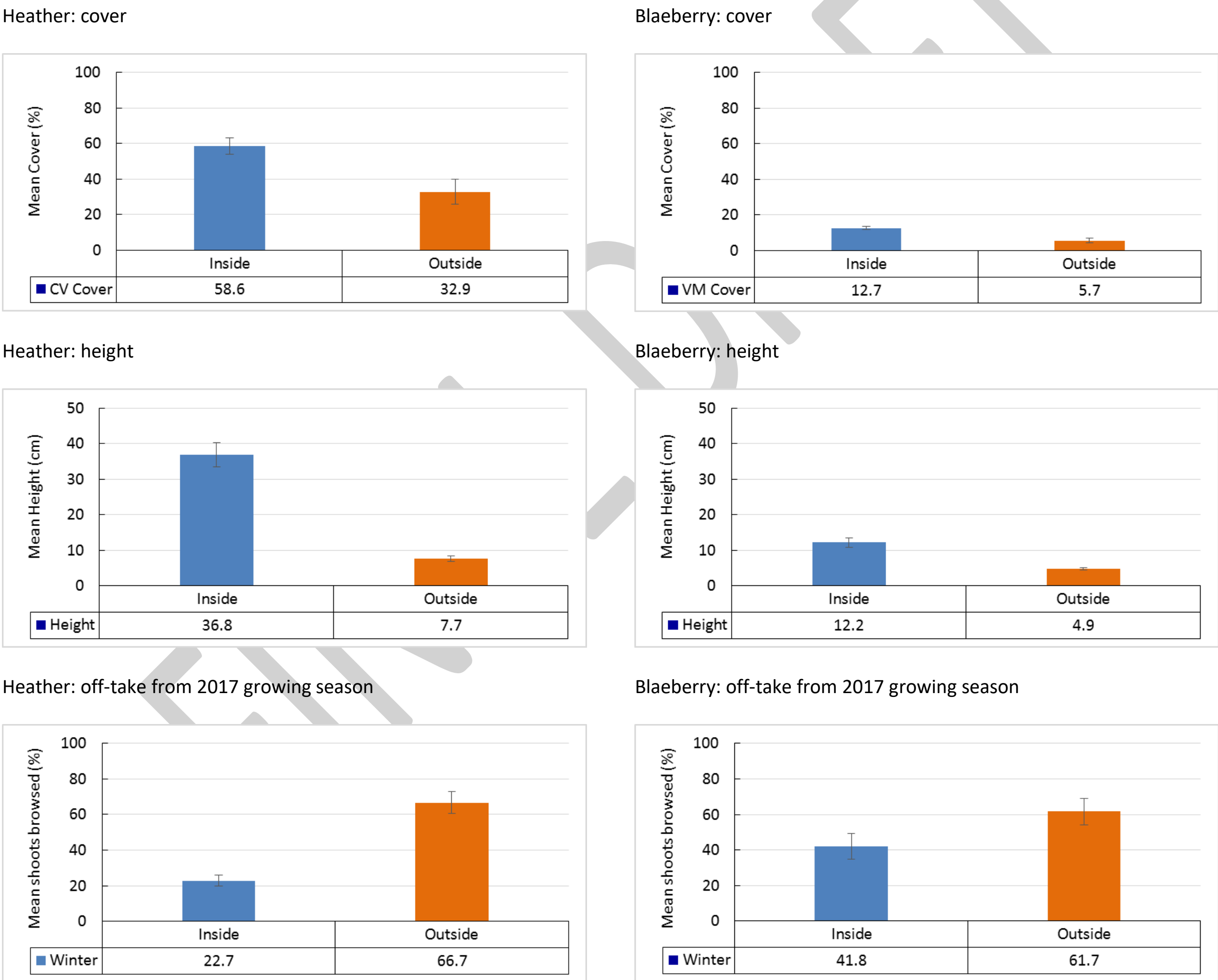


Figure 32 The status of heather (left hand column) and blaeberry (right hand column) on matched pair samples obtained from inside and outside of a woodland enclosure in Caenlochan Glen assessed in autumn 2018.

211. The strength of the effect of the fence on heather height declined with increasing altitude, as expected given that dwarf shrubs become more prostrate higher on the hill (Figure 33).

212. The typical height of plants at the highest altitudes on site appeared to be ~ 7-9cm, and taking into account the evidence from the enclosure, high levels of off-take may well suppress heather height up to 650m or 700m altitude and perhaps higher depending on the exposure level on site.

213. Based on the evidence available, the suppression effects of browsing by deer/sheep and perhaps hare in the vicinity of the Caenlochan Glen enclosure study site (typical height of around ~ 8cm) are akin to the weathering effects which restrict heather to growing in a very prostate form at the highest altitudes on the wider site (7-9cm).

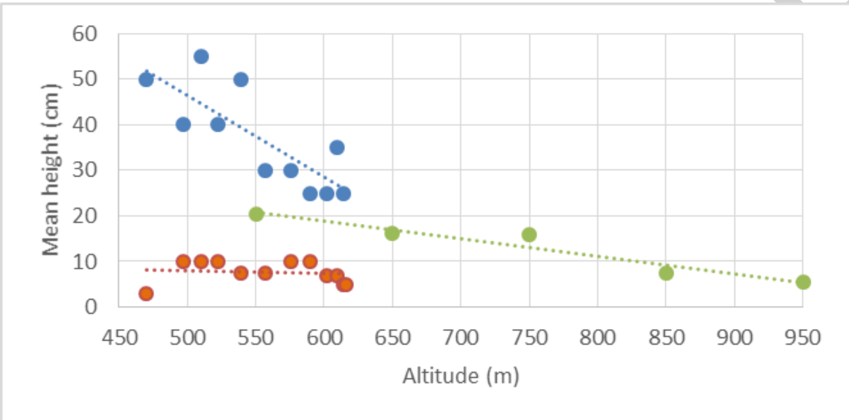


Figure 33 The trend in mean height of heather plants inside (blue) and outside (orange) the enclosure fence in Caenlochan Glen (with linear trend lines fitted for reference) in autumn 2018. An additional set of data is included for reference – mean heather height (cm) in each altitude band sampled at multiple locations during the grid-based transect impact assessment in autumn 2018. The grid-based data were all obtained in un-enclosed conditions.

Image 1 Visual appearance of the enclosure study site in Google Earth.

STATUS OF MONTANE WILLOW SCRUB

214. Part of the proposal at tender stage was to gather additional data on the status of montane willow scrub if the opportunity arose. A focus was placed on this because the citation for the Caenlochan SAC notes the sites is considered to be an exceptional example[75]. An attempt was made on site to expand the existing set of formal assessment records, by searching locations at which montane willow scrub had been noted (e.g. during previous SCM assessments) but at which no contemporary data was available. Several additional samples were obtained, meaning in total 19 quadrats were assessed across a total of 13 squares.

215.A total of 50% of squares sampled had a Low or Low-Moderate impact class sampled with the original framework, but only 30.8% of squares were in this category using the framework which included additional squares sampled (Figure 34). Quantitative assessment showed – where locations were safe to access – that average plant height was around 40cm (varying from 10-100cm) and around 40% of current year's shoots had been browsed (varying from 0 -100% depending on location) at the time of the assessment in autumn 2018.

[75] "Sub-Arctic *Salix* spp. scrub is relatively frequent at Caenlochan, growing to a high altitude on highly to moderately calcareous schist. Corrie Sharroch holds the largest single patch (around 0.5 ha) of W20 *Salix lapponum – Luzula sylvatica* scrub remaining in the UK. The scrub is also found spread across a larger area of crag and steep rocky slope than on any other site in the UK. The most abundant species, and generally the dominant one, is downy willow *Salix lapponum*, which probably occurs in larger numbers here than on any other site in the UK."

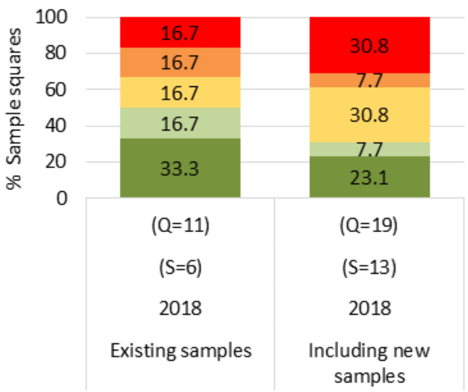


Figure 34 The results of an HIA assessment of montane willow scrub, based on use of existing sample squares compared against a framework which included some additional willow locations identified by surveyors in summer 2018. Additional 2018 locations tended to be spatially distinct from each other, and from existing samples, hence were treated in the main as independent samples (of 8 new quadrats, 6 were treated as independent and 2 were treated as being within one 'square'. The original samples were analysed by treating the square as the independent sample not the quadrats within them. A median impact class was calculated per 'square' as for the other HIA analysis within this report.

AIR IMAGERY ANALYSIS

216. A selection of 5 historic air images was obtained, each within the altitude zone where heather might be expected to be commonplace, in order to look for visual evidence of habitat changes since the mid-1940's. These were matched with contemporary imagery from 2008 and 2018 available online (Figure 35).

217. The georeferencing process cannot be exact as each image is obtained from a particular height and camera angle relative to the piece of ground being studied but all images had sufficient natural features (e.g. stream confluences) to enable the majority of each image to match closely. Upon inspection, the RAF images form the 1940's had the best contrast as they were in black and white. The best contemporary match was from winter 2018 as the vegetation had died back and the heather was more obvious as a consequence. It cannot be guaranteed that visual inspection of these images can yield definitive results, but in general terms the heather cover appeared to show up darker than all other vegetation types in both sets of images and hence a visual inspection seemed to be a useful activity to undertake even if not entirely reliable.

218. A preliminary inspection[76] of the imagery revealed the following:

[76] A more formal inspection, taking more time and looking in more detail, is eminently possible. More images could also be obtained, as well as obtaining imagery from intermediate periods (e.g. 1960's, 70's and 80's to track changes over time). However, the time and project budgets precluded any more detailed investigative work being done at this stage.

a) Carn Dearg (Invercauld - Glenshee): there were several areas where it appeared that heather cover had clearly shrunk in extent most notably in the eastern part of the image (particularly the north-eastern quadrant).

b) Carn Ait (Invercauld - Glenshee): as for Carn Dearg but on the western side of the image and in particular the south-western quadrant, albeit the differences visible could conceivably in part relate to image contrast.

c) Carn Aig (Invercauld - Glenshee): as for Carn Ait but in the south-western quadrant, and with the same caveat on image contrast.

d) Spying Hillock (Tulchan): shows the enclosure study area to be the location of a previous woodland, which may mean habitat was at times protected before the more recent fence was put in place. The estate also reports that some heather seeding was undertaken as part of the more recent work on site, hence cover levels might be higher (inside the fence) than would be expected in a natural system.

e) Auchallater (Invercauld – Callater): widespread signs of muirburn in both the older and newest image, across the entire area of each image, suggest that heather cover has not changed markedly since the time of World War 2.

219. Overall, there would appear to be some strong visual evidence that a degree of local shrinkage in heather cover has probably arisen since the 1940's.

220. It is possible that the increase in deer numbers – and hence densities – identified within the historic count data set presented earlier is in part responsible for this. Of course, mountain hare could have played a part too, but on the basis of the images from the 1940's it would appear if anything that heather cover was more extensive and hence muirburn was more prevalent. If anything, with all else equal, it is possible that hare numbers might have been higher. That said, management by culling might have more prevalent than it is today.

221. Another possibility is that changes in the stocking density of sheep could have played a part. The existing deer management plan for the Caenlochan area was examined but no specific long-term records of sheep numbers in the local area were presented in it. Attention turned to the agricultural census records for Scotland that are available online[77]. Again, there were no specific local records but some regional records were extracted for interest (Figure 36). The figures suggest that from the time of World War 2 sheep numbers rose regionally and peaked in the late 1980's before declining. Numbers regionally have declined somewhat since the time of the original Section 7 agreement at regional scale, but local figures are not available.

[77] https://www2.gov.scot/Topics/Statistics/Browse/Agriculture-Fisheries/Publications/histagstats

222.On balance of evidence available, it would seem likely that any long-term reduction in local heather cover since the 1940’s might be related in part to increases in sheep stocking and in part to increases in deer stocking.

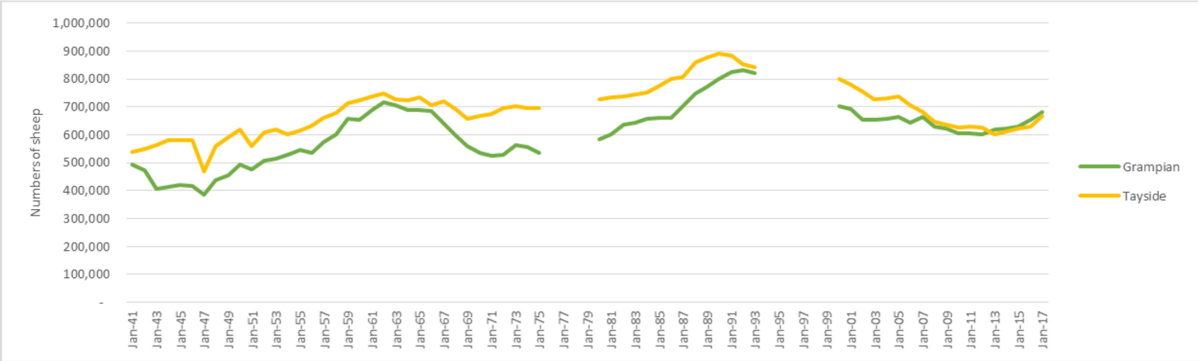


Figure 36 Historic trends in sheep numbers stocked at regional scale. Some records could not be recovered (gaps in the charts). Recent records (1980 onwards) were labelled Tayside and Grampian, whereas in older data sets other names were used (Perth, and Aberdeen/Angus respectively). An attempt was made to match the old and newer data sets up but no guarantee can be given it is 100% accurate as further detailed research would be needed to provide this assurance.

223.In undertaking the air analysis comparison, the presence of widespread ‘contour tracking’ was noted in contemporary images. These are tracks caused by animals constantly walking across the hillslopes present and forming, over time, path networks. A sample image from the upper reaches of Caenlochan Glen is shown for reference (Figure 36). These types of features can be seen on other upland sites but rarely in such concentrations locally.

Figure 36 Image obtained from ESRI Basemap showing the presence of intense networks of animal contour tracks in Caenlochan Glen at the ‘break of slope’ between the valley side and the plateau (right-hand portion of the image).

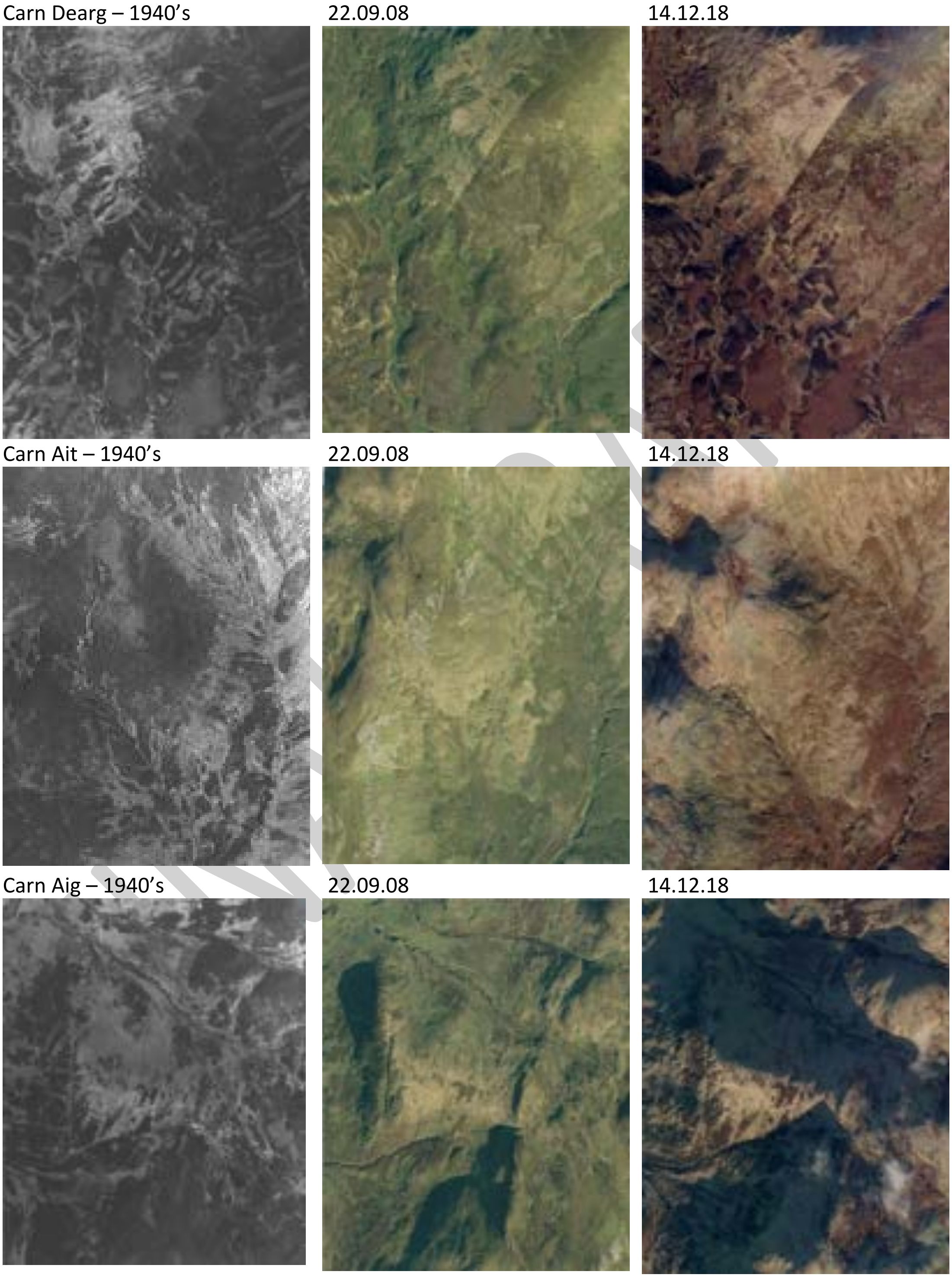


Figure 35a Historic air images (left-hand column) contrasted with contemporary imagery from the past decade (middle and right hand columns).

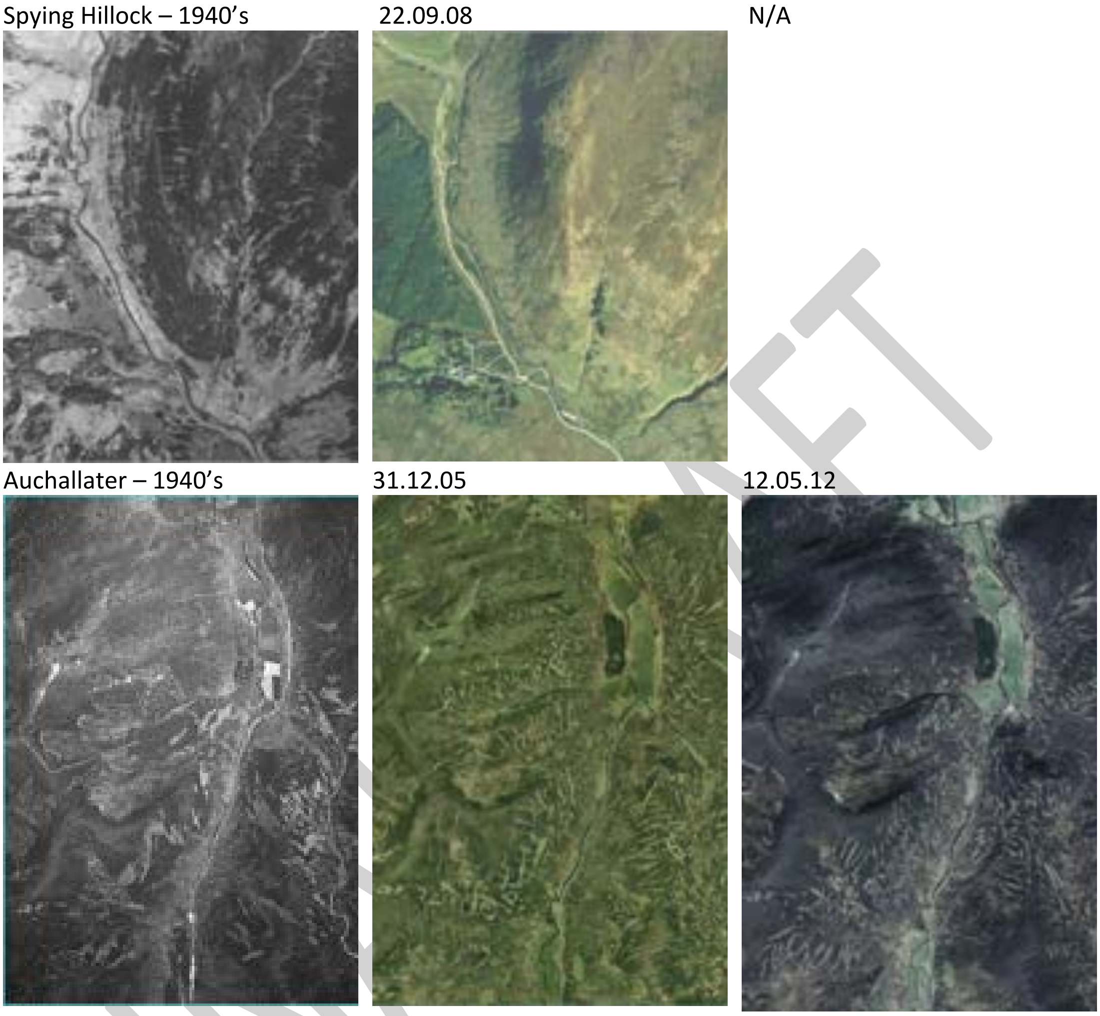


Figure 35b Additional historic air images (left-hand column) contrasted with contemporary imagery from the past decade (middle and right hand columns).

INTERPRETATION

ANNUAL TRENDS IN DEER DENSITY

224.The aim of the current Caenlochan Area Section 7 Control Agreement (2014-19) is to ensure a specified set of designated upland habitats are moving towards 'favourable condition' across the combined land area of three sites: Caenlochan SAC, Glen Callater SSSI and Cairnwell SSSI. The current agreement was preceded by a previous Section 7 agreement (2003-2013) that aimed to prevent damage within a smaller damaged site (Caenlochan Glen).

225.Both agreements had at their heart a plan to reduce deer densities to an agreed level (original S7 agreement) or maintain them at it (current S7 agreement) for a period of time to prevent further damage (original S7) or allow habitat recovery (current S7):

a) In the original agreement a winter density target of 19 deer per km^2 was set for the Control Area. This target level was presumably chosen because SNH specialists considered that it was low enough, based on evidence available at the time, to prevent deterioration and allow recovery in Caenlochan Glen.

b) The current Section 7 agreement, which began in 2014, refers to a winter density proposed by the estates. The density level was selected to ensure a desired number of 'shoot-able stags' was produced for sport annually[78] across the Section 7 area. The density proposed was between 18.6 and 20.9 per km^2.

c) Given the mid-point of the deer density target range in the current Section 7 agreement is 20 per km^2, it could be argued that the original agreement and the current agreement had density targets that, to all intents and purposes, were the same.

226. The DCS specified large culls for the winters of 2005-06 and 2006-07, and later intervened under Section 10 in both seasons, to help the estates cull the numbers of red deer needed to reach the winter density target of 19 per km^2. The evidence available from historic counts suggests the density of red deer in the area had reached a high point of ~ 29 per km^2 in or around 2005 based on winter counts. The reduction culls specified by the DCS appeared to drive down the winter density to ~ 17 per km^2 by 2007. According to the counts, winter densities then remained in the range ~ 17-19 per km^2 until January 2018, when a winter density of 23.5 per km^2 was recorded.

[78] The plan quotes a stated number of stags (2000-2200) and hinds (2200-2500) but calves are not specified. It is assumed that ~40% calves would have been added to the stated hind population to calculate a total (as one was not presented in the document). The DMP quotes a land area of 33,000ha. Note: Clova South is discussed separately in the DMP, and was not part of the target population ranges quoted above.

227.Interestingly though, summer count data over the same period showed a slightly different pattern. The 'peak density' from summer counts was 32 per km^2 prior to the large culls in 2005-07. However, the rate of decline in summer densities was slower - the summer density reached its lowest measured point of 20 per km^2 in July 2010. Summer densities then appeared to rise again immediately from 2011 to 2013 at which point there was a gap in the data as summer counts ceased. By the time of the current Caenlochan study beginning, summer densities may have risen to as high as ~ 29 per km^2 (based on modelling forward the January 2018 count).

228.A historic deer population model covering the same period as the counts was built, which involved using all the formal cull records and estimates of recruitment, to estimate changes in population size annually from 2005 – 2019. It proved possible to obtain outputs that were in broad agreement with the number of deer actually counted. That said, the model built for the site was more easily 'balanced' for hinds and calves than for stags (i.e. actual counts and model predictions matched fairly well, with all else equal, for hinds and calves).

229.There is a range of possible reasons why the stag model did not balance as easily as for the hinds. Stags could be moving across the boundaries of the study area more than hinds, particularly during the rut when they might move to neighbouring areas. There may also be differential rates of mortality or recruitment between the sexes, as well as a bias towards unrecorded culling given the tendency for stags to maraud onto farms etc. There was also a considerable degree of uncertainty over the most appropriate levels of annual recruitment and natural mortality to employ in the model (and related uncertainty over how these factors would have, in reality, interacted annually over the period). In essence, the trends predicted in the model could never hope to match the trends in actual count data exactly.

230.That said, it would be surprising if modelled and measured trends matched exactly anyway because there are undoubted biases in the count data themselves. Examples include an inherent bias caused by lack of detection of deer in deep woodland cover, as well as arising from potential inter-observer observational biases within and between count years. Variable forms of bias might arise between years (e.g. when allocating unclassified counts to the sex and age classes, albeit photographic analysis has more recently made this less of a problem). There is also the likelihood of reduced detection of small calves in summer to consider, when they are mixed in amongst large groups of mobile adult hinds.

SEASONAL VARIATION IN DEER DENSITY

231.Complimentary analysis work was undertaken to understand more about how deer densities varied seasonally inside the Caenlochan Section 7 area. The approach used was to model forward a winter count into the following summer, and then compare it with the actual number of deer counted that same summer. A significant mismatch could be indicative of deer movement between seasons. The analysis indicated that the vast majority of deer counted in the winter probably reside in the area all year round, but there was a possibility that stags may move in and out.

232. On balance of evidence available from the seasonal analysis and from historic modelling, it seems sensible to assume that a very high proportion of the adult females and calves culled within the area are born and reside in it all year round; most stags probably also behave in this way but presumably not all given the propensity for stags to travel in the rut.

233. The winter-summer range relationship is of particular interest ecologically because of the way the deer population interacts in each season with the various habitats present. In winter, it appears that the vast majority of the herds spent most of their time below 700m in altitude. In summer the vast majority of the herds spend most of their time above 500m. The fact that deer distribution is not even over time and space has significant implications for how we interpret deer count data.

234. When count data are analysed such that the total winter count is allocated solely to the core winter range of the deer, and the total summer count is allocated solely to the core summer range, we see that the local deer densities are much higher than when calculated conventionally by SNH in either season (total count divided by total range). 'Winter range' densities since 2005 have varied from a low of 23 to a high 39 per km^2. On the same basis, 'summer range' densities have varied from a low of 34 to a high of 51 per km^2. When calculated for the Section 7 area as a whole, as per SNH convention, using the same data the lowest density was 17 and the highest was 28 per km^2.

235. Each analysis approach produces a somewhat different impression of what is happening on site. The 'core winter' and 'core summer' range densities are arguably somewhat overstated because some counted deer spend their time in the other altitude bands. The conventional approach, on the other hand, clearly understates local densities.

236. On balance, the range density approach seems to provide a more useful statistic than the conventional approach given that the ultimate aim of the Section 7 agreement is manage deer to a target density to facilitate habitat recovery. In essence, it makes sense for managers of the Caenlochan site to use a density statistic that best reflects reality on the ground.

S7 HABITAT TARGETS AND THE RELEVANCE OF DEER DENSITY

237. The relationship between deer density and deer impacts is of particular interest on the Caenlochan site because the current Section 7 agreement is underpinned by a set of habitat targets. The target levels set within the agreement refer to the outcomes of HIA surveys. Targets refer, on a per habitat basis, to a particular % of sampled locations falling within a specified impact range during site surveys. For most of the habitats present, SNH determined that at least 90% of sampled locations should have a 'Low' or 'Low-Moderate' impact score. SNH considered that the designated sites present at Caenlochan would move towards favourable condition if impact levels on site were held at or below the target level for a

period of years. Therefore, at the time of the current agreement being developed in 2013/14 a key issue for SNH was to establish what density of deer might be needed on the site to help achieve the habitat targets set.

238.Baseline HIA data had already been gathered in 2008 and a follow-up assessment had also been undertaken in 2012 - both data sets were available to SNH (and owners) at the time of the new agreement being drafted. The HIA baseline survey data clearly showed that most of the habitat targets set for the site had not been met in 2008, even at a point in time when the deer density was at its lowest ebb based on available winter count data (~ 17 deer per km^2 in 2008). The 2012 HIA survey results also indicated that the majority of habitat targets were not being met, albeit a rising trend in summer deer densities was apparent by then within the summer deer count data set. Given the core data produced by the HIA method (small-scale indicators) reflects *current* impacts it could be argued that a solid base of evidence had already been built to show that deer densities on the site were too high under the original Section 7 agreement hence densities needed to be reduced markedly in the successor agreement.

239.An additional opportunity to identify the mismatch between habitat targets and target deer densities presented itself concurrently in 2013, before the new agreement was finalised, when a new site-specific DMP was being developed by the landowners (R. Putman; completed in 2014). A core aim of the new DMP was to try and identify management measures that would ensure the designated sites moved back towards favourable condition. In this plan, the proposed deer densities were slightly higher than in the original agreement.

240.A further set of HIA surveys undertaken in 2015, the year after the new agreement was signed, confirmed broadly the same set of outcomes was apparent on site (i.e. almost none of the habitat targets were being achieved).

241.In 2016, albeit their purpose was not to address the issues of the Section 7 agreement *per se*, two updated DMP's were created - using public funds - for the DMG's whose areas overlap the Section 7 control area. These plans should have ideally taken the condition of the designated sites at Caenlochan into consideration, and hence they could have suggested heavier culls given the poor HIA results from 2008, 2012 and 2015.

242.Next, the January 2018 deer count indicated that winter deer densities at Caenlochan seemed to be on the rise – this corroborated a developing trend already visible within the historic summer deer count data that had been gathered up until 2013.

243.The most recent set of HIA surveys undertaken in summer 2018 showed – somewhat predictably by this stage - that the majority of the habitat targets were still not being met, and in most cases were falling far short of being met. On the basis of all the evidence available it is clear that the habitat targets set for Caenlochan cannot be met by holding deer at any of the deer density levels apparent over the past 20 years.

Postcript 1: During the period this report was being edited, following comments from SNH on a first draft of it, the contractor completed a first draft of the Site Condition Monitoring results for the Caenlochan SAC and Callater SSSI. These data will be presented in detail in a separate report. In summary, six features were sampled (alpine & subalpine heath; base rich fens; blanket bog; montane acid grasslands; dry heaths; spring-head rill & flush). All 6 features failed the SCM assessment. The % of sampled plots which failed varied from ~ 20 to ~ 90%. A considerable number of plots failed on more than one indicator. The majority of failures were attributable to the presence of high levels of grazing, browsing or trampling by herbivores.

EXPLORING RELATIONSHIPS BETWEEN DEER DENSITY AND IMPACTS

244. Following the survey work of summer 2018 a large body of new evidence and analysis, over and above the repeat HIA, is now available to help SNH and owners understand more about the relationship between deer density and impacts at Caenlochan. Also, a related body of relevant evidence is available from work that has been undertaken in recent years on similar upland sites across Scotland[79].

245. The estimated occupancy level of deer and sheep on the Caenlochan study area over the summer and early autumn of 2018 was high from an ecological perspective. It averaged ~ 55 per km^2, albeit considerable spatial variation was apparent. In some areas the local occupancy level was equivalent to ~ 200 animals per km^2 but this is perhaps unsurprising given the size of herds which inhabit the area in the summer (upwards of 200-300 is not uncommon). It was also apparent that some areas were consistently used less. When the data were explored in more detail it was evident that areas of consistently higher occupancy (termed in combination the 'Higher zone'; average of ~69 per km^2) were present mainly to the north-west and the south-east of the study area. The middle section of the site had lower occupancy on average (Lower zone; average of ~43 per km^2, albeit this is still high in ecological terms).

246. Of course, the study site is also used by mountain hare and red grouse. These both utilise heather as a major part of their diet, in the same way sheep and red deer do, alongside grasses. The dung count data gathered on site clearly indicate that hare must contribute significantly to the patterns and levels of impacts apparent. Sheep clearly contribute also based on their distribution as evidenced by direct counts and range mapping. A model using accumulated dung dry weight as a proxy to estimate relative contributions to grazing off-take on site suggested that ~25% of accumulated dung by dry weight came from sheep, hare or grouse in the 'Higher occupancy' zone. The equivalent figure for the 'Lower occupancy' zone was 14%, with the figure for the site overall being ~20%. The spatial patterns evident in the data sets from the 2018 surveys indicate that sheep were restricted to certain areas of the study site, presumably in the main because of hefting and/or shepherding activities. The grouse – and less so but still noticeably so – the mountain hare seem to be most active in the areas actively managed by muirburn and otherwise in their vicinity. This correlates

[79] In the coming months, the situation might be further strengthened by SNH publishing a meta-analysis of their national HIA data sets.

fairly closely with the boundaries of the zone of Higher occupancy for sheep and deer.

247.The strong spatial patterns in herbivore density evident enabled us to undertake an exploratory analysis using the OIA data sets to look for local relationships between occupancy levels and impact levels on key plants and habitats. The analysis focused on the occupancy of deer and sheep, given their dominance on the site coupled to the fact that they are actively managed across it presently[80]:

a) A variety of the impact indicators assessed appeared to vary broadly in line with deer-sheep occupancy levels. The most notable was in relation to the browsing off-take levels on the dwarf shrubs, closely followed by key associated variables (e.g. shrub flowering levels and frequency of shrub stem breakage). Impact levels were noticeably reduced at lower deer/sheep densities than at higher densities. Also, most of the relationships appeared to be broadly linear (i.e. where deer occupancy was 50% lower so was the level of browsing impacts on heather, for example).

b) Levels of uprooting of plants and mosses - and levels of disturbance to the ground - were typically at very low levels in absolute terms despite the exceptional density of deer and sheep measured. There was therefore no clear relationship between density and these types of impacts (according to the way there were measured on site, at least). That said, the level of physical trampling of the ground from large mammals in summer on the Caenlochan site is clearly exceptional even if it does not seem to cause adverse physical impacts to the moss heath mat itself[81]. It might, for example, be expected to make nesting conditions for upland birds very challenging given the high frequency of hoof passage. The lack of dwarf shrub stature at the mid-altitudes might arguably exacerbate this problem, in respect of a lack of cover and shelter for some bird species. The paucity of flowering on heavily grazed stands might also be expected to reduce the availability of fruit and seeds etc later in the autumn that may also produce adverse impacts on birds directly (i.e. lack of food) and indirectly (e.g. low abundance of some smaller bird species resulting in a lack of prey for raptors).

c) Data relating to grazing on the grasses showed little or no relationship with deer-sheep occupancy level; these plants were undoubtedly being utilised, sometimes to quite high levels, but in general the deer-sheep occupancy level seemed markedly less important as a determinant of current % off-take than in the woody plants. These plant groups of course grow in different ways, with grasses specifically adapted to withstand constant grazing in a way that woody plants are not (in essence, grasses grow from the base of the plant

[80] Of course, landscape-scale management of hare could be undertaken to try and influence the patterns of impact on site also. Moreover, the contribution of hare could also become more important in relative terms if deer and or sheep densities were be reduced.
[81] If there is a need to measure trampling pressure in the future then deer-sheep occupancy survey data would provide a very reliable indirect measure of it.

whereas woody plants actively grow from the shoot tips). It might therefore be expected that impacts are broadly cumulative on woody plants whereas they would not be on plants that grow continuously from their bases each year during the growing season (and which otherwise die-back for autumn and winter).

d) The other group of woody species most commonly found on upland sites in Scotland is trees and tree seedlings. Tree seedlings were almost universally absent on site, other than occasional Sitka spruce. However, other OIA studies across the Scottish uplands have shown that deer and sheep browsing (and hare locally) can severely suppress tree seedlings even when large mammal occupancy levels are very low (e.g. 5-10 per km^2). Of course, montane willow scrub is present on the Caenlochan site. Whilst only rarely encountered across much of the Scottish uplands these willows are 'widely' present at Caenlochan albeit typically only in locations where herbivores cannot gain free access. The evidence available from site showed that where herbivores are getting access, they are likely to be suppressing willow scrub stature and/or cover levels. The extremely localised distribution of these plants is of course assumed, in large part, to be a function of the historic way land has been managed over many centuries. That said, it is also the case that regeneration of these plants is a complex issue with factors other than grazing often being implicated in a failure to regenerate[82].

248.On the basis of the evidence available from the baseline OIA in summer 2018, it would be possible to make judgements about the likely habitat end state achievable under different long-term levels of deer-sheep occupancy. That said, the choice of occupancy level would ultimately depend on the perspective of the person making the judgement (e.g. conservationist, estate focused on grouse production, forester etc).

249.On the other hand, SNH's system of assessment – the HIA – was developed specifically to guide their staff and other land managers to know when upland sites were likely to be moving towards favourable condition in the presence of large grazing mammals and when they may not be. It was for this reason that HIA data formed the basis of the current Section 7 agreement habitat targets.

SELECTING A NEW TARGET DENSITY: ISSUES TO CONSIDER

250.The HIA quadrat data gathered from the OIA grid produced some potentially useful insights. The evidence available indicates that the current deer/sheep occupancy level on site would need to be reduced markedly if the SNH habitat condition targets are to be met. A 50% reduction in deer/sheep occupancy appears unlikely to allow all the short-term measures of impact to become compliant given the range of occupancy levels measured locally in each habitat under consideration. The analysis undertaken indicates that a 75% reduction (or more) might conceivably be needed.

[82] See Appendix 5

251.Given the findings of the enclosure study in Caenlochan Glen, this reduced occupancy level may then need to be maintained for a period of several decades in order that habitat structure in the zone between 500-800m was able to re-develop to its full potential. The suppressing effects of climate will, in effect, prevent the plants from growing quickly and this suppressing effect will increase in line with altitude (and, to an extent, exposure levels). The findings of the historic imagery assessment corroborate the enclosure study, in that it also shows changes in dwarf shrub cover have occurred on the site over a multi-decadal timescale. Evidence from agricultural census records and historic deer counts indicate that the decline in heather cover observed probably began to arise from intensive sheep grazing, with densities certainly rising after World War 2, but more recently would likely have been sustained by increasing deer densities. That said, the effect observed in the air images study was related to a slow *decline* in cover over a long period of time due to chronic levels of over grazing – if the current level of grazing pressure was reduced the positive effects would likely become visible in a markedly shorter timescale as per the Caenlochan Glen enclosure (and other similar fenced areas around Scotland more widely).

252.Of course, a marked reduction in deer-sheep occupancy 'on average' would not guarantee that the local levels of occupancy in each zone and habitat would change in proportion as expected. That is because the deer may re-distribute themselves in relative terms. A clear corollary flowing from this is that the local spatial response of habitats to a major reduction cull on the designated sites would also be hard to predict with a high degree of certainty[83]. Clearly, a considerable part of the herd seems to prefer the highest parts of the site in summer and it might be safest to assume they always will do. That said, the impacts on key woody shrubs do seem to vary broadly in line with occupancy level. It might therefore be equally safe to assume that the effect of a cull will still be felt on average across the wider site even if not evenly across all parts. In essence, it is a question of scale.

253.The scale at which site management is planned at, and undertaken, in the future is a key related consideration. The designated sites could be considered the lowest common denominator for guiding deer management decisions within the wider Section 7 area. Or, in a more extreme sense, the more sensitive elements of habitat within them could be adopted such as the dwarf shrubs or in turn the blanket bogs or in turn the montane willow scrub. If management decisions and plans are driven solely by a lowest common denominator of this type then the clear corollary is many of the deer and sheep (and possibly hare in years of peak population) may need to be culled or otherwise removed from a wide area. It would follow that this reduced density would need to be maintained for a long period of time. Other changes to land management regimes may also need to follow, for example planning for the need to undertake muirburn more widely

---

[83] The additional complication is that the future response of mountain hare to any marked change in deer occupancy levels is unknown – it might be that they become a more significant consideration over time as a consequence.

than now to ensure that the developing heath-dominated habitats do not provide a new pathway for fire to spread (or otherwise to ensure they are not themselves destroyed by it).

254.The level of change likely to be needed to deliver the conservation objectives on the ground, and the likely duration of it, means that considerable adverse effects could be experienced by the current owners of the Caenlochan site along with their managers, staff and families. Depending on how changes were put into effect, particularly in relation to the speed of change but also who funds it, adverse socio-economic impacts will arise locally and possibly regionally in the short-term at least. The regional impacts would arise because of the level of interconnectivity between economic activities in rural areas (e.g. sporting activity generates bed nights for hotels, and in turn petrol stations etc) and also the relative paucity of alternatives.

255.A related consideration is that the major deficiencies in habitat structure and condition that are visible on the site now – from a conservation perspective – must have arisen over many decades, and in all probability several centuries or more. These changes began, and many of them probably took place in the main, long before the current network of designated sites was developed. Even if the current incumbents owned the land at the time – some did – they had little say in how the sites were designated or what it would mean for them going forwards.

256.That said, the law of the land does state that these habitats and sites are protected. Also, the law states that deer need to be managed by owners in a manner that ensures the public as well as the private interest is taken into account. This is the case in general terms, as well as specifically in relation to designated sites. On the one hand, SNH has the responsibility to protect important sites and improve their condition – which most people would likely agree with, in principal - whilst on the other it does have a balancing duty to consider, for example in relation to private interests and socio-economics. In turn, the Scottish Government on the one hand has a duty to ensure the environment of the nation is in good health – because of the importance of biodiversity and ecosystem services for example. On the other hand it has to consider the views of the electorate, as well as consider wider public needs in - for example - healthcare provision and funding of schools.

REVISING THE APPROACH TO SITE MANAGEMENT

Recent changes made by the DMG

257.As a precursor to SNH deciding on its future requirements for the site, which will presumably happen after the outcomes of this Review have been digested, the owners of the Caenlochan Section 7 area have recently made several steps forward in recognition of the current situation:

a) Several estates responded immediately to the high January 2018 count result, and reported that ~ 200 extra hinds were shot late in the winter to try and begin reducing deer densities back to the target level in their DMP.

b) In the 2018-19 season, just over 1,900 hinds were shot within the Section 7 area by the estates. The culls were organised and taken by estate staff, mainly acting as individual estates but in places working collaboratively. The culls were taken without any direct financial input from SNH. In contrast, during the year of largest hind cull (2,363 in 2005-06) significant amount of government support (in time and money) was provided. The delivery of the 2018-19 cull is a notable event, as it required the efforts of many people and involved long working hours in often very difficult conditions. Interestingly, the stalkers report that the presence of several popular Munros is of particular significance to operations such as these, and that their popularity has made culling operations progressively more difficult in recent years due to increasing levels of disturbance most notably in summer.

c) Around the time of the contractor and SNH engaging with estates in late 2018, to share the interim results of the project, the estates concurrently began to re-organise themselves:

   i) A new chairperson, who is not a local landowner, was appointed to the East Grampian Sub-Area 1 DMG. This DMG covers most of the current Section 7 control area. SNH has been supporting the group financially in the period since (e.g. providing funding to allow the new Chair and Secretary to do their work).

   ii) The DMG began to review the boundary of the group to rationalise it in line with the Section 7 area as well as to take in land to the south where red deer are present. The group has now re-named itself the South Grampian DMG in recognition of this fact.

   iii) Several extra meetings have been held by DMG members to discuss the situation on site, more than in previous years, in addition to the 5 meetings held during the contractor's time of involvement on the project. The contractors have also endeavoured to support the estates as much as possible during the project period[84].

   iv) A new Executive Group has recently been formed to help oversee production of a new deer management plan specifically, and to streamline future decision-making within the DMG more generally.

Future site monitoring: the need for change

258. Irrespective of the specific decisions made by SNH and the local landowners about the future of the Caenlochan site in coming months, it would seem essential that they are evidence-based. Therefore, independent and robust but cost-effective site monitoring and appropriate data analysis will play a crucial

[84] The contractor did offer to spend further time with the estates discussing interim results and trying to help them map out a way forward, in advance of the end of the Section 7 agreement in autumn 2019. However, the estates formally declined this offer at a meeting in January 2019. For this reason, part of the contract's scope – to engage in more detail with the estates to better understand their management objectives – was not delivered. Similarly, any analytical work that might have arisen as a consequence of these meetings and discussions has not been undertaken.

ongoing role in the DMG's activities. In this regard, the 2018 Caenlochan study established a number of potentially important findings that should be considered by SNH and the landowners when developing a future monitoring strategy for the site.

259.Whilst it has proven to be a benefit in writing this report, the large number of deer counts (n=27 since 2000) undertaken at Caenlochan raises a related question. Most upland areas are managed with far fewer counts being undertaken over a 20-year period – few would have more than 4 and some may only have 2 or 3. It would seem that an opportunity to develop detailed population dynamics models, as were built for this report, might have been taken much earlier in the process in order to save a substantial sum of money on counts. It is unclear why this was not done, but such tools have certainly always been available. DMG's such as the Monadhliath in Inverness-shire have recently shown that models can be successfully used (with counts at 5-yearly intervals or longer) if robust parameterisation is developed and then models re-calibrated annually with up to date parameters (e.g. actual recruitment and mortality).

260.It appears that the design of the random-plot HIA could have been improved somewhat. The high level of spatial autocorrelation between sets of quadrats produces an inefficient design in a statistical sense. The narrow geographic range of the study, being restricted to the designated sites themselves, arguably also reduced the value of the data set when it came to understanding deer density-impact relationships across the wider site under management. The wider and more systematic coverage of the grid survey in 2018, obtained using no more than the level of overall effort required to complete the original random design, indicates the potential for similar high-intensity HIA survey designs to be amended to cost less) or provide greater insight.

261. The national deer count data set and national HIA data set could have been used to undertake meta-analysis.

262.SNH has begun to recognise the potential benefits of Occupancy-Impact Assessment (OIA). A particular benefit of the method is that local relationships between impacts and occupancy can be generated, and then tested by taking an increased cull on site. The study at Caenlochan has clearly demonstrated the potential technical benefits of undertaking such work, even if the outcome obtained was somewhat compromised by the fact that the very high deer density present precluded measurement of impacts across a normal gradient of low-moderate red deer densities. A related point is that the delivery of the deer counts and impact assessment work at the same time and in the same places in 2018 (i.e. the OIA) produces cost synergies as well as analytical synergies. SNH might consider reviewing the cost base and rationale for their standard approach (deer count + HIA, done at different times) at a national level and comparing it to approaches such as OIA given their relative performance at Caenlochan.

263.Another reason for conducting a review of the standard approach to monitoring deer in the uplands relates to some of the difficulties experienced in analysing and interpreting the results of HIA surveys at Caenlochan. A particularly noteworthy finding relates to the response of trampling indicators in comparison with grazing indicators. At the very least it would seem sensible to increase and or equalise the numbers of indicators for trampling if they are to be assessed in isolation[85]. It would also seem to be worthwhile investigating why grazing indicators on the site produce markedly lower impact scores relative to trampling indicators, given it is the same deer density that is acting on both. A related query arises in respect of whether to use the mean, median or modal indicator score in analyses when assessing performance against targets.

264.The absence of deer count data for the Glen Doll forest, which is part of the Section 7 area, is another potential issue. Red deer use the area and have access to it from the open range, hence the helicopter counts undertaken in winter are assumed to underestimate abundance. It would be worthwhile considering in any monitoring review and including as part of any future program of work. Extending out the dung count to the wider winter range is another possibility, to add value to the current system.

265.Another potential weakness in the data available for the Caenlochan site, and one which points to a further opportunity for cost and analytical synergies, relates to the strong focus SNH puts on red deer at the expense of all other grazing herbivores (e.g. hare and sheep). It would be useful to increase the knowledge base on this aspect and hopefully the findings of the work undertaken on multi-species dung counts and on faecal dry weights at least demonstrates the importance of making an attempt on sites with multiple species present. The cost of adding in this work in 2018 was very low relative to the knowledge gain obtained.

CONCLUSIONS

266.The aim of the current Caenlochan Area Section 7 Control Agreement (2014-19) is to ensure a set of designated upland habitats are moving towards 'favourable condition' across the combined land area of three sites: Caenlochan SAC, Glen Callater SSSI and Cairnwell SSSI. In order to ensure this shift is delivered, SNH specified a set of habitat targets within the agreement in 2014. The owners developed a new deer management plan in 2014 that was designed to help deliver favourable condition on the designated sites at the same time as allowing them to meet their sporting aspirations. SNH agreed they would commission survey work regularly to ascertain whether the specified habitat targets were being met.

267.The results of habitat monitoring undertaken in 2015 showed that the targets were failing to be met, with few exceptions. The results of repeat monitoring in summer 2018 reinforced this pattern and conclusion - impacts in most cases

[85] The original MacDonald et al (1998) method did not analyse the data in this manner – all indicators were assessed together and a single score calculated.

remain well beyond the target levels agreed. The failure, by a large margin, to reach the habitat targets set by summer 2018 suggests that the current Section 7 agreement is unlikely to be judged a success when it concludes in autumn 2019.

Postscript 2: The results from a recent deer count at Caenlochan (August 2019) show that despite a considerable cull having been taken in 2018-19 the post-cull winter deer density (May 2019; pre-recruitment) was in the order of 19 per km^2 in the Section 7 area (see Appendix 6 for a detailed analysis). Given the nature of the relationships established in this report between deer occupancy levels and impact levels on site, and that successive habitat surveys and multiple deer counts have proven that a density of ~17-20 deer per km^2 is incompatible with achieving the habitat targets set, it would seem unlikely that SNH can judge the current Section 7 agreement to have been a success when it ends in October 2019.

268. Analysis of a wide range of data from new site surveys in 2018 - when viewed alongside evidence available from other upland study sites in Scotland - suggests that a major reduction in the combined levels of deer and sheep occupancy at Caenlochan would be needed to deliver the habitat targets SNH has set. A reduction in deer/sheep occupancy - from 2018 levels - of 75% or more could be required. Winter densities may need to be reduced to as low as 5 per km^2 to ensure that summer occupancy levels of deer/sheep on the designated sites are in or around 10-15 per km^2.

269. That said, the 2018 survey results also indicate that other herbivores (e.g. mountain hare) contribute to the patterns of impact observed. Modelling indicates that even a reduction in deer-sheep occupancy of 75% might only result in a decline in *overall* herbivore off-take levels of ~ 60%. Management of other herbivores such as mountain hare would therefore at least need to be *considered* as part of any future management planning exercise for the site.

270. Deer and sheep population reductions of the size calculated simply do not seem deliverable at the present juncture. Not least, this is due to the potentially serious consequences they would have for the socio-economics of the estates and related local communities in the short-term. In addition, there is no up-to-date management plan for the area that identifies the approach that would need to be taken in practical terms (e.g. co-ordination of culling, local cull targets etc) to deliver such a large change.

271. The fact that 15 years have passed since the onset of the first Section 7 agreement – a period sufficient to have seen some very marked changes in habitat condition already take place – lends further weight to the argument for hitting the ‘pause button’. In doing so, all the parties involved in managing the site would have time to participate in a thorough, objective and balanced debate about its future.

272. This review concludes that potentially difficult decisions over the future management of the Caenlochan site will undoubtedly need to be made, but that the situation is highly complex and will take time to work through in a balanced and objective manner. In our experience, any new package of solutions developed for the site would benefit immensely from being formulated and adopted jointly by the private and public sector in a new partnership. The

processes used to develop any new solutions, and to underpin their delivery, should be *independently* led and evidence-based to help ensure balance of debate as well as long-term sustainability of outcomes.

RECOMMENDATIONS

273.**It is considered essential that an in-depth consultation is undertaken with the estates involved and their stakeholders (including the local community) to better understand their views and concerns over any proposed deer density reduction.** The results of such a consultation would have immense value in informing the debate over the future management of the Caenlochan site itself (as well as being of value nationally).

274.Over the course of the next year, **it would seem that a new strategic management plan should be developed for the Caenlochan area** - and perhaps a wider area incorporating it. Such a plan would ideally be integrated, and thus consider most or all aspects of land management plus related socio-economics. It would need to genuinely deal with the complex and often conflicting demands of managing large tracts of land in the Scottish uplands, and somehow navigate a way through. The objectives of any plan would need to deliver on a wide range of local and national objectives, and thus be designed to serve the interests of the local economy and local communities of the area as well as the environment and the estates themselves. The outcomes would need to be palatable to owners and government alike, as well as being sustainable and enduring in all foreseeable respects.

275.**Whatever solution is proposed or eventually adopted at Caenlochan, it would seem essential to undertake robust monitoring of the natural environment to provide the evidence needed to drive strategic-scale decision-making**. SNH and the landowners should consider – from each of their perspectives individually, as well as jointly – what information they think they need to do this. This report hopefully provides them with some of the basis at least. Clearly, monitoring evidence should be gathered in the most cost-effective manner where possible - but it must, in the end, be robust and allow for corroboration in order to avoid drawing misleading conclusions. Independence and reliability of data is key.

276.Given the extensive and multi-layered nature of the monitoring results now available for the Caenlochan site, and because such a wide variety of techniques have been used there over the years, **an excellent opportunity has arisen for SNH to review and possibly update its approach to the monitoring of deer on upland sites**. We hope they take up that opportunity.

277.In addition, **it would seem right for the Scottish Government to take the findings of this Review into account when they consider whether to re-formulate their approach to regulating the deer industry in autumn 2020**[86], as there are undoubtedly valuable lessons to be learnt for all. Of course, it should be noted that this Review only deals with a particular type of site – namely, an upland site in the Eastern Grampians with little woodland cover and sparse

[86] This will involve, amongst other things, examining the findings of the updated Review of Deer Management being prepared by SNH as well as the parallel review being undertaken by the independent Deer Working Group.

human settlement – and that many other types of site need also to be considered. Systematic and wide-ranging reviews of available *empirical* evidence, such as the one that has been undertaken herein for Caenlochan, would be useful to undertake for other key site types too as, in our view, there will undoubtedly be lessons to learn from them.

278.In producing this Review, the contractors have learned a considerable amount about the recent history of management at Caenlochan as well as its present status. Inevitably, we have also spent time thinking about what the future might hold for it. In the last section of this report **we propose a step-wise planning process, and sketch out a range of potential future management scenarios, in the hope that it might help signpost a way forward for the Caenlochan site.** We hope that the agencies and the owners of the site both might find the ideas outlined in this section to be useful in steering their deliberations - however, we fully appreciate that either or both of the key parties involved could disagree with most or all of what is suggested. Either way identifying a way forward will without doubt be a challenging and thought-provoking task, but one which we believe will ultimately be seen by all as well worth persevering with.

A WAY FORWARD?

PROCESS

We suggest the undernoted process might usefully be employed in determining a Way Forward for the Caenlochan site (notes in reduced size font are provided below each key point):

1. A new '**planning process'** should be put in place, to ensure sustainable deer management is delivered in (and around) the current Section 7 Control Area. A **follow-on project** is needed to deliver the process.

Previous & existing deer management plans have, to date, failed to deliver most of the Section 7 habitat condition targets set. Thus, deer damage has not been and is not being prevented. In turn, sustainable deer management has not and is not being delivered. When previous plans were prepared, in 2014 and 2016, only some of the current evidence was available hence their effectiveness had not been adequately tested nor was their advance formulation robustly guided.

Key principles of any planning process:

- Inclusive: involve estates (owners and staff), SNH & key stakeholders
- Informed: robust evidence -> rigorous, objective analysis
- Integrated: multi-faceted (e.g. ecological + socio-economic factors considered)
- Innovative: no barriers – use an open-minded, logical approach

2. **Independent technical advice**, underpinned by robust empirical evidence, will drive the planning process to ensure key decisions flowing from planning meetings are competent and reliable.

The data arising from the 2018 Caenlochan survey and review project should be used to underpin a new objectively produced management plan. The selected consultant (being independent) along with the chair (being independent) both need to facilitate the process, and thus both need to be trusted by each side to deliver.

3. A **Task Group** (a cross-section[87] of decision-makers[88]) is needed to make decisions during the process[89]. **An independent chair** is required to ensure TG meetings are well run and reach clear conclusions.

The process needs a smaller group of decision-makers (there are 'too many present in the room' based on experience of recent DMG meetings) led by a Chair who can act impartially. The TG will act on behalf of the owners (who include SNH and NFE) and the agencies (and stakeholders) to ensure all perspectives are clearly put across as discussions progress.

4. The main deliverable should be a **new Strategic Land Management Plan**. This should describe how the uplands are to be managed in future to ensure an optimal balance is struck between the needs of landowners, the needs of land users[90], the condition of the natural environment and the condition of the wild deer present therein. By considering deer in a broader context than previously has been the case at Caenlochan, land managers will demonstrate to the Scottish Government that a robust long-term plan is now in place to deliver an optimal mix of private and public benefits in future.

The socio-economic impacts of any agreed reduction in deer density (if one happens) should be mitigated as far as possible – this needs a broader and more considered approach to planning than has hitherto been employed. For any given target density, there are many possible approaches to delivery to explore. A tapered-down stag cull over 10 years (as opposed to a fast 2 year reduction cull of hinds) is one good example (see Appendix 6). This would need discipline (and thus a new model & agreement for sharing stags). Planting of new woodland for deer shelter is another (in time, this will improve deer condition including stag condition, and also smooth out current fluctuations due to 'natural deaths' which make owners uncomfortable in reducing densities for fear of a bad winter causing a rapid loss of breeding stock). Rather than doing this *ad hoc*, a new plan would identify the optimal locations and extents of woodland so that deer benefit from them in future (and government targets for woodland expansion are met)

[87] Key interests need to be represented, but the group cannot be too large - the largest estates by land area (e.g. Invercauld, Balmoral, Tulchan, Glen Prosen) along with perhaps 2 other estates (to cover the remaining interests e.g. Auchavan, Clova, Glen Isla, Balintore)?
[88] Owners preferably, and otherwise their agents (other people may attend but they will be present only as observers *unless* asked to contribute to a meeting by the Chair)
[89] They might be expected to meet up to 10 times over a period of 12 months during the planning process
[90] Land uses such as: deer stalking, farming, forestry, grouse, nature conservation, renewable energy, recreation & tourism. Impacts on the aquatic environment downstream (for fisheries, for flooding) should also be considered.

5. The SLMP should be **underpinned by a Shared Vision** for Land Management[91].

A shared statement prepared and agreed by all parties describing the common ground (owners and SNH) that is used to steer decision-making. This is needed early on. It would be produced by interview and discussions followed by negotiation (the Applecross Trust project is a good recent example of conflict resolution leading to a new SV). It needs to reflect the 'new reality' (and not what individual owners 'desired' previously from their estates in isolation of (i) each other and (ii) the Scottish Government. The results of the 2018 project suggest there is already much common ground.

Common threads of discussion during project meetings in 2018 were as follows:

- Owners & keepers are 'the custodians of the land'
- People are central
- The local rural economy is fragile
- Employment is important (both the level & its sustainability)
- Deer welfare is absolutely key
- Estates are proud of the stags they produce
- The natural environment underpins everything

An example of how to convert this into a Shared Vision:

- "We will be leaders in land stewardship, not followers"
- "Increase employment & improve its sustainability"
- "Minimise deer natural mortality"
- "Maximise skills & competence in managing deer"
- "Strive to improve stag quality"
- "Create a world class stalking environment"
- "Manage the land to balance current <u>and</u> future needs & benefits for <u>all</u>"

6. The SLMP's overarching aim should be to **deliver the Shared Vision over a realistic period (30-50yrs).**

[91] In turn, this will have been informed by the previous completion of a provisional 'Review of Deer Management'. The review will be finalised as part of the planning process (by whoever delivers the planning process).

Upland habitats generally take time to respond to a change in management, and with increasing altitude the period of response lengthens markedly. Likewise, if work such as woodland creation is required then trees also take time to establish and mature. Moreover, change is always difficult to deal with in human terms, hence from the perspective of the owners and staff of the estates, as well as SNH's staff, time is needed to ensure any new approach is given the right amount of time to bed down and be adapted as required.

7. The SLMP should consider covering a somewhat **larger geographic area** than the previous Caenlochan Deer Management Plan (Putman 2014)[92] to ensure the full range of the main deer herds is taken into account.

There are arguments for keeping the management area broadly the same as at present, with the exception of adding in the estates to the south who are also part of the EG SA1 DMG but are not currently signatories to the Section 7 agreement. The reason for this is that red deer using these estates move between them and the Control Area to some extent. It is also possible that other areas could be brought into the management area, because of the potential mobility of stags for example. However, this needs to be thought through in more detail as part of a future planning process.

8. An **ecologically appropriate target deer density** needs to be agreed for the SLMP (given available evidence[93], a winter density at the *lower end* of the range 5-15 per km^2, held for 20 years+ [94] across the wider S& area, is ideally needed for the SSSI's to transition towards favourable condition). In tandem, however, the SLMP must take account of the need to reduce adverse socio-economic impacts from planned changes to an acceptable level.

The evidence available from the site, and from many places around Scotland, suggests that a target density of 19 per km^2 is far too high for Caenlochan in an ecological sense, as it results in summer densities of 40-50 per km^2 on the high ground and also very high winter densities on the low ground. The risk is that if the key parties individually or jointly decide to deliver a small reduction from the present density, to 'see what happens', then in 10 years' time nothing is likely to have changed. Moreover, it has been proven over the last 15 years that managing the herd to a particular density is not that easy even with a lot of count data to hand, unless robust analysis is conducted on the data – even then, accuracy cannot be entirely guaranteed. A decisive and measurable change in density is ideally needed, but it needs to be underpinned by a range of new measures to mitigate the change. This is where government and the private sector need to come

[92] As a minimum, estates to the south of the current S7 will be included. Estates to the west, east and north may be brought in as the process evolves.
[93] And unless other robust empirical evidence becomes available in due course.
[94] Unless recovery to an agreed state is reached in advance of this point.

together to explore potential options then work out deliverable solutions – realistically it can only be delivered by joined-up thinking and by employing a team-effort.

As an example: *the various government agencies and departments individually may not be able to provide the kind of support needed, but perhaps jointly (i.e. with a joined-up approach) they could…. perhaps part of NFE Glen Doll could be opened up for 'official' stag wintering as part of a new plan, but in return owners in treeless areas just now agree to an ambitious new plan to plant 1,000ha of new native woodland. This might ideally be centred round some old birch remnants, and then the agriculture department may help find a way to allow owners to temporarily put their cattle in to stimulate regeneration in the local area, but still claim the subsidy for their existing farmland.*

9. A new **Executive Committee**[95] should oversee delivery of the SLMP once adopted, via a Land Management Action Plan (derived from the SLMP). The EC should meet ~ 4 times per annum, formally review progress annually and update key documents every 5 years.

Without regular meetings of a core group of decision-makers, delivery of any new plan will falter. Also, things will change over time and decision-makers need to remain alert to this and be willing to engage and steer any new plan (still to the Shared Vision) in a different direction as required.

10. **Time is of the essence** in producing the new SLMP as the current Section 7 Control Agreement runs out in Oct/Nov 2019. In the intervening period, culls will be set under the existing S7 agreement or an extension of it. SNH should be able to place the site into 'assured management' once the new plan is adopted by all parties, assuming any hind culls proposed in the interim have been delivered.

A new plan is needed as soon as possible, given the pressures on SNH and on owners to be seen to be making serious progress, but it should not be to the detriment of the quality of the new plan (and thus its long-term value).

[95] Formed, for example, from the local DMG's memberships

FUTURE SCENARIOS

Any Steering Group formed to help develop a new strategic land management plan would need to consider, during its deliberations, a range of possible future scenarios for the Caenlochan area.

In this section we therefore consider four potential future scenarios for deer management in the area, from the current density downwards, and what they would likely deliver in terms of habitat recovery plus future supply of mature stags for sport (Table 20). The scenarios are not worked through in any detail whatsoever; this would be a job for an independent consultant to work through in practical and local detail should SNH and the owners take up the suggestion to engage one as part of the process. They are intended merely to help readers consider the key points arising, which include the following:

- ✓ The most likely difference apparent on the Caenlochan site in the future, should herbivore off-take levels be reduced markedly, is that the woodier species – most notably the dwarf shrubs – will increase in cover and stature in places where they are currently very suppressed:
    - Recovery of dwarf shrubs will be quickest, and stature will develop to the greatest extent, at the lowest altitudes. Some other plant species (including some rarities potentially) will likely be outcompeted as a result of these changes.
    - Montane scrub could in theory respond if densities are heavily reduced, but (i) a small number of deer may still browse them heavily and (ii) additional factors are likely to control their recovery and expansion (see Appendix 5). Either way change will be very slow.
    - Natural regeneration of native tree species may arise locally at lower altitudes but is not likely to be widespread due to a lack of seed trees.
    - Peatlands do not seem likely to respond to any great extent in respect of bare peat cover – in the short term at least - because of the nature of the surface erosion present. This is acting across a large proportion of the land surface, and shows a strong degree of vertical development implying that permanent drawdown effects are likely to be acting on the bog water table. In turn, this will lead to ongoing instability of the peat mass locally, and an inevitability of further de-watering and loss of

particulate matter ongoing. Other intervention may therefore be needed to help restore peatlands[96]. Peat Action funds are likely to be available for the foreseeable future hence provide an obvious opportunity for owners to engage positively with the climate change agenda. That said, high levels of trampling will make it much less likely that restoration is funded as deer trampling can damage the integrity of the restoration techniques typically employed. Also, the extremely high levels of trampling will undoubtedly be preventing the development of a fully expressed natural hummock-hollow topography which can help control the level of the bog water table locally during droughts – this may well develop with time, if densities of deer were reduced thus improving the condition of those larger areas of bog currently unaffected by erosion.

- ✓ Any change in habitat condition will be slow, particularly in respect of vertical development in woody shrubs, as many plants are highly suppressed and their growth rate at altitude will be relatively slow. This will especially be the case when they have no mutual shelter (e.g. from other plants, from being located on protected slopes or from boulders etc) to benefit from. It is likely to take 10-20 years at least depending on the altitude of the site in question.
- ✓ Reducing deer densities will not result in a proportionate reduction in overall herbivore off-take levels as multiple other species are present. A 75% reduction in deer numbers is predicted to result in only a ~ 60% reduction in overall herbivore dry matter off-take. Of course, mountain hare could respond 'favourably' to deer density reductions and, on average, increase their numbers in places hence the level of overall reduction might in reality be lower still.
- ✓ Deer densities calculated at the overall site scale need to be converted into summer range densities to better understand their likely effects on the designated sites. A reduction at the whole site scale to 10 deer per km^2 in winter for example could still mean a density of ~ 20 deer per km^2 (including new calves) on the higher parts of the site at peak times in the summer.
- ✓ It is possible that deer behaviour, and thus distribution, may alter as a result of operations to reduce their densities. In this case, the occupancy level of deer on the highest parts of the site may not vary in accordance with an overall density reduction. Occupancy levels may decline less than expected in these areas. Shooting each deer will likely require much more effort too.

---

[96] Whether or not this is appropriate is an entirely different matter. Erosion processes on the site may be an entirely natural phenomenon, arising for example due to peat growth and subsequent peat pipe collapse. It may of course have arisen due to man's activities in the past e.g. introduction of sheep, uncontrolled muirburning etc.

- ✓ The number of shoot-able stags will inevitably decline if a very large density reduction is sought. Some compensatory mechanisms may kick in (e.g. a higher % of male calves being born, stag calf survival rates improving) with time[97]. Those estates relying heavily on winter hind stalking with clients – and there are some – will experience an additional change.

- ✓ Modifications to wintering grounds would help mitigate the impacts on mature stags, and thus on income, to an extent. For example a very major expansion of woodland cover could help, in the long-term, as would a reduction in local wintering hind density to improve the condition of habitats locally on the lower slopes of the glens (improved spring feeding during gestation). The government targets for woodland expansion have recently been increased significantly and the funding packages available seem generally to be well regarded by landowners.

- ✓ Moreover, if discipline is held by all estates, and only mature stags are shot, then a large reduction in hind density (the key to population control) will not immediately cause a shortfall in mature stags. Rather, it will occur slowly over a period of 5 years or so as new cohorts of young stags become less numerous. In order to guard against a fast decline, male calves should not be culled if at all possible and thus be left to mature. The expectation is that, over time, stag maturation rates could also gradually increase with improvements in woodland cover and forage availability coupled to the reduced stress on hinds from an improved environment etc. Stag mortality levels should also decline on average.

- ✓ The socio-economic impacts of any marked reduction in deer numbers will be significant, but with some estates likely to be affected markedly more than others. All of the estates in the Control Area share the common objective of deer stalking. Many of these estates rely heavily on income generated from stalking clients as part of their business model, albeit even with the high deer densities present the availability of shoot-able stags is reported to be somewhat variable on smaller estates. Other estates try to run a mixed estate with grouse playing a part also - and this arguably could provide a degree of resilience to reduced deer densities at least in the longer-term. Some estates have inherently stronger finances than others, either because of the availability of other income streams (e.g. recreational tourism, farming, renewables) or the personal financial position of some owners.

- ✓ Economic impacts 'downstream' of estates will be felt also, presumably with hotels and guest houses feeling any changes in stalking-related tourism activity the most – others down the chain will also feel the change to an extent, depending on how diversified they are,

[97] https://www.nature.scot/sites/default/files/Publication%202015%20-%20Red%20deer%20research%20on%20the%20Isle%20of%20Rum%20NNR%20management%20implications.pdf

including agricultural mechanics and equipment suppliers along with services such as petrol stations and shops. There is also the social and cultural impact to consider - deer stalking has long played a central role in countryside life.

In essence, any decision to markedly reduce the number of the deer in the Caenlochan area needs to be very carefully thought through - and should be approached in a holistic manner - to ensure unforeseen or perverse effects in the short-term and long-term are minimised.

Table 20 Four possible future 'deer density scenarios' across the current Caenlochan Section 7 control area (with supporting notes)

Scenario	Winter population size	Deer density per km^2	Summer deer density (per km^2) in core summer range		% Decline in deer density from 2018 (approx)	% Decline in **herbivore** off-take from 2018 (approx)		Change in *annual* level of impacts	Habitat recovery		Mature stags available annually for sport (@ 6 yrs old) - approx	Socio-economic impacts
Notes ->	*1*	*2*	*3*		*4*	*5*		*6*	*7*		*8*	*9*
1	7,086	20	40		0%	0%		Little or none	Negligible		380	None
2	5,315	15	30		-25%	-20%		Minor	Limited or local		285	Fairly limited
3	3,543	10	20		-50%	-40%		Considerable	Widespread but gradual		190	Considerable
4	1,772	5	10		-75%	-60%		Major	Widespread and rapid		95	Widespread & major

No.	Notes
1	Section 7 land area (354.3 km^2) x winter density
2	Winter count divided into entire Section 7 land area
3	Winter count + recruitment, divided into core summer range (land > 500m)
4	Assume winter density already at ~20 per km^2, following culls of 2018-19
5	Calculated using dung dry weight model, assuming other herbivore levels stay static
6	Immediate change arising in grazing, browsing and trampling
7	Extent of recovery likely over time
8	Conservative number - calculated from models: 45% calving, mortality for stags - 20% for calves, 5% annually for all others
	Avoiding killing of male calves during annual culls & culling only mature stags - defined as 6 years old average
	5-year average for stags has been ~ 425 per annum (which presumably includes a proportion of younger stags shot)
9	Degree if disruption to estates and local economy in the absence of any mitigation

APPENDIX 1 – OVERVIEW OF DUNG COUNTING

Deer are ruminants, and defecate distinct groups of faecal pellets regularly through time. These pellet groups are identifiable in most situations and conditions, hence can be counted with relative ease at any time of year. The distribution of these pellet groups, if assessed by a detailed formal survey, can help a manager to assess (i) how deer disperse themselves through a landscape and (ii) how long they spend at each location ('deer occupancy'). With a degree of careful planning and collaboration between owners, dung count surveys can also be designed to help managers establish how long deer spend in different habitat types (e.g. woodland as opposed to neighbouring farmland or open range land) or ownerships. With a degree of skill on the part of the surveyors, and by following empirically-derived rules, dung pellet groups can be broadly separated into species also (e.g. roe and red deer).

Dung count surveys, if repeated over time, can also provide a very powerful monitoring tool for land owners. Not only can changes in 'occupancy level' be quantified over time, on average, to help identify the impacts of a culling program but local changes in the spatial distribution of pellet group density can help show how patterns of use between areas or habitat types have changed.

Monitoring analysis is undertaken using the pellet group density data themselves, whereas an estimate of the number of deer present requires transformation of the data using a range of other parameters (how long dung has lain for & how often deer defecate per day on average). The two forms of data produce results with markedly differing levels of statistical precision. This has implications for how the data are then used.

In terms of monitoring, precision depends on the sample size of transects employed (low cost surveys use less plots) as well as factors such as the deer density (higher densities = improved precision) and length of time plots are left to measure faecal accumulation rates (longer time = improved precision). Forestry Commission Bulletin 128[98] provides interested readers with the technical reasons behind this. Suffice to say, however, that a baseline survey undertaken with a reasonable budget (ideal minimum sample size of n=100 transects) can produce data with an overall Coefficient of Variation – CV - of 10-40% (10-20% is attainable in areas where the deer density is typical for upland Scotland, and therefore ranges from 10-30 per km2; the higher CV's arise on sites with much lower deer densities of 5-10 per km2 or lower). If the data set is then split down into sub-areas, for example to undertake impact-occupancy analysis, then the precision of each sub-area is of course poorer. Surveys with larger samples sizes (e.g. 200 transects), as are often used for landscape scale projects achieve CV's of 5-10%.

In relation to deer abundance estimation, the statistical precision of estimates is markedly poorer (e.g. CV's of 15-30%) than for pellet group density alone. That is

[98] https://www.forestresearch.gov.uk/documents/656/FCBU128.pdf

because other forms of sampling error need to be accounted for. When estimating abundance using the faecal accumulation rate method, for example, the sampling error of the deer defecation rate also needs to be accounted for when estimating overall survey precision. In doing so, the precision of the overall estimate on deer abundance becomes poorer. This is because the second form of error is partly additive, when incorporated, but also because the precision of this part of the estimate is proportionately poorer in the first place (it is a function of the original study designs used by government departments in the 1970's and 1980's, albeit work is underway on new trials to improve the precision of these estimates).

In essence, dung counts used for monitoring are far more powerful – on paper - than dung counts used to estimate deer densities. However, in practice 100's of dung count surveys have been delivered where deer density was estimated and many of these places were then very heavily culled (using culls set with the baseline survey data). When counts are repeated, there is typically a good correspondence between predicted (from baseline models using cull records) and measured population size (from a second dung count). Where there is major disparity, it is often due to large numbers of deer moving in and out of the blocks being studied, and otherwise is because budgets were very tight and survey sample sizes had to be small (e.g. 50-70 transects).

APPENDIX 2 – OVERVIEW OF HIA

The methods of MacDonald *et al* (1998) were originally developed to provide a rapid means of characterising land management impacts across large tracts of the Scottish uplands. The original method involved assessment of a variety of impacts including: herbivore grazing, herbivore browsing, herbivore trampling, land drainage/drying, muirburn and peat cutting. The assessment was undertaken for a range of broad habitat types – dwarf shrub heath, blanket bog, bracken etc – in recognition of the fact that some impacts only occurred in some areas, and also that impacts had different effects on each habitat.

The assessments were undertaken at two scales: landscape scale (Phase 1; using 'large scale' indicators) and local scale (Phase 2; using 'small-scale' indicators and 'trend indicators'). Phase 1 work was done by eye from a distance, or using binoculars, and helped the surveyor gain a general appreciation of whether land management impacts were noticeably high from a distance or not. They then proceeded, if required as part of the contract scope, to undertake a Phase 2 assessment.

The original method for Phase 2 was designed to be applied during a structure walkover to areas of homogenous habitat (more latterly to each 1 km square in a survey area). In each, the surveyor would assess 10 points (of c. 1m^2) in each habitat type then record a result based on an average of the conditions they observed. Each area or (square) was assessed by the observer as 'Low', Moderate' or 'High' impact based on a range of indicators (e.g. level of browsing on heather, level of disturbance to bare peat etc). The aggregate result for each mapped area was arrived at from the most common of the indicator scores recorded (e.g. 5 indicators scored L, L, L, M, H so the most common was L). Most indicators related to current impacts (e.g. % heather long shoots browsed) but some related to longer-term impacts (termed 'chronic'or trend indicators e.g. growth form of heather plants present).

The result of the assessment would be a map, showing each area or square coloured according to the impact level assigned (e.g. High = red; Moderate= orange; Low = yellow). A map would either be produced for each habitat, or results integrated for all habitats. The idea was to produce an 'at a glance' picture of where impacts were highest on large sites. Whilst the original authors had suggested the system could, in principal, be employed to monitor sites the original design was not developed with this purpose in mind.

An evolution of the system occurred in the early 2000's when SNH began to deploy it on a fixed plot basis (typically 2x2m quadrats) when surveying 'Priority Sites' (in essence, designated sites with high deer densities). The idea was that observers could return to the same place several years after a baseline assessment and try to detect any difference in impact levels apparent. This revised approach was termed Herbivore Impact Assessment (HIA).

The approach commonly adopted was to use the Phase 2 assessment technique, but on a random set of ~ 30 fixed locations in each feature of interest (e.g. a set of 30 random quadrats in Wet Heath, a set in Flushes etc). The plots were photographed for follow up, and sometimes marked.

Subsequent iterations of the HIA approach, designed to improve the system further, involved:

1. Gathering additional 'quantitative' indicators' from the same plot. For example, the original 1998 system asked observers to categorise heather browsing as < 33% of shoots, 33-66% of shoots or > 66% (relating to L, M or H impact respectively). The quantitative system adds to the qualitative assessment and asks observers to record the actual % measured (e.g. 27%) so that a more refined analysis might later be undertaken and future change might be more likely to be detected.

2. Amending the methods for DCS 'Best Practice Guidance' publications, whereby the approach employed in the field was revised to make it quicker for estate gamekeepers to use (Best Practice Guides 2008).

A key issue with the HIA method (as with other open range methods) identified by the authors in the original text of 1998 is that the functional significance of many of the indicators used was not well understood. The response of heather to browsing by sheep and deer was heavily studied in the 1970's and 1980's, due to its importance for upland agriculture. Therefore, relationships between grazing off-take and heather cover, for example, were relatively well understood. However, the functional significance of other indicators such as the 'level of moss uprooting' were much less well understood. Attempts were made latterly to 'weight' the HIA analysis towards the 'better understood' indicators but ultimately SNH decided against this approach due to concerns over subjectivity in the choice of weightings used.

As the system of 'small-scale indicator' assessment is somewhat complicated, it is worth briefly explaining here how it works. The method, at the quadrat scale, involves an examination of a wide suite of indicators of Grazing or Trampling on each plot, assuming the plant (or physical feature) relevant to the assessment is present and hence the indicator is applicable. Each habitat type has its own set of 'small-scale indicators' and its own set of 'trend indicators'. Each indicator is assessed as being in one of three classes (Low, Moderate or High; sometimes there is an option to use LM or MH as intermediates). An example set for some of the Blanket Bog assessment has been copied below, from the original handbooks of MacDonald *et al* (1998) or interested readers to examine.

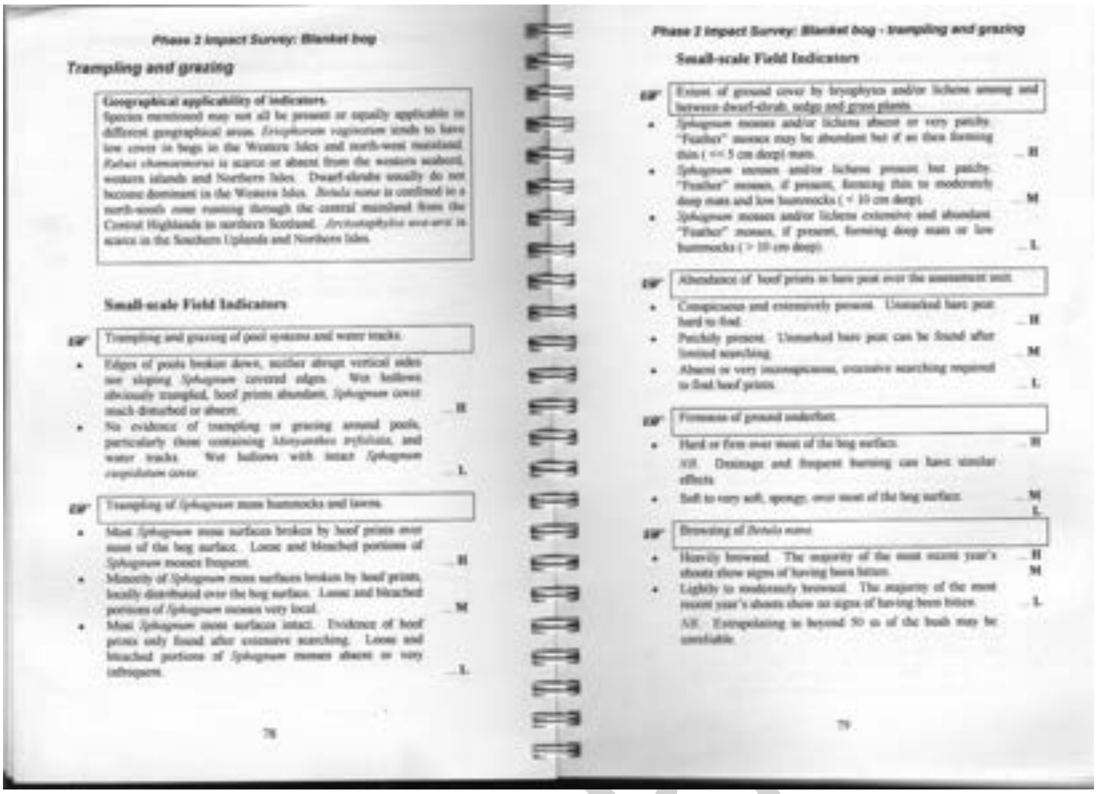
There are different ways of analysing the data, but common ways include using the most common or the middle class as a value for the plot (e.g. 15 Low values and 3 Moderate values from a plot would be classed as a Low score overall) for that plot. The data from each plot are often mapped, to assess spatial variations in impact, and are also often presented in tables or graphs which show the % of plots in a feature which were recorded as Low, Moderate or High overall.

Trampling and grazing

Phase 2 - Small-scale Indicators	**H**	**M**	**L**
Pool systems and water tracks			
Sphagnum hummocks and lawns			
Cover of *Sphagnum* and/or lichens vs "feather" mosses			
Hoof prints in bare peat			
Firmness of ground underfoot			
Browsing of *Betula nana*			
Signs of browsing of less palatable dwarf-shrubs (*Auu, En, Et, Vu*)			
Amount of flower and fruit on *Rubus chamaemorus*			
Amount of flower and fruit on *Eriophorum*			
Growth form and signs of browsing of *Myrica*			
Browsing of *Calluna* and/or *Vaccinium myrtillus*			
Dung			

Trend	**I**	**CH**	**CM**	**D**	**CL**
Changes in growth-form of dwarf-shrubs					
Height of *Myrica*					
Height and cover of dwarf-shrubs vs graminoids					
Abundance and vigour of *Juncus squarrosus*					
Presence of "grassland" species (*Ac, Ac, Ao, Df, Fo, Ns*)					
Abundance of *Carex panicea* on drier "ridge" areas					

Image 1. Blanket bog small-scale and trend indicators presented in a format that field surveyors can use (Copyright of SNH). They then need to refer to a set of descriptions and definitions to know which option to tick (see below).



Phase 2 Impact Survey: Blanket bog

Trampling and grazing

Geographical applicability of indicators.

Small-scale Field Indicators

Phase 2 Impact Survey: Blanket bog - trampling and grazing

Small-scale Field Indicators

Image 2. An excerpt of the blanket bog small-scale indicators, as presented in the SNH handbook (Copyright of SNH). Surveyors read through the options then decide, based on conditions on the ground, which class is most applicable.

APPENDIX 3 – VARIANCE CALCULATIONS

ACKNOWLEDGEMENTS

This section of the report was written in conjunction with Chris Glasbey, Head of Research, Biomathematics & Statistics Scotland, JCMB, The King's Buildings, Edinburgh, EH9 3JZ, Scotland, UK.

BACKGROUND

There are many ways to sample a region in order to estimate the mean value of a variable (see, for example, Ripley, 1981, Chapter 3). Of these, systematic sampling is known to be the most efficient in a broad range of situations (Bellhouse, 1977).

Unfortunately, there is no generally accepted way to estimate the precision of the estimate obtained from this sampling scheme (Dunn and Harrison, 1993; Aubry and Debouzie, 2000 and 2001; D'Orazio, 2003). Because the data are essentially a sample of size one, no design-based standard error can be derived; and the alternative, a model-based approach, is time consuming to implement and relies on subjective assumptions that are difficult to validate. Conservative standard errors, that is, over-estimates, can be obtained by treating the data as if they had been obtained using a different, less inefficient sampling scheme as described below.

In simple random sampling, the standard error of the sample mean is given below:

Equation 1 Standard Error (SE) = $\sqrt{\frac{\hat{\sigma}^2}{n}\left(1-\frac{n}{T}\right)}$

where $\hat{\sigma}^2$ is the variance of the n sampling units and T is the total possible number of sampling values present within the overall sampled area.

If there is no indication of spatial clustering in the data, then such a standard error is also realistic for a systematic sample, but it can be a severe over-estimate if there is clustering.

A tighter upper bound can be obtained by assuming a less inefficient sampling scheme than simple random sampling, by invoking strata (Ripley, 1981, Chapter 3; Dunn and Harrison, 1993). Given prior knowledge of the direction of maximum variation (i.e. before examination of the data), blocks of ideally 2 adjacent points are formed orthogonal to this direction. So, if variation is maximal down columns, blocks are formed along rows, with the final block in each row containing three sampled points if necessary. The standard error is as above, but now with the variance $\hat{\sigma}^2$ obtained from the within-strata variability alone as follows:

Let Y_{ij} denote the ith of m_j observations in the jth of b blocks. Then the variance σ^2 is estimated using

$$\hat{\sigma}^2 = \frac{1}{N}\sum_{j=1}^{b}\sum_{i=1}^{m_j}\left(Y_{ij}-\bar{Y}_j\right)^2 \qquad \text{where } N=\sum_{j=1}^{b}(m_j-1) \qquad \text{and } \bar{Y}_j\frac{1}{m_j}\sum_{i=1}^{m_j}Y_{ij}$$

If there is spatial clustering in the data, then results based on this process of 'pseudo-stratification' are likely to over-estimate the true standard error for a systematic sample, but they are well established in the literature, are simple to compute and do not rely on unsubstantiated modelling assumptions. Therefore, this is the recommended method for computing the standard errors in systematic sampling, pending further research.

APPROACH

Pseudostrata were formed by pairing up sampling locations on each row in the sampling grid in an east-west direction. The east-west direction is normally chosen for the blocking unless an inspection of the data shows that the main axis of variation is in fact north-south.

Each pseudostrata is normally created from 2 adjacent sampling locations constrained to one east-west row such that if an odd number of locations are present at the end of the row the relevant pseudostratum is formed from 3 sampling locations. Pseudostrata are normally numbered consecutively from the bottom (i.e. south-west) corner of the study area to the top (i.e. north-east) corner. Sampling locations at the extreme corners of the study area can be isolated from the main body of samples. A separate pseudostratum is normally formed for these such that they contribute to the calculation of the overall mean but not to the calculation of variance $\hat{\sigma}^2$.

Each variate under study is input into a spreadsheet and the pseudostrata codes appended. The data are imported into Genstat 9.2© and a general Analysis of Variance (ANOVA) run for each of the variates that required an estimate of the variance $\hat{\sigma}^2$ to be obtained. The within-strata sum of squares from the Genstat output is used to calculate the variance $\hat{\sigma}^2$ then Equation 1 is used to calculate the standard error with n equal to the overall sample size associated with that variate. 95% confidence limits are formed using the degrees of freedom relating to the within-strata variance estimate.

Aubry, P. and Debouzie, D. (2000). Geostatistical estimation variance for the spatial mean in two-dimensional systematic sampling. Ecology, 81, 543-553.

Aubry, P. and Debouzie, D. (2001). Estimation of the mean from a two-dimensional sample: The geostatistical model-based approach. Ecology, 82, 1484-1494.

Bellhouse, D. R. (1977). Some optimal designs for sampling in two dimensions. Biometrika}, 64, 605-611.

Dunn, R. and Harrison, A. R. (1993). Two-dimensional systematic-sampling of land-use. Applied Statistics, 42, 585-601.

D'Orazio, M. (2003). Estimating the variance of the sample mean in two-dimensional systematic sampling. Journal of Agricultural Biological and Environmental Statistics, 8, 280-295.

Ripley, B. D. (1981). Spatial Statistics. New York, Wiley.

APPENDIX 4 – HERBIVORE DIETS IN THE UPLANDS

RED DEER

Red deer (*Cervus elaphus*) eat a wide variety of species. The plants eaten vary according to habitat type and geographic and climatic zones [1]. It is clear that dwarf shrubs, mainly *Calluna*, are a very important food, at least in terms of quantity taken. Forbs do not form such an important part of the diet in Scotland as they do elsewhere, probably because they constitute a low proportion of the available forage [1]. In upland habitat, *Calluna* may constitute up to 90% of a red deer's diet [2].

Heather is an important food source as it does not die back completely and provides live matter throughout the year, and season is an important factor influencing deer diet [3]. Investigations on plant preference on dwarf shrub community in upland Scottish habitats (*Calluna vulgaris*-dominated) found graminoid species preferred strongly over *C. vulgaris*, and that consumption of grasses was greater in spring than in summer [4]. Compared to stags, hinds eat less heather and more grasses, particularly the more digestible, fine-leaved species. It has been suggested that hinds select for quality and stags opt for greater quantity of poorer-quality food [5].

Red deer can be highly selective, and have been observed to browse more heavily on replanted nursery-grown seedlings of Scots pine *(Pinus sylvestris)* than on naturally-regenerating plants, and browsing pressure can even increase following fertilisation [1]. Burning also affects feeding behaviour in red deer, which prefer to feed on the subsequent growth as it is more accessible and more nutritious [1].

SHEEP

Similar to red deer and roe deer, heather is an important food source for sheep, and can constitute 30% of their diet [8]. Sheep are also attracted to areas of newly burned ground, and prefer to eat regenerating, rather than older, heather [2]. Sheep eat less heather in summer, and in a study of populations on moorland habitats in North-East Scotland they were observed feeding mainly on grasses [2].

RED GROUSE

Red grouse (*LAgopus lagopus*) are dependent on heather for food and cover. The main food of grouse is younger heather, and they select mature heather with good cover for their nest sites [9]. Thirgood et al [10] reported that grouse densities were higher and overwinter losses were lower on areas with higher heather cover.

Diet studies have shown that adult red grouse diet can be almost exclusively heather [11, 12], although they can also eat Blaeberry (*Vaccinium myrtillus*) [13]. Savory [14] showed that grouse at a study site in NE Scotland always avoid the youngest and the oldest material and age range of material selected varies with season.

Red grouse ideally require an intimate mixture of short heather (10 cm to 20 cm tall) for feeding and taller heather (20 cm to 30 cm) for nesting. Red grouse tend to avoid heather which is taller than 35 cm [9, 2].

MOUNTAIN HARE

The mountain hare is primarily a grazing animal, feeding on browse species such as heather or twigs and barks of trees. *Calluna* vulgaris comprises the main food source for mountain hares in North-East Scotland, comprising 50% of their diet. *Agrostis* grasses (18%) and *Deschampsia flexuosa* (13%) are also important food sources. Consumption of *Calluna* increases in winter to 70%, and decreases to 30% in summer [15].

In Scotland, mountain hares exhibit a preference for grasses and herbs in summer, and heather in winter, when other food sources are no longer available. In upland habitats, *Calluna* is also an important food source for red deer (*Cervus elaphus*) (90% of diet), red grouse (*Lagopus lagopus scoticus*) (60-100% of diet) and sheep (30% of the diet of blackface sheep) [2], and these species may compete with mountain hares for food. A study of moorland habitats in North-East Scotland found that heavy heather grazing by mountain hares over winter may reduce the availability of young, high quality heather for both red grouse and hares in spring [2].

Moss and Miller [17] found that at Lochnagar, where red deer where the main grazing animal, there were 50% less grouse and 13 fold fewer mountain hare than at Corndavon, where the deer population was much lower. This suggests that food competition with red deer has a stronger effect on hare than grouse [17]. Sheep may also compete for food resources [15, 18, 19], and hare numbers have been observed to decline after sheep have been introduced to an area [19].

[1] B. Mitchell, B. W. Staines and D. Welch, Ecology of red deer: a research review relevant to their management in Scotland, Cambridge: Institute of Terrestrial Ecology, 1977.

[2] C. J. Savory, “Utilisation of different ages of heather on three Scottish moors by red grouse, mountain hares, sheep and red deer,” *Ecography,* vol. 9, no. 1, pp. 65-71, 1986.

[3] M. G. Sherlock and J. S. Fairley, “Seasonal changes in the diet of red deer Cervus elaphus in the Connemara National Park,” *Biology and Environment: Proceedings of the Royal Irish Academy,* vol. 93B, no. 2, pp. 85-90, 1993.

[4] M. Fraser and I. Gordon, “The diet of goats, red deer and South American camelids feeding on three contrasting Scottish upland vegetation communities,” *Journal of Applied Ecology,* vol. 34, no. 3, pp. 668-686, 1997.

[5] B. W. Staines, J. Crisp and T. Parish, “Differences in the quality of food eaten by red deer (Cervus elaphus) stags and hinds in winter,” *Journal of Applied Ecology,* vol. 19, no. 1, pp. 65-77, 1982.

[6] J. Latham, B. Staines and M. Gorman, “Comparative feeding ecology of red (Cervus elaphus) and roe deer (Capreolus capreolus) in Scottish plantation forests,” *Journal of Zoology,* vol. 247, no. 3, pp. 409-418, 1999.

[7] D. Storms, P. Aubry, J.-L. Hamann, S. Saïd, H. Fritz, C. Saint-Andrieux and F. Klein, “Seasonal variation in diet composition and similarity of sympatric red deer Cervus elaphus and roe deer Capreolus capreolus,” *Wildlife Biology,* vol. 14, no. 2, pp. 237-251, 2008.

[8] D. J. Martin, “Analysis of sheep diet utilizing plant epidermal fragments in faeces samples,” *Grazing in terrestrial and marine environments,* pp. 173-188, 1964.

[9] J. Lawton, “Red Grouse Populations and Moorland Management (British Ecological Society Ecological Issues No. 2),” *Field Studies Council,* 1990.

[10] S. J. Thirgood, S. M. Redpath, D. T. Haydon, P. Rothery, I. Newton and P. J. Hudson, “Habitat loss and raptor predation: disentangling long--and short--term causes of red grouse declines,” *Proceedings of the Royal Society of London. Series B: Biological Sciences,* vol. 267, no. 1444, pp. 651-656, 2000.

[11] D. S. Eastman and D. Jenkins, “Comparative food habits of red grouse in northeast Scotland, using fecal analysis,” *The Journal of Wildlife Management,* vol. 34, no. 3, pp. 612-620, 1970.

[12] A. N. Lance and G. Mahon, "Foods of a marginal red grouse population in western Ireland," *The Journal of Wildlife Management,* vol. 39, no. 1, pp. 183-187, 1975.

[13] C. Wilcock, C. Robeson and C. MacLean, "On fruit eating by Scottish Red grouse," *Biological journal of the Linnean Society,* vol. 23, no. 4, pp. 331-341, 1984.

[14] C. Savory, "Food consumption of red grouse in relation to the age and productivity of heather," *Journal of Animal Ecology,* vol. 71, pp. 269-282, 1978.

[15] J. E. Flux, "Life history of the Mountain hare (Lepus timidus scoticus) in north-east Scotland," *Journal of Zoology,* vol. 161, no. 1, pp. 75-123, 1970.

[16] S. E. Townsend, S. Newey, S. J. Thirgood and D. T. Haydon, "Dissecting the drivers of population cycles: Interactions between parasites and mountain hare demography," *Ecological modelling,* vol. 222, no. 1, pp. 48-56, 2011.

[17] R. Moss and G. Miller, "Production, dieback and grazing of heather (Calluna vulgaris) in relation to numbers of red grouse (Lagopus l. scoticus) and mountain hares (Lepus timidus) in north-east Scotland," *Journal of Applied Ecology,* vol. 13, no. 2, pp. 369-377, 1976.

[18] R. Hewson, "Food and feeding habits of the mountain hare Lepus timidus scoticus, Hilzheimer," *Proceedings of the Zoological Society of London,* vol. 139, no. 3, pp. 515-526, 1962.

[19] R. Hewson and M. Hinge, "Characteristics of the home range of mountain hares Lepus timidus," *Journal of Applied ecology,* vol. 27, no. 2, pp. 651-666, 1990.

[20] I. A. Hulbert and R. Andersen, "Food competition between a large ruminant and a small hindgut fermentor: the case of the roe deer and mountain hare," *Oecologia,* vol. 128, no. 4, pp. 499-508, 2001.

APPENDIX 5 – THE ECOLOGY OF MONTANE WILLOWS

CURRENT STATUS

Montane willow scrub is a highly endangered habitat (10ha total area) in the United Kingdom, confined to the Scottish Highlands and northern England [1, 2]. Based on the current much more widespread distribution of similar vegetation in Scandinavia, it is likely that it was once much more widely distributed in Scotland, and current habitats are thought to be remnants of a much more widespread community [3].

Montane willow scrub in the United Kingdom consists of seven species including one red data book species, woolly willow (*Salix lanata*), and four which are nationally scarce (occurring in between 16 and 100 10×10–km grid squares in the United Kingdom) [1]. Woolly willow is a montane species that is vulnerable in Scotland because most of its few remaining populations are small and threatened with the further loss of individuals. It was listed as a Priority species under the UK Biodiversity Action Plan (UKBAP), and is included on the Scottish Biodiversity List. It is also a component of subarctic willow scrub, a habitat type listed on Annex I of the EC Habitats Directive. The species is confined to 13 sites in Scotland, of which three are functionally extinct and three are at risk. Several of the remaining seven sites require reinforcement [4]. Corrie Sharroch holds the largest single patch (around 0.5 ha) of W20 *Salix lapponum – Luzula sylvatica* scrub remaining in the UK [5]. Sub-Arctic *Salix* spp. scrub is relatively frequent at Caenlochan, growing to a high altitude on highly to moderately calcareous schist. The most abundant species, and generally the dominant one, is downy willow *Salix lapponum*, which probably occurs in larger numbers here than on any other site in the UK [5].

ECOLOGY

Under favourable conditions, sub-arctic willows can form extensive scrub communities. In Great Britain these have been classified under the National Vegetation Classification as W20 – *Salix lapponum – Luzula sylvatica* scrub. This tends to occur on moist, relatively base-rich soils in rocky situations with a north to east aspect, generally at altitudes from 600m to over 900m. A degree of shelter may be favourable to scrub development and there may be a positive association with late snow-lie which offers some protection from spring frosts and browsing [6].

Its rarity in Scotland is a reflection of the scarcity of basic rocks at high altitude and its vulnerability to grazing. Hence the sites where it occurs are inaccessible and rocky, and/ or are areas with late snow-lie. Late snow-lie may protect the willows from frost and wind damage as well as grazing.

In addition to supporting a variety of rare types of vegetation, montane heaths and willow scrub are home to many rare and local arctic-alpine plants and invertebrates. It also provides important nesting habitat for other important upland birds [7].

REPRODUCTIVE BIOLOGY

Knowledge of reproductive mode is important for the design of grazing management and restoration programmes. Willows can reproduce both sexually and asexually, but sexual reproduction is the predominant means of perpetuation [8]. Willows are dioecious (male and female catkins occur on separate plants), and pollen transfer is carried out primarily by insects, but also by wind. Seeds are wind dispersed [6].

There are concerns that small and isolated plant populations could become low in genetic diversity. This tends to limit their capacity to respond to both acute and chronic environmental change. Furthermore, small numbers of individuals in populations can lead to problems through inbreeding. However research shows that even small willow populations show high levels of genetic diversity and low levels of population differentiation. There is no evidence of them being affected by major genetic bottlenecks and high levels of genetic drift. Although gene flow between fragmented populations is possible, it is unlikely. More likely is the possibility that the genetic consequences of reduced population sizes and physical isolation have been limited by the longevity of willows and a limited number of generations since fragmentation. Consequently, even the smallest fragments represent a useful genetic resource. They represent both potentially useful sources as donors for new populations/ex situ collections, as well as reservoirs of diversity for the expansion of existing sites. However, those fragments with population sizes of less than 50 are of conservation concern and it would take few generations or environmental catastrophes to lose diversity or whole plants [6].

HERBIVORE IMPACTS

Montane willows are very sensitive to browsing, and the reduction in this habitat in the United Kingdom is generally attributed to high numbers of sheep and deer [9]. The role of sheep and deer in preventing regeneration of woody perennials by removing seedlings has been well documented. Marriott *et al.* [4] found that planting efforts at Coire Sharroch were significantly hampered by mountain hares (*Lepus timidus*). Grazing of flowering shoots may have a serious effect on seed production.

Large herbivores may impact willows in other ways [6]. Browsing by large herbivores has the potential to remove large proportions of flowering shoots. Browsed plants are more pollen limited than unbrowsed plants, and studies show that browsing of adult plants has a negative impact on the reproductive success of *S. arbuscula* through a reduction in attractiveness to pollinating insects [6, 9]. Exclusion of large herbivores (sheep and deer) permitted more vigorous vegetative growth of shoots, flowering and pollen and seed production. Limiting the numbers of these herbivores in areas where their impacts on the vegetation is significant would promote growth and sexual reproduction [6, 9].

However, large herbivores also play a positive role in montane willow reproduction. One of the problems associated with removing large herbivores altogether is that a dense sward of rank grass can develop. This may reduce the number of suitable germination and establishment sites for regenerating plants. When suitable microsites are limited, then seed production and dispersal, sufficient to ensure that they are exploited, becomes crucial. Development of tall grass may also encourage growth of populations of small herbivores such as voles and slugs [6]. Shaw *et al.* [1] found that protecting seedlings from small mammals made no difference to the levels of survival; however, protecting seedlings from slugs (*Arion* spp.) resulted in approximately 45% of seedlings surviving until the end of the summer compared to only 30% when seedlings were available to slugs.

CONSERVATION

Based on ongoing research and conservation work by the Species Action Framework Woolly Willow Project, it has been suggested that the requirements to maintain a viable population of a montane willow are [4]:

- Male and female plants well within an estimated maximum 50 m of each other for effective pollination.
- Bare ground for seedling establishment.
- Appropriate (low) levels of grazing.

- Snow cover that protects plants from frost damage and grazing during the winter and late spring.
- Relatively cool/damp soil conditions.
- A minimum number of plants to produce sufficient ‘seed rain’ to colonise bare ground at rates equal to the loss of mature plants.
- It has also been suggested that a viable population would also require a minimum of 50 plants with approximately equal numbers of males and females [4].

Research by the Scottish Montane Willow Research Group [6] shows that, due to low frequencies of seed production and/or poor dispersal, regeneration from seed is likely to require collection and translocation of seed to new sites or within or close to existing sites which are already colonised. Mardon [9] suggests that fencing is necessary to provide protection from grazing, and planting may be required to provide enough individuals for effective pollination and regeneration to occur.

More successful establishment from seed has been recorded in areas where ground was experimentally disturbed. Scarification or mechanical ground disturbance to reveal bare soil could be used to promote establishment. This is particularly necessary in areas where a grassy or mossy mat forms the main vegetation community, and would be unnecessary where the soil or other substrate is naturally mobile, such as flushed areas on steeper slopes. It is suggested that larger (c. $1m^2$) disturbed areas would reduce seedling losses due to predation as this would render a larger area unsuitable for small mammals and slugs [6].

[1] R. F. Shaw, G. R. Iason, R. J. Pakeman and M. R. Young, “Regeneration of Salix arbuscula and Salix lapponum within a large mammal exclosure: the impacts of microsite and herbivory,” *Restoration Ecology,* vol. 18, pp. 1-9, 2010.

[2] J. N. C. C. (JNCC), 1999. [Online]. Available: http://www.jncc.gov.uk/idt/sac/sitelist/sitename/data/I44.htm. [Accessed 20 October 2003].

[3] S. Mortimer, A. Turner, V. Brown, R. Fuller, J. Good, S. Bell, P. Stevens, D. Norris, N. Bayfield and L. Ward, The nature conservation value of scrub in Britain, Peterborough: Joint Nature Conservation Committee, 2000.

[4] R.W, MArriott, H. McHAffie and D.K., Mardon, “Woolly willow. Version 1.0.,” in *The Species Action Handbook*, Perth, Scottish Natural Heritage, 2015.

[5] JNCC, “Habitat account - Temperate heath and scrub,” Joint Nature Conservation Committee, [Online]. Available: http://jncc.defra.gov.uk/protectedsites/sacselection/habitat.asp?FeatureIntCode=H4080. [Accessed 03 06 2019].

[6] Scottish MOntane Willow Research Group, “Biodiversity: taxonomy, genetics and ecology of sub-arctic willow scrub,” *Royal Botanic Garden Edinburgh,* 2005.

[7] JNCC, “Mountain Heaths & Willow Scrub,” Joint Nature Conservation Committee, 2015. [Online]. Available: http://jncc.defra.gov.uk/page-6327. [Accessed 03 06 2019].

[8] K. Stamati, P. Hollingsworth and J. Russell, “Patterns of clonal diversity in three species of sub-arctic willow (Salix lanata, Salix lapponum and Salix herbacea),” *Plant Systematics and Evolution,* vol. 269, no. 1-2, pp. 75-88, 2007.

[9] D. Mardon, “Conservation of montane willow scrub in Scotland,” *Transactions of the Botanical Society of Edinburgh,* vol. 45, no. 5, pp. 427-436, 1990.

APPENDIX 6 – PROSPECTIVE POPULATION MODELLING

During the preparation of a late draft version of this report, in September 2019, the contractor was provided with the results of a deer count within the Section 7 area from August 2019. It was agreed with SNH that it would be useful to incorporate these results somehow in an appendix. Following discussion, it was further agreed that the contractor would produce a population model for the Caenlochan Section 7 area which utilised the findings of the August 2019 count to forecast the size of culls needed in future to reduce deer densities to a level that might allow habitat recovery. The following approach was undertaken:

1. A model was built using the results of the January 2018 deer count as the starting point (2983 stags, 3984 hinds & 1473 calves = 8,440). It forecasted forward for a period of ~ 11 years (the 2018-19 cull season, leading to summer 2019, plus 10 years on from this point reflecting the likely time period of a new deer management plan).
2. The model would be calibrated to ensure that its near-term predictions broadly reflected the now-known outcomes of the August 2019 count (3238 stags, 3209 hinds & 918 calves = 7,365 or 20.5 per km^2; calculated by omitting estates not in the current Section 7 control area).
3. The longer-term element of the model – from summer 2019 onwards – would illustrate the size of culls needed to effect a rapid density reduction to below 15 per km^2 by summer 2020, and thence an incremental reduction to 10 per km^2 over 5 years followed by a period of maintenance. Such a trend in density would be modelled in recognition of the fact that (i) habitat recovery is unlikely to take place in any substantive way until the deer density is reduced to such a level, but (ii) the adverse effects of such a reduction need to be mitigated against as far as possible in the near-term, to avoid serious socio-economic impacts locally.
4. The initial modelling framework built was as follows:
    a. January 2018 count had hind numbers reduced by 200 (plus followers, at 37% as per the count) to allow for post-count culling. Stags were reduced by a margin of 200 to allow for spring mortality.
    b. No immigration was allowed for. The adult sex ratio was as recorded in the 2018 deer count. The sex ratio at birth was 50: 50.
    c. Net recruitment for 2018 was set at 31% (reflecting a lower than average recruitment rate due to the hard preceding winter and severe drought in summer).
    d. The recorded cull for the 2018-19 season within the Section 7 area was input (599 stags, 1902 hinds, 544 calves).
5. The model was run, but failed to correspond closely enough to the August 2019 count result to be deemed robust for onwards forecasting. The primary imbalance related to a surplus of stags and deficit of hinds.
6. A sequence of model iterations was attempted, to better balance the model:
    a. Stag mortality for spring 2018 was increased, and female reduced.

b. Winter 2018 count result was inflated to allow for under-counting of deer in woodlands (and other possible errors such as under-inclusion of calves).
c. The sex ratio at birth was skewed in favour of females (54: 46).

7. The best fit model which was obtained, following multiple model runs, was:
   a. January 2018 count data: 2.5% inflation factor to the winter count (reflecting the fact that the January 2018 count with all else equal was likely an underestimate due to uncounted deer in woodlands etc).
   b. Net recruitment rate into the population was 29 per 100 adult females in 2019 (as measured in the summer 2019 count; assumes no predation or immediate post-partum losses). Thereafter, from 2020-21 the rate is set at 40 per 100 adult females drifting linearly (0.5 per annum) up to 44 reflecting reducing densities and gradually improving habitat condition in the wintering grounds.
   c. Sex ratio (at birth) of 54: 46 in favour of females, for the 2018-19 and 2019-20 seasons. In essence, this parameter is used to force more females into the system and more males out (it is not strictly taken to mean that the birth sex ratio itself is so biased). From next year onwards, this ratio drifts linearly over time so that it is male biased (53: 47) by the end of the model run.
   d. Natural mortality: set at 0 (recruitment rate of 40% is assumed to be a net rate, taking into account mortality in the long-term).
8. The rationale for accepting this model set up for analysis was as follows:
   a. The population in January 2018, on balance, is likely to have been underestimated (e.g. woodland cover).
   b. The interaction between recruitment rate and sex ratio at birth in the model produces a net inflow of stags and hinds annually – irrespective of the exact contributions of each, a number of factors influence this on a site such as Caenlochan:
      i. Sex ratio at birth may well be female biased, given that densities of deer are extremely high.
      ii. Stags calves and adult stags tend to suffer an elevated level of mortality compared to females (particularly when deer densities are high and where winter shelter is lacking etc).
      iii. Unrecorded culls may have occurred (e.g. farmland) and culls elsewhere locally (e.g. in forestry) have not been included. These are likely to be stag-biased.
      iv. It is possible that stags born and otherwise resident at Caenlochan in summer may move away from the site during the rut at which point they could be officially culled elsewhere.
9. The outputs from the final modelling exercise are presented below (Chart 1-6). They show the size of culls needed, and the predicted response in population size and density over time. Obviously, many alternative scenarios can be modelled by varying the parameters somewhat.

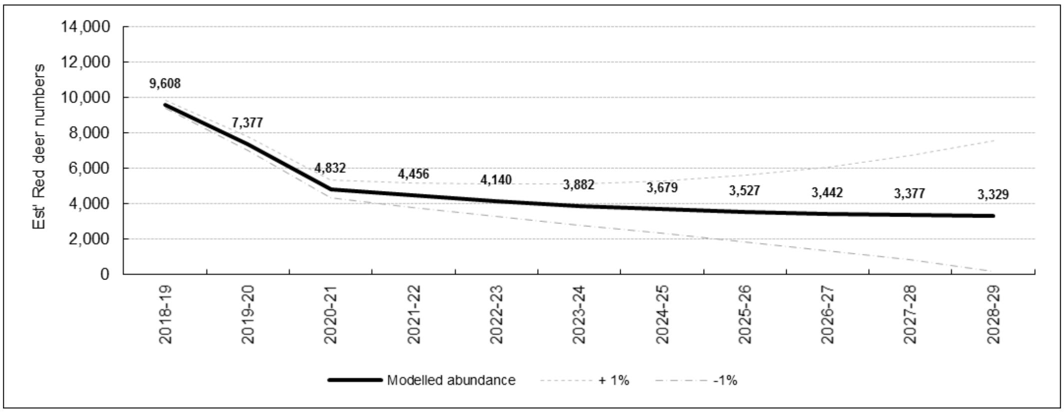


Chart 1 Predicted number of red deer in the Caenlochan Section 7 area (with the effects of a 1% count error shown). The August 2019 count was 7,365 (7,377 in this model based on the parameters outlined above.

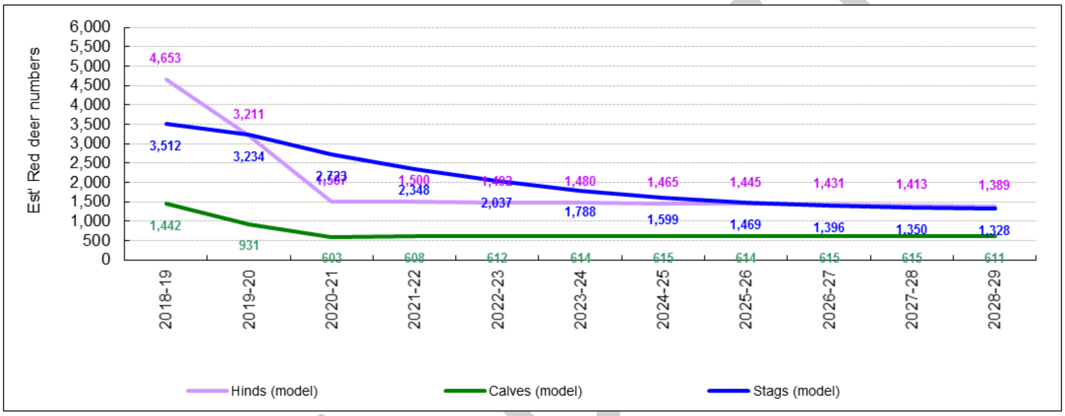


Chart 2 Predicted number of stags, hinds and calves in the Caenlochan Section 7 area. The August 2019 count was 3238 stags, 3209 hinds and 918 calves (3234, 3211 and 931 in this model based on parameters outlined above).

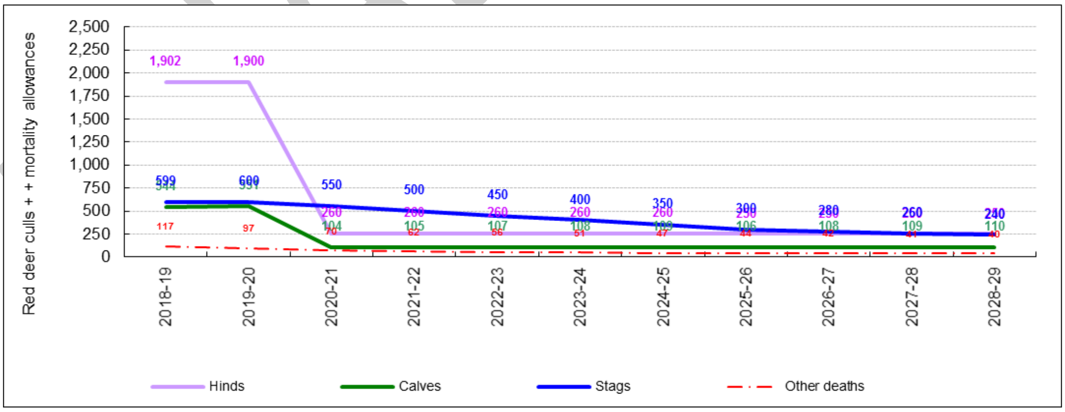


Chart 3 The culls taken (2018-19) and forecasted (2019-20 onwards) to produce the abundance trends (Charts 1 & 2) and density trend (Chart 4) presented. The stag cull (assumed to be exclusively mature stags) is deliberately tapered down year-to-year to allow time for estates to adjust to the constriction in stag supply that would ultimately arise from a major density reduction overall. To help ensure this tapering is as predicted, estates should try to avoid culling stag calves wherever possible. This model produces a relatively high sustainable cull of stags in the long-term, post reduction, but is based on a potentially 'optimistic' set of model parameters whereas in the Next Steps section of this report the parameters are more pessimistic (e.g. it has no strong skew towards male calves at birth etc).

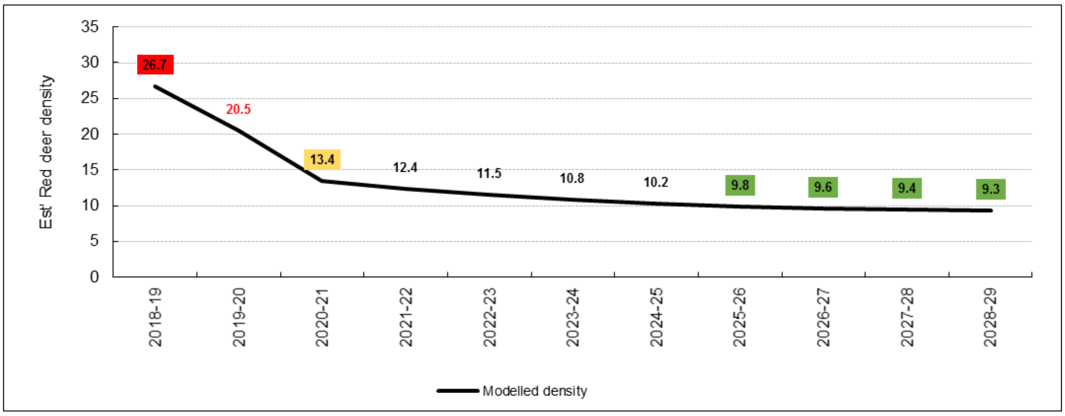


Chart 4 Predicted trend in summer deer density in the Caenlochan Section 7 area based on the culling program outlined in Chart 3. The density in summer 2018 was predicted to be 27 per km^2 (habitat targets far from being met) falling to 20.5 per km^2 (as per the August 2019 count) falling to ~ 13.5 per km^2 (by summer 2020; very localised and very gradual habitat recovery may take place in some habitats at this density) and then to 10 per km^2 by summer 2025 (recovery of habitats likely to occur across a considerable proportion of the site albeit over a very long timescale, assuming densities are held at or below this level continuously). Based on the suite of evidence available, a summer density of 5 per km^2 across the Section 7 area is believed most likely to deliver a rapid change habitat condition (albeit this would still equate to ~ 10 per km^2 in the summering grounds, hence it still carries some risk).

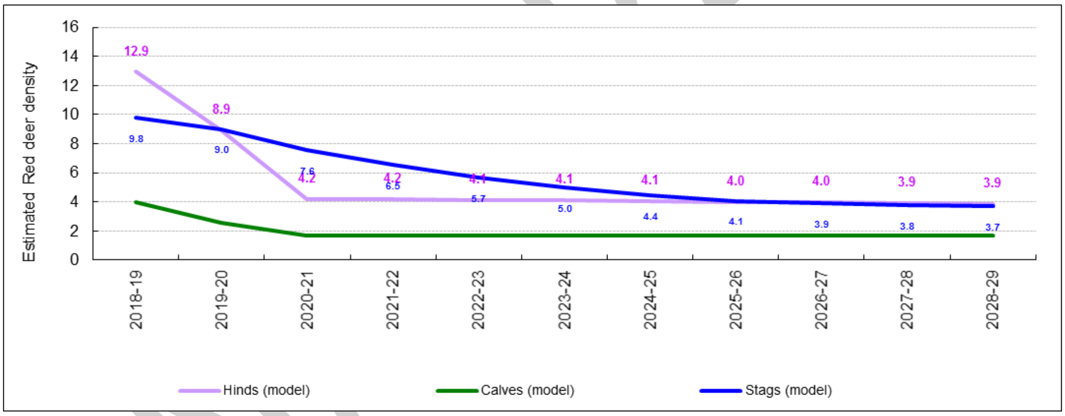


Chart 5 Predicted trend in summer density of stags, hinds and calves in the Caenlochan Section 7 area based on the culling program outlined in Chart 3.