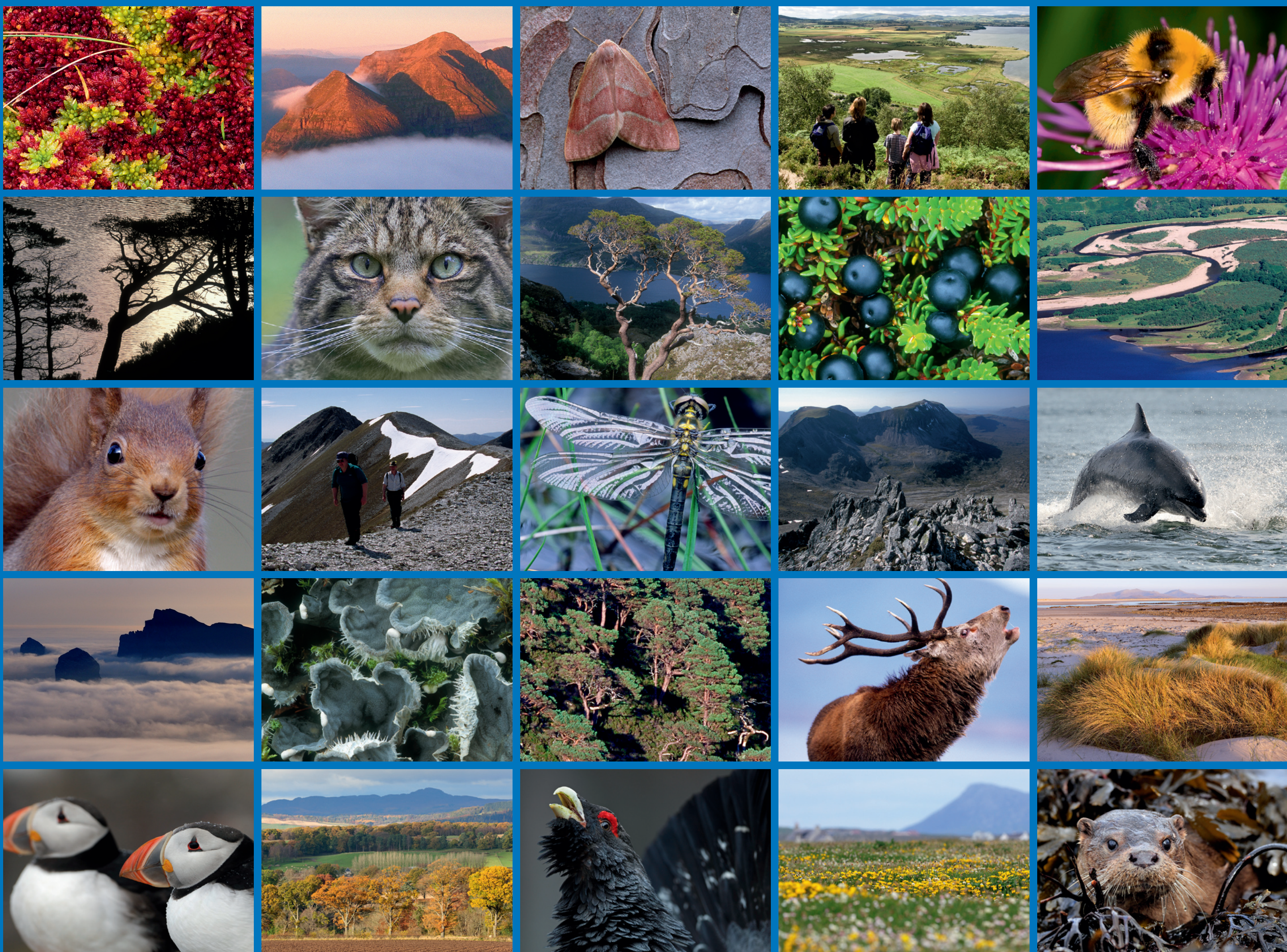
Scottish Natural Heritage
Commissioned Report No. 405

A woodland profile survey and assessment of herbivore impacts for Ben Hope SSSI



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For further information on this report please contact:

Valerie Wilson
Scottish Natural Heritage
The Links
Golspie Business Park
Golspie
Sutherland
KW10 6UB
Telephone: 01408 634063
E-mail: Valerie.Wilson@snh.gov.uk

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COMMISSIONED REPORT

Summary

A woodland profile survey and assessment of herbivore impacts for Ben Hope SSSI

Commissioned Report No. 405
Project no: iBids 10228
Contractor: Neil Mackenzie & Tim Clifford
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Background

The three fragments of Upland Birchwoods in Ben Hope SSSI, Leitir Mhuiseil, Creag na garbh-baid and Merkan, are among the largest and best examples of native woodland remaining in the north of Scotland. The woods occupy a discontinuous band between the shore of Loch Hope up to an altitude of 220m on the western slopes of Ben Hope in Sutherland.

The aim of this survey was to profile the current structure of the woodland, assess the extent of herbivore and other impacts on the woodland and review the current situation, including existing conservation management measures, in relation to the site's Conservation Objectives. Previous reports had concluded that the birchwoods were in unfavourable condition due to overbrowsing and that there was significant evidence of browsing damage by deer and sheep.

A field survey was carried out in June 2010 using a systematic plot based methodology to sample tree species, life stage class, DBH (diameter at breast height) and browsing impact. A total of 50 variable sized plots, equivalent to 1% of the survey area, were assessed and the data presented separately for each woodland area. A secondary aim was the setting up of a monitoring programme based on 80 marked tree seedlings.

Main Findings

The woodland profile results showed that Leitir Mhuiseil and Creag na garbh-baid woods were dominated by mature birch and possessed an aging and declining population with no recent recruitment. Leitir Mhuiseil in particular exhibited very low stocking density and fragmentation, which had probably been taking place over many decades. The age structure of Merkan wood was more diverse as a result of a few patches of birch regeneration that became established some 25 years ago but there has been no successful establishment since that time. In all three areas tree seedlings were very common, but key life stages such as saplings and understorey

shrubs, were rare or absent. These omissions mean that there are insufficient developing trees to replace the mature trees as they progress towards the end of their life cycle. Holly, hazel and other less common species were in danger of local extinction because of the lack of established saplings. Preferentially browsed species such as bramble and honeysuckle were also rare or poorly developed. Browsing by deer and sheep was severe on all species of seedlings and on the epicormic/basal shoot growth of the mature trees and was the principal causal factor for the unfavourable condition of the Ben Hope woodlands.

Current conservation management measures included the erection in 1992 of two enclosures. The enclosures were successful in helping to diversify structure and species composition but only inside these limited areas, which was about 10% of the total woodland. If the remaining areas of unenclosed woodland were protected from overbrowsing, the potential for the regeneration of birch in existing gaps and beyond the woodland edge is excellent while the rarer species, such as hazel, holly and willow, should also colonise suitable sites. There will also be an increased development of sub-shrubs such as bramble and honeysuckle across the site.

The risk to the Conservation Objectives – to ensure that there is a continuous presence of mature trees across the majority of the site and that the biodiversity of the habitat is maintained in a favourable condition, were evaluated. Management options to reduce browsing impact, to restore the missing life stage classes and to improve the woodland habitat, were recommended.

For further information on this project contact:
Valerie Wilson, Scottish Natural Heritage, The Links, Golspie Business Park, Golspie, Sutherland, KW10 6UB
Tel: 01408 634063
For further information on the SNH Research & Technical Support Programme contact:
DSU (Policy & Advice Directorate), Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or pads@snh.gov.uk

Cover photo shows Creag na garbh-baid wood from the north

Acknowledgements

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1. INTRODUCTION

The woodlands of Ben Hope SSSI are situated on steep west-facing slopes and crags below Ben Hope in Sutherland. The three fragments of upland birchwoods, Leitir Mhuiseil, Creag na garbh-baid and Merkan, are among the largest and best examples of native woodland remaining in the north of Scotland. The woods occupy a discontinuous band between the shore of Loch Hope up to an altitude of 220m ASL. Scattered trees and shrubs, including the nationally scarce rock whitebeam *Sorbus rupicola*, are also found on the inaccessible crags and cliffs above the main wooded areas. Most of the woodlands appear on the Roy map of 1747-1755 and all are classed as ancient in Scottish Natural Heritage's Ancient Woodland Inventory.

The most recent site condition monitoring report has classified the wood as "Unfavourable – no change" (SNH, 2009). The main adverse impact on the birch wood is overgrazing by herbivores, particularly wild deer, and their impact on tree and shrub regeneration.

The Ben Hope SSSI contains land owned by three estates; Strathmore, Hope and Kinloch though only the first two have ownership of the woodlands with Strathmore owning the largest portion including both Leitir Mhuiseil and Creag na garbh-baid. The last deer census of 2008 recorded 1,893 red deer across the whole of Strathmore, Hope and Kinloch Estates. This gives a deer density of about 7.77 deer per square kilometre. Livestock were also present in the area but sheep numbers have declined during the past ten years and in October 2009 about 300 sheep were removed from the Strathmore part of the SSSI. However, sheep from the northern section continue to have access throughout the whole woodland area, although there was only limited evidence of recent activity south of Merkan during the time of the survey.

In 1992 two enclosures were erected in the Leitir Mhuiseil and the Creag na garbh-baid woods and these have been the main conservation management measure designed to encourage regeneration and restore woodland structure and biodiversity.

The key aim of this survey was to profile the current structure of the woodland, assess the extent of herbivore and other impacts on the woodland and review the current situation, including existing conservation management measures, in relation to the site's Conservation Objectives. In addition, a baseline monitoring programme of marked tree seedlings were established across the survey area.

2. OBJECTIVES

In order to fulfil the aims of this survey the following tasks were undertaken:

1. A woodland profile survey – a field-based survey to include all native woodland and tree regeneration within the SSSI
2. An assessment of current herbivore impacts on the woodland
3. Review of existing conservation management measures
4. An assessment of risk to Conservation Objectives
5. Establishment of marked tree seedling baseline

3. TERMS OF REFERENCE

The contract specifications required that a statistically robust sampling methodology be employed for the field survey and recommended the use of a systematic plot based survey for the collection of stand type and other information (Kerr *et al*, 2002). The Ben Hope woodland survey area was estimated at about 96 ha, based on the area of woodland on the current edition of the 1:10,000 scale OS map. In order to achieve a minimum 1% sample for the whole native woodland area a total of 50 fixed-area plots of 0.02 ha were required to be established across the site.

For the purposes of data analysis the woodland was divided into four units –

1. The two enclosures
2. Leitir Mhuiseil
3. Creag na garbh-baid
4. Merkan

4. METHODS

The principal method for obtaining quantitative information on the woodland profile and browsing impact (Objectives 1 – 3) was a field survey based on a systematic plot based sampling strategy.

4.1 Survey area

Although the woodland comprised several fragmented blocks the area was treated as one unit in the design of the sample grid. Linear areas of woodland along the burns in the northern and southern edges were included in the survey but due to their small size they were not captured in the sampling procedure. The full extent of the two enclosures was included in the sample grid although woodland and regeneration were subsequently found to only occupy a part of the enclosed areas. The survey did not include the non-native conifer plantation at the south edge of the SSSI.

The data from the four woodland units were then analysed and presented as a separate set of results as well as a combined presentation of results for the whole native woodland area.

4.2 Sampling method

4.2.1 Number of plots and plot size

A systematic plot sampling method was designed based on the methodology of Kerr *et al* (2002). Plots were circular, with a fixed area of 0.02 ha and a radius of 8 m, as proposed in the SNH Statement of Requirement. Plots were located at regular intervals along a grid, which would cover the whole of the survey area (Figures 1, 2 & 3). On steep ground a slope correction factor was added to the plot dimensions. The number of plots and the distance between plots on the grid is related to the size of the area to be surveyed.

4.2.2 Plot spacing and grid layout

Each area of stratification was treated as one block in order to calculate the space between plot centres. Spacing was then calculated using the following formula:

$$S = 100 \times \sqrt{\frac{A}{n}}$$

Where S = spacing between plot centres in metres; A = area of the strata in hectares; and n = the number of plots required.

For the 96 ha of woodland plot centres were at 136 m (S = 136).

A south-west to north-east direction of transect was chosen for the grid layout as this would ensure the best altitudinal representation. The first plot centre on the grid was located at a distance of S/2 into the woodland near the south-west boundary of the survey area. Thereafter, plot centres were located at intervals of 136 m along a south-west to north-east bearing. The transects then continued on parallel bearings 136 m from the first transect as per the method described in Kerr *et al* (2002). Plot locations included a few open ground areas and woodland edge where tree seedlings were present but did not include non-woodland habitats without seedlings.

The final number of plots identified for survey amounted to 52 plots. During the survey two plots were discounted due to their inaccessibility and a few were moved a short distance because of obstacles, usually cliffs.

Due to the steep slopes and rugged terrain it was anticipated that pacing between plot centres would be difficult and inaccurate, particularly when a slope correction factor would have to be employed. Instead, all plot centres and a grid were measured and marked on a 1:10,000 scale OS map and grid references taken for each plot location on the map. These were then pre-loaded onto a hand-held GPS unit (Garmin GPSMap 60CSx with an average 5 m error margin), which was subsequently used in the field to locate all the plots.

4.2.3 Plot measurements

At each plot location the following data were measured and recorded:

- A 10 digit grid reference of plot centre.
- Species, diameter at breast height (dbh) and life stage class (see Appendix 4 for definitions) of all trees and shrubs (> 7 cm dbh).
- Species and count of all standing dead, fallen dead and visible stumps.
- Species and count of all seedlings and saplings (Life stage classes 1.1 to 3.1).
- Species and count of all seedlings and saplings with browse damage (loss of lead shoots within past year i.e current and previous season).
- Species and count of all seedlings and saplings with bark strip or fraying damage.
- Species and count of all trees with epicormics or basal shoots and those with browse damage (damage was recorded if equal to or greater than 50% of the shoots on any one tree were browsed).
- Dominant ground flora and woodland NVC type.
- Browsing, trampling and dunging impact on ground flora (see Appendix 5 for method).
- A digital photograph (7 megapixel camera) taken from the plot centre with record of direction of shot.

Each plot location was given a unique ID, which was also used as the filename for the digital photograph.

The fence lines and general condition of the enclosures were also assessed whenever possible.

The field survey began on 22 June 2010 and was completed on the 26 June 2010. The field-work part of the survey required ten person days to complete. To ensure consistency in the collection of quantitative data at each plot the two field surveyors operated together.

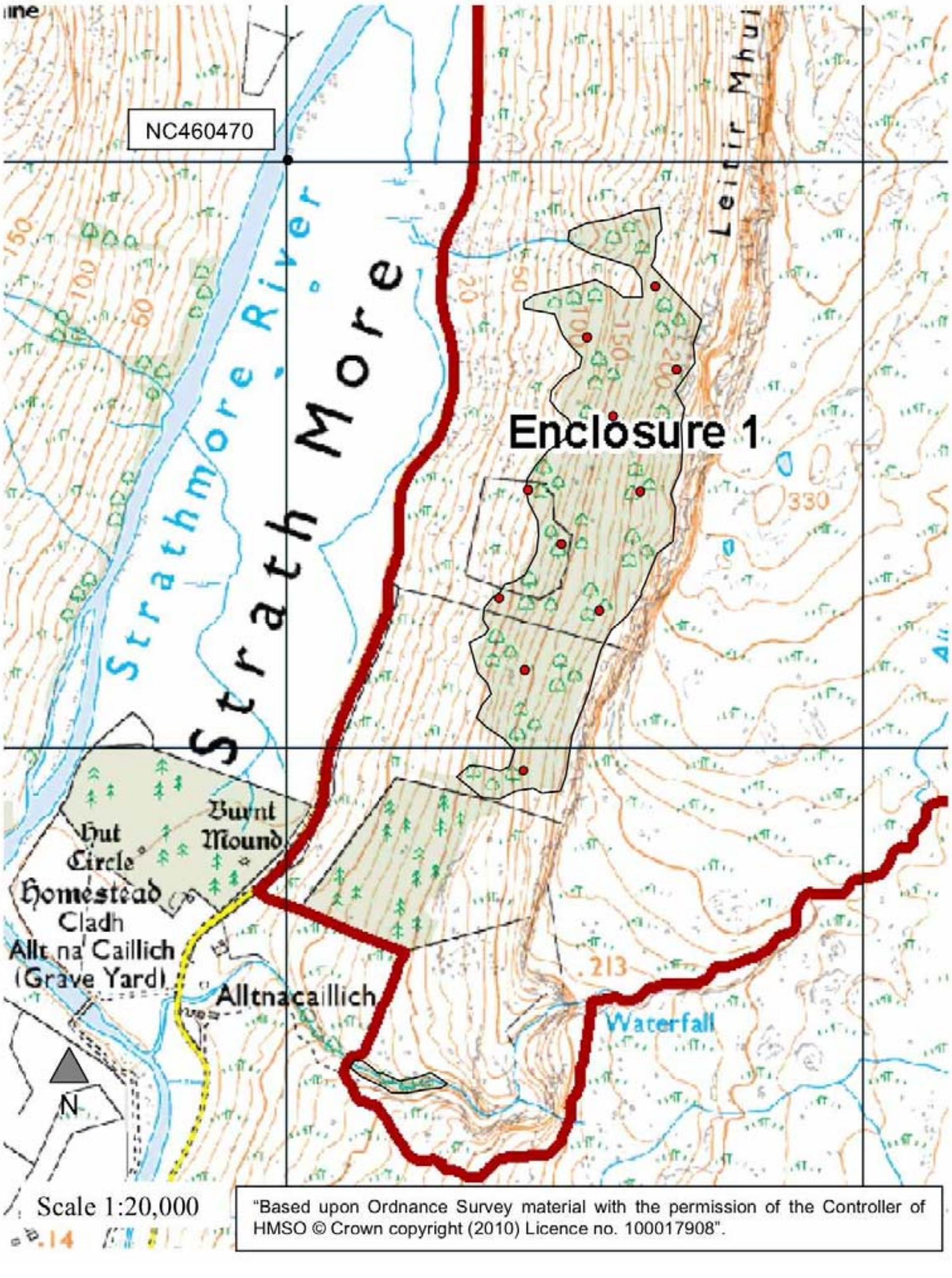

Figure 1 Leitir Mhuiseil wood with plot layout and location of Enclosure 1

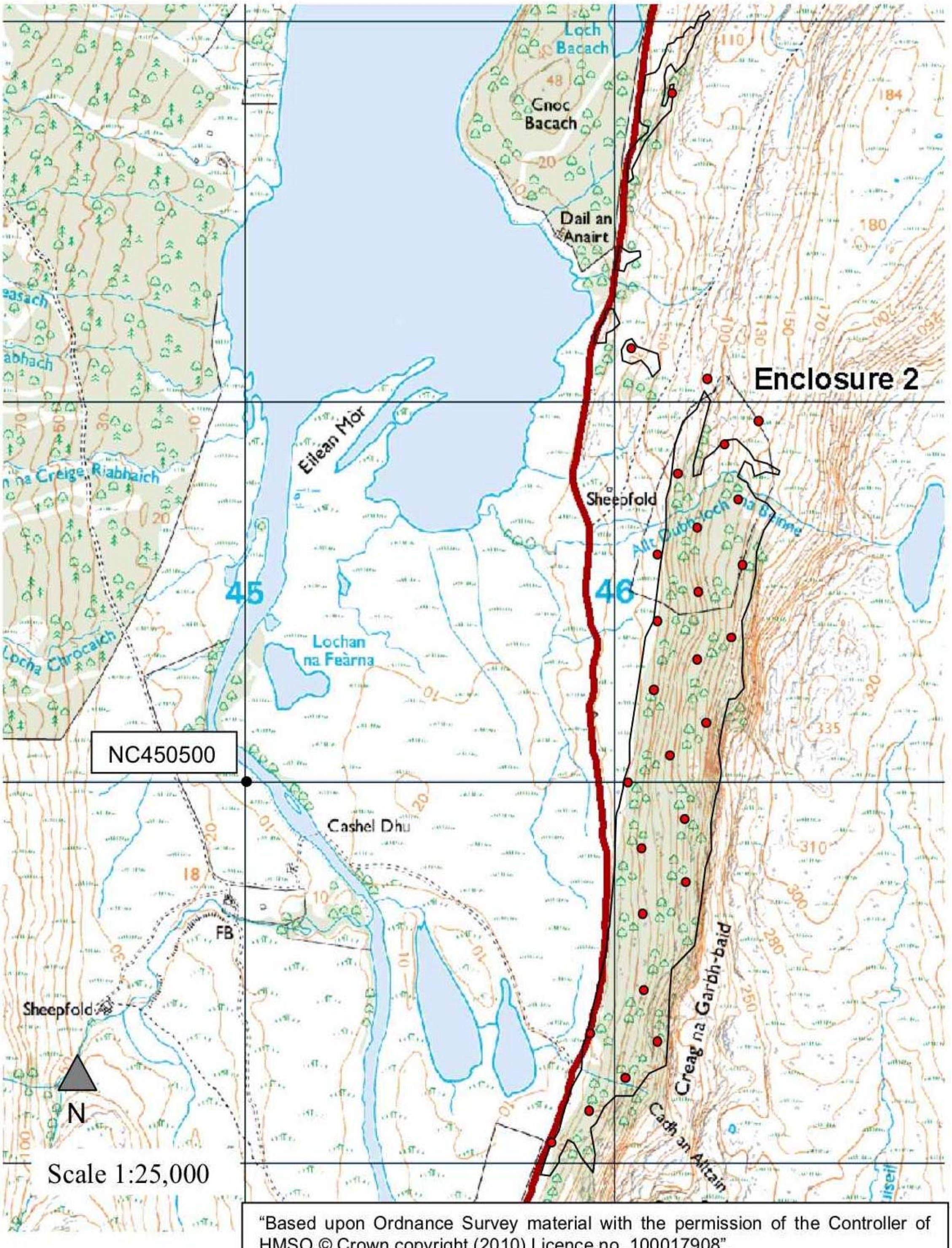

Figure 2 Creag na garbh-baid woodlands with plot layout and location of Enclosure 2

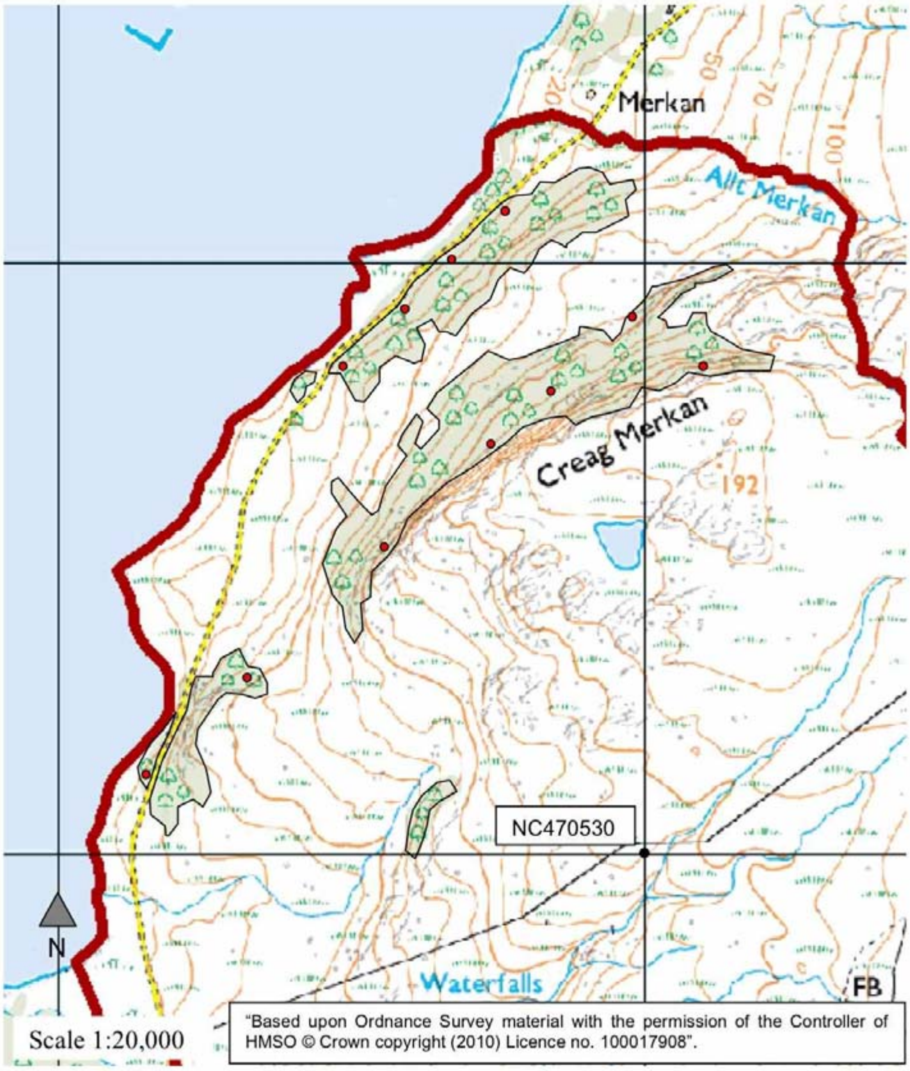

Figure 3 Creag na garbh-baid woodlands with plot layout

4.3 Marked tree seedling survey

At each of the sample plots two randomly identified tree seedlings were selected by choosing the nearest seedling to the north and south of the centre point of the plot. All selected seedlings were between 4 cm and 0.9 metres in height – i.e. below browse height. A black plastic cable tie was attached around the base of each seedling stem in order to allow identification of the seedling. In addition, a small wooden marking peg with an aluminium tree tag nailed to the side was positioned 0.3 m to the north of the seedling and a larger marking post, also with an aluminium tree tag, was positioned 3 m due north of the seedling. Each of the aluminium tree tags had a unique identification number.

The following data were recorded for each of the marked seedlings:

- Seedling ID number (the same number as the plot number plus letter 'a' or 'b' to differentiate the two seedlings).
- Tree species.
- Peg number.
- Post number.

- Grid reference (10 digit easting and northing plus GPS accuracy).
- Height of seedling (cm) (as measured against a calibrated measuring board).
- Lateral or leader longest shoot?
- Current seasons growth on longest shoot (cm).
- Lead shoot browsed by deer, hare or none in current season.
- Lateral shoot browsed by deer, hare (rabbit) or none.
- Height of surrounding vegetation (cm) (four measurements, north, south, east and west).
- Digital image of the seedling against measure board taken from the south.
- Digital image of seedling location and surrounding vegetation taken from the south.

4.4 Data analyses

The quantitative data from the 50 plots were summed and averaged for each sample plot and for each of the four woodland areas. Variances with confidence limits set at the 95% probability level were applied to all the quantitative assessments. In total the survey sampled 1% of the total survey area.

All tree species counts were grouped into the relevant life stage class for each species and used to compile woodland profiles of the main tree species. Diameter at breast height (DBH) measurements were analysed in the same way and used to provide additional information on woodland structure. As there is a relationship between stem growth, expressed as DBH, and life stage class Forestry Commission yield class models were used to provide a guide as to when a tree reaches maturity (Forestry Commission, 1981). Birch, rowan, aspen and goat willow on upland sites were unlikely to exceed yield class 4 and most probably will be less. Reference to the yield class tables for birch would show the size class that is equivalent to the age of maximum mean annual volume increment - the point at which growth begins to slow down, i.e. life stage class 4.1 (mature). Thus birch trees (and the other species) with a DBH equal to or greater than 20 cm are considered to be mature. However, in the north of Scotland, and particularly on exposed crags and scree or in areas with poor drainage, growth rates can be depressed due to environmental stress and maturity could be reached at a smaller DBH class. The survey protocol for the Forestry Commission's *"Native Woodland Survey of Scotland"* (Clifford & Mackenzie, 2008) indicates that the DBH maturity thresholds should be reduced by at least 25% (approx. one yield class) in such circumstances, giving 15cm for birch and the other broadleaved species. This reduced threshold was therefore used to allocate the 'mature' life stage class for each species recorded in the Ben Hope survey.

Mean basal areas were also calculated from the DBH measurements and averaged for each of the woodland areas. Basal areas, expressed as square metres/ha, were calculated using the following formula, and utilising the volume assessment tables in Hamilton (1975):

$$\text{Basal area} = \frac{\pi \times dbh^2}{40{,}000}$$

Stocking density figures were obtained directly from the count of live trees > 7 cm DBH and/or saplings exceeding the 2.1 life stage class in each plot then summed, rated up with the appropriate multiplier (x 50) and divided by the number of plots to obtain the number of stems per hectare. Comparisons could then be made with the expected stocking density categories for a given range of DBH size classes (Table 1). The range of stocking density categories in Table 2 has been adapted from those of managed plantations but the categories have been broadened in order to encompass the wider variation found in semi-natural stands. Previous survey work by the authors has shown that these categories will apply to all semi-natural woods, although the “over-stocked” category is not relevant to natural systems.

Table 1 Stocking density categories

Mean DBH [cm]	Trees/ha			
	Over-stocked	Normal	Under-stocked	Grossly Under-stocked
< 10	>4,500	1,200 – 4,500	500 –1,200	<500
10-20	>2,500	600 – 2,500	300 –600	<300
20-30	>1,100	200 – 1,100	100 –200	<100
30-40	>600	160 –600	70 –160	<70
40-50	>400	140 – 400	50 –140	<50
50-60	>200	100 - 200	40 -100	<40
>65	>150	50-100	<40	<25

(After MacKenzie, 1991; adapted from ADAS, 1986)

4.5 Herbivore impacts

Browsing impact on all seedling and sapling classes (Life stage classes 1.1 to 3.1) were assessed for each plot as damage to or loss of the terminal bud or shoot or as bark stripping or fraying. Browsing impact on the older life stage classes was assessed as damage to epicormic or basal shoots or as bark stripping. These could then be expressed as a percentage of the total number of seedlings/saplings/trees of each species for each plot.

The level of grazing, trampling and dunging impacts on the ground flora and field layer were assessed for each plot on a semi-quantitative basis based on the guidelines in the SNH Statement of Requirements (see Appendix 5).

5. RESULTS

5.1 Extent of woodland and sample area

The areas of native woodland in the three main blocks at Ben Hope are given in Table 2. Area measurements were taken from the 1:10,000 scale OS map but may not accurately reflect current areas as recent expansion at Merkan and a possible increase in fragmentation elsewhere may not have been accounted for.

The distribution and boundaries of the main blocks of woodland on the OS First Edition 1878 map are remarkably similar to their contemporary outline, particularly Leitir Mhuiseil and Creag an gharb-baid. The recent expansion of the Merkan woods along the public road and on the southern fringes of the main wood has returned this area to a size similar to that on the 1878 map. However, the density of tree symbols on the 1878 map suggests that canopy cover may have been less fragmented during the 19th century and there were numerous scattered clumps of trees between the main woodland blocks that are not present today.

A total of 3,449 trees, including seedlings and saplings were counted, measured and assessed in the 50 plots. In addition, 71 dead trees were assessed in the plots. One plot in enclosure 2 did not contain any trees and/or seedlings as the habitat was largely bog and unsuited to tree growth, although *Salix aurita* was present outside the plot area and some stunted birch were regenerating on the fringes of the bog. The total sample area was 1% of the total survey area (Table 2).

Table 2 Survey and sample plot areas

Woodland unit	Area of woodland (ha)	No. of 0.02 ha plots	Total area of plots (ha)	Area of plots as % of woodland	No. of trees sampled (all life classes)
Leitir Mhuiseil	16.6	9	0.18	1.1	557
Creag na garbh-baid	42.8	21	0.42	1	2210
Merkan	18.7	11	0.22	1.2	305
Enclosures*	17.8	9	0.18	1	448
Total surveyed woodland	96	50	1	1	3520

* Area of enclosures includes open ground inside the fenced area.

5.2 Woodland types and species composition

The Ben Hope woodlands were dominated by downy birch *Betula pubescens* with occasional rowan *Sorbus aucuparia*. Hazel *Corylus avellana* and willow (*Salix cinerea* and *S. caprea*) were less frequent components, holly was rare and there were several small discrete stands of aspen *Populus tremula*, particularly in the Creag na garbh-baid woods. Bird cherry *Prunus padus* has previously been identified in the Ben Hope woodlands but was not recorded during this survey (SNH, 2008). Also in the Creag na garbh-baid woods was the rare rock whitebeam *Sorbus rupicola* and a single healthy seedling was identified in one of the plots. Dog rose *Rosa* spp. occurred occasionally but honeysuckle *Lonicera periclymenum* and bramble *Rubus fruticosus* were rare except inside the enclosures where honeysuckle in particular was well developed in places. Bracken was dense at a number of open ground locations, particularly in the northern sections.

The main woodland HAP type was Upland Birchwood and the corresponding NVC communities were the W11 *Quercus petraea - Betula pubescens – Oxalis acetosella* and the W17 *Quercus petraea - Betula pubescens – Dicranum majus* woodlands but without the oak component. Small areas of the W4 *Betula pubescens – Molinia caerulea* woodland community were also noted.

Of the 50 plots that were sampled, 47 contained tree seedlings (Table 3). Birch and rowan were the most common seedlings encountered in the plots. Saplings were found in 24 plots but generally in very low numbers and usually on rock ledges or scree except for the dense birch and rowan thickets inside the two enclosures. Sapling growth of hazel was often associated with older stools or fallen-over stems rather than as new young regeneration.

Table 3 Number of sample plots with seedlings and saplings and other life stage classes of the main native tree & shrub species (excludes dead trees)

	No. of sample plots		
	Seedlings (1.1 & 1.2)	Saplings (2.1 & 3.1)	Other life stage classes (3.2 to 7.2)
Birch	36	18	41
Hazel	7	1	1
Rowan	45	13	16
Goat willow	1	1	1
Grey willow	2	0	0
Eared willow	4	0	0
Aspen	2	1	2
Holly	2	3	2
Rosa spp.	2	2	0
Rock whitebeam	1	0	0
ANY SPECIES	47	24	42

5.3 Woodland profile

The life stage classes for the main tree species in each of the four woodland strata were obtained from the mean number of stems per hectare converted to percentage frequency and are presented graphically in the following figures (Figures 4 - 8). The distribution of seedlings and saplings (all species) is also mapped graphically against each of the plots in Figures 22 to 27.

The profiles for birch illustrated some notable differences in the life stage class structure of the woodlands in the four blocks. Excluding the seedling stage Leitir Mhuiseil and Creag na garbh-baid showed a truncated bell shape curve with a complete absence of the key sapling stage life class (3.1). The majority of trees in Creag na garbh-baid were mature and in Leitir Mhuiseil the limited number of trees in the sample plots indicated that both areas possessed an aging and declining population with no recent recruitment. Leitir Mhuiseil in particular exhibited a clear degree of canopy decline and fragmentation which had probably been taking place over many decades. The limited numbers of small saplings tended to be located on unstable boulder scree which may have been a partial barrier to browsing herbivores. The potential for regeneration in both areas was very good as there were a high proportion of birch seedlings present throughout the woods.

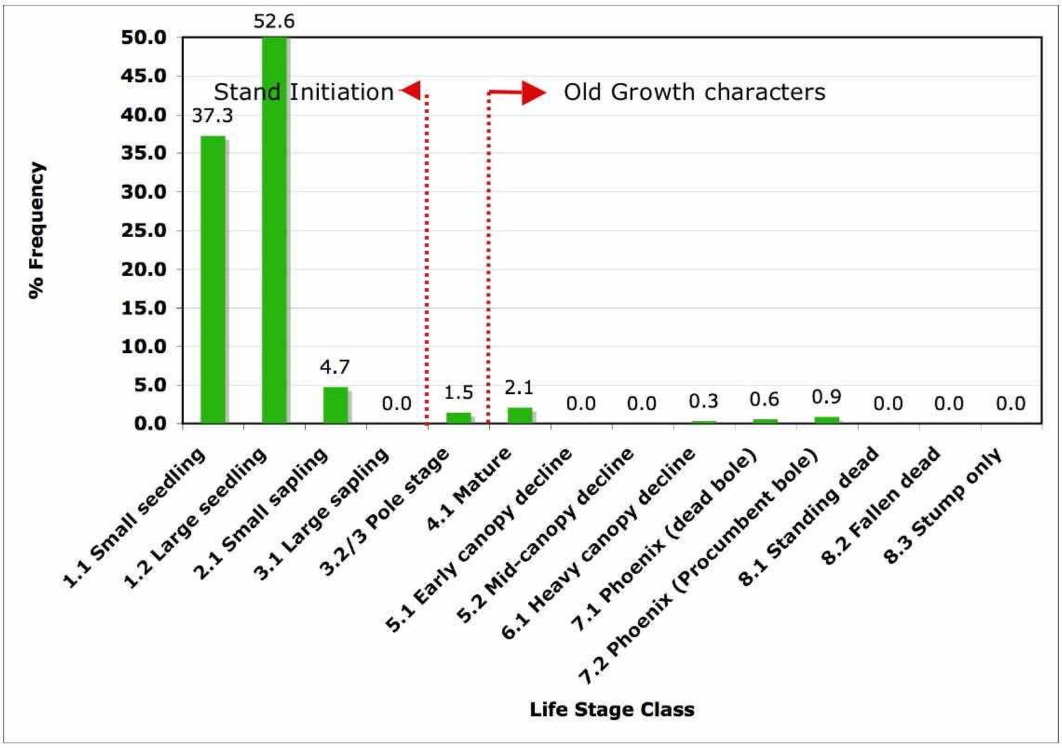

Figure 4 Life stage class profile of birch at Leitir Mhuiseil

Figure 5 Life stage class profile of birch at Creag na garbh-baid

In contrast the Merkan profile for birch exhibits a wave shaped curve centred on the mature life stage class with some limited recruitment to the sapling life stage and a healthy pole stage class. Birch regeneration near the public road and around the woodland edge some twenty or so years ago will have helped to diversify the age structure of the Merkan woods. However, the stand initiation phase, and particularly the key large sapling size (3.1), is quite low at 24% in comparison to the 57% old growth stand development phase comprising mature, canopy decline, phoenix and dead component.

Figure 6 Life stage class profile of birch at Merkan

The profile for birch in the enclosed areas suggests that regeneration is beginning to become established, although the profile tends towards a bell shape rather than the ideal reverse J. There was a dominance of the large seedling, and to a lesser extent small sapling, size classes which indicates steady progression to the subsequent life stage classes. The potential for further recruitment was low however as there were only small numbers of the small seedling size class. This is partly due to the density of the large seedlings occupying most of the available ground and partly because sections of the enclosures were blanket bog over deeper peats and thus unsuited to tree growth.

The profile for rowan in the enclosed areas was similar to that for birch. The large seedlings and the sapling stages dominated the profile but there were only limited numbers of the small seedling size class because of the reasons stated above.

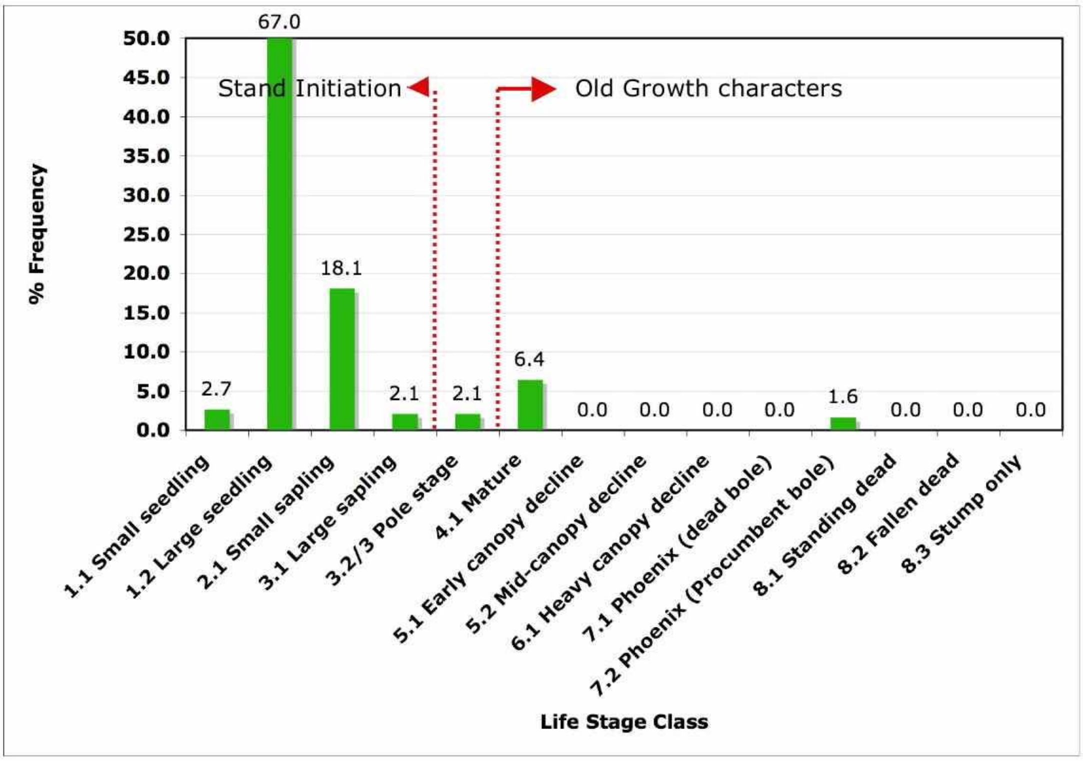

Figure 7 Life stage class profile of birch in the two Enclosures

Figure 8 Life stage class profile of rowan in the two Enclosures

Despite the dominance of mature trees and the open canopy structure of most of the woodlands the dead wood component was relatively low. This suggests that there has been no significant recent mortality of the mature trees in any of the woodland areas.

There were insufficient data for some of the less common species recorded in the plots to compile realistic profiles. Rowan seedlings were common at Leitir Mhuiseil and Creag na garbh-baid but there were only limited numbers of small saplings, mainly associated with boulder scree areas or cliffs, and virtually no large saplings (3.1) – a key life stage class. At Merkan rowan was mainly recorded in the plots as seedlings and there were no saplings or young rowan.

As for other tree species saplings were absent or very rare. At Merkan there were no sapling willow or hazel and only two pole stage aspen were recorded; at Leitir Mhuiseil there were a few willow seedlings but no saplings or young trees; and at Creag na garbh-baid, the largest of the woodland blocks, saplings of holly, hazel, willow and aspen were rare.

5.4 DBH Range

The mean DBH of each measurable tree species (i.e. trees with a DBH equal to or greater than 6 cm) are listed in Table 4 and the distribution of the range of DBH classes are displayed graphically in the subsequent histograms (Figures 9 – 13). The DBH range provides another indication of the size class profile and structure of the woodland at Ben Hope.

Basal area data of all live measurable tree species combined for the four sites and the total woodland area are given in Table 5. These data provide a useful benchmark and comparative guide to woodland structure between the sites and with other similar woodland.

Table 4 Mean DBH of tree species in the four woodland strata

	Leitir Mhuiseil		Creag na garbh-baid		Merkan		Enclosures		Total woodland	
	DBH (cm)	Sample size	DBH (cm)	Sample size	DBH (cm)	Sample size	DBH (cm)	Sample size	DBH (cm)	Sample size
Birch	21 ± 6	18	22 ± 1.7	116	15 ± 1.3	128	24 ± 5.1	17	19 ± 1.1	279
Rowan	14 ± 8	6	16 ± 2.9	28	-	-	7 ± 1	4	15 ± 2.5	38
Hazel	-	-	-	-	-	-	8 ± 2.4	4	8 ± 2.4	4
Goat willow	14 ± 5	3	-	-	-	-	-	-	14 ± 5	3
Aspen	-	-	-	-	6	2	-	-	6	2
Holly	-	-	-	-	-	-	16	2	16	2

Table 5 Mean DBH and Basal areas/ha in the four woodland strata

	Leitir Mhuiseil	Creag na garbh-baid	Merkan	Enclosures	Total woodland
No. of sample plots	7	19	11	4	41
No. of sampled trees (measurable stems only)	27	144	130	27	328
Mean DBH (cm) (all species)	19 ± 4.3	21 ± 1.5	15 ± 1.3	18 ± 4.3	18 ± 1
Mean basal area/ha (m^2)	5.4 ± 4.4	15.3 ± 7.2	13 ± 4.1	12	13 ± 3.7

- Measurable stems are equal to or greater than 6 cm DBH.
- Mean DBH is based on a summation and mean of all measurable stems of all species in the 50 plots.
- Mean basal area for all species is based on a summation and mean of total BAs in the 50 plots.
- Confidence limits are given at the 95% probability level. Data without confidence limits are unreliable due to low sample size.

There are some differences in the DBH profiles for downy birch, most notably at Merkan where the DBH profile closely resembles a reverse 'J' curve with 59% of the measurable trees below the likely age of maturity. This would indicate that the population has regenerated in the recent past (Figure 9). This is confirmed by the mean DBH in Table 4, which at 15cm indicates a healthy population of trees that includes both immature and mature stems.

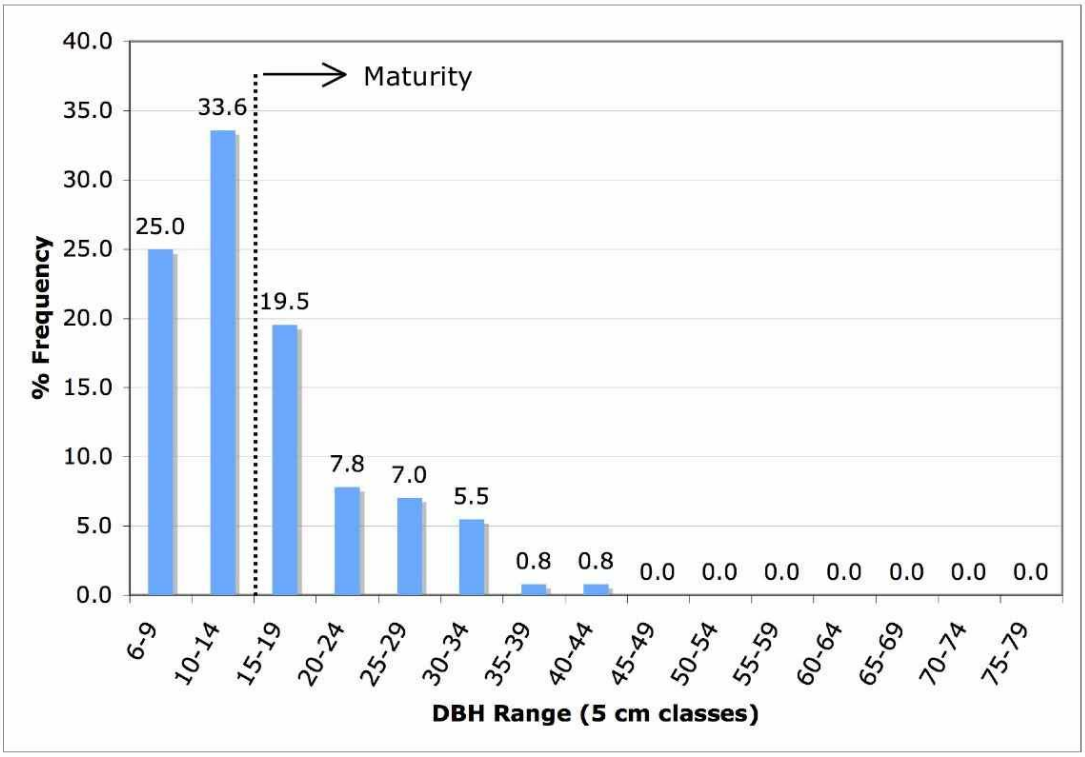

Figure 9 DBH range of birch trees at Merkan

In contrast, the DBH profiles for the other three sites are bell or wave like in shape where the majority of trees are mature (Creag na garbh-baid 76%, Leitir Mhuiseil 67% & Enclosures 82% mature) and the mean DBH, including the extent of the confidence intervals, are well above the maturity threshold of 15cm (Figures 10 to 12; Table 4). Although there were birch trees below the maturity threshold at Creag na garbh-baid and Leitir Mhuiseil many of these were growing on boulder scree areas where there was some degree of protection from browsing herbivores. Others were growing in situations that created depressed growth and were older than indicated by their DBH.

In the enclosures the DBH profile needs to be considered along with the life class profile as the extensive areas of thicket growth birch with DBHs less than 6cm were excluded from the DBH profile[1]. The sample size from the enclosures is also quite low and DBH by itself only partly reflects the true woodland structure. Taken together however, the life class profile and the DBH profile indicates a woodland structure that contains mature birch, small numbers of young birch and a great many sapling stage birch.

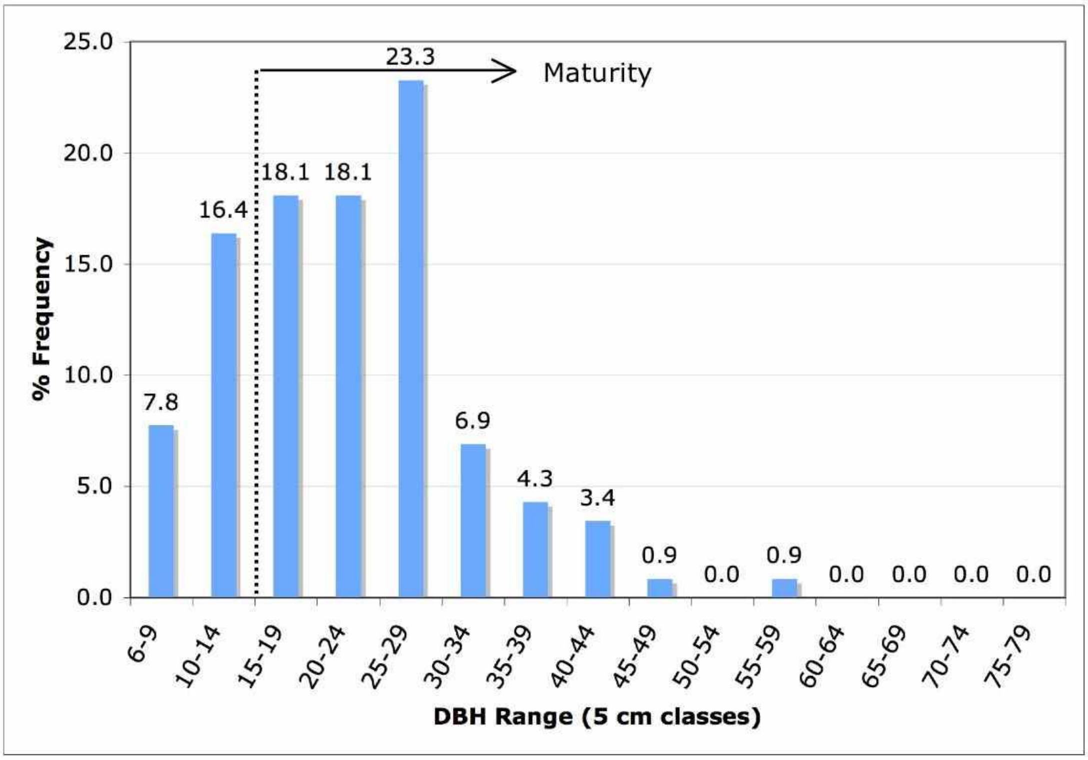

Figure 10 DBH range of birch trees at Creag na garbh-baid

[1] DBH profiles exclude the 'stand initiation phase' and will always be different to the life class stage profile curve i.e. the DBH curve will always be truncated.

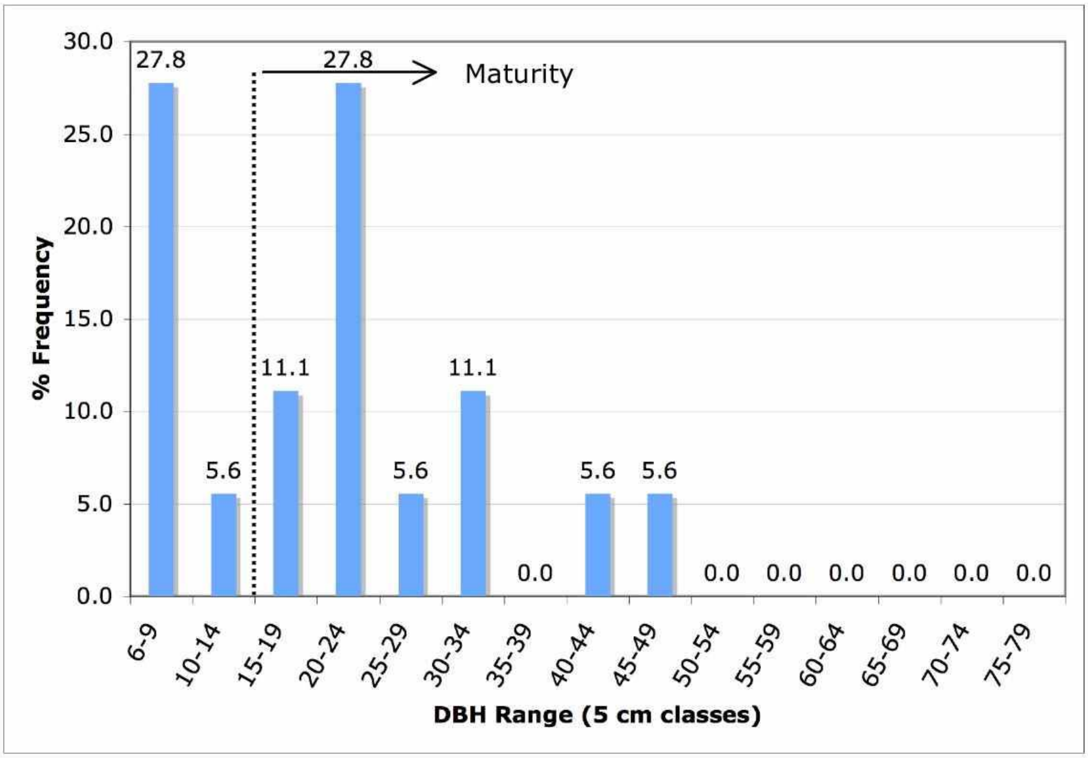

Figure 11 DBH range of birch trees at Leitir Mhuiseil

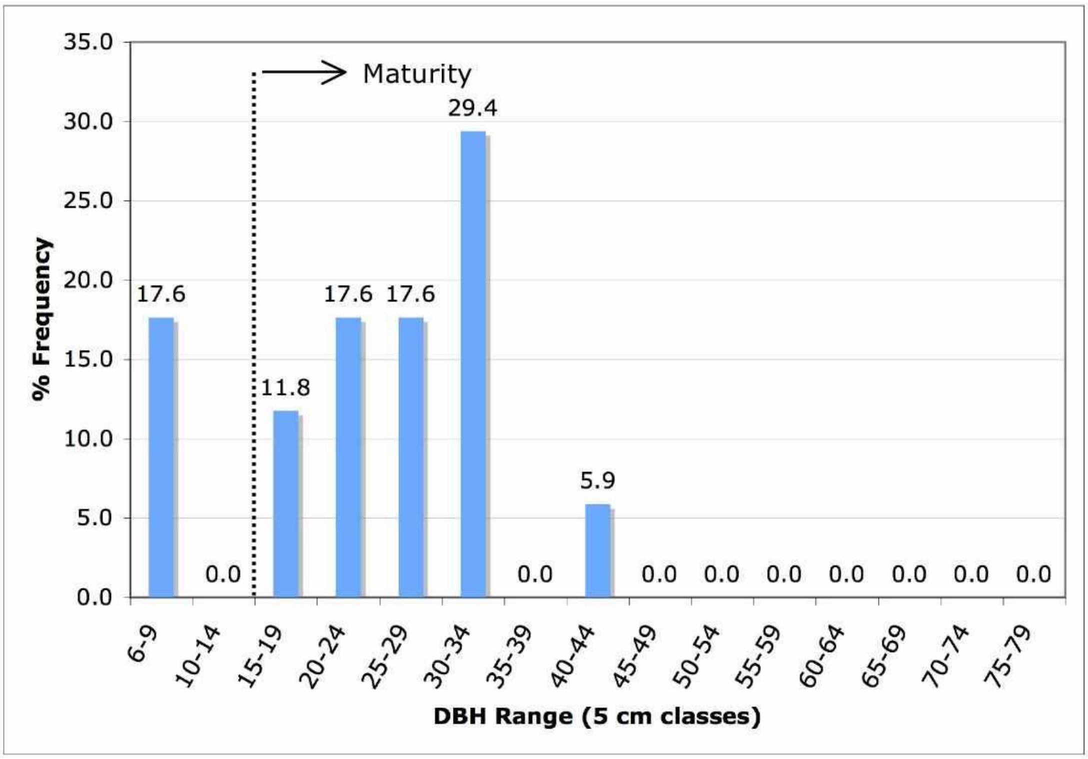

Figure 12 DBH range of birch trees in the two Enclosures

Rowan at Creag na garbh-baid was the only other species found in sufficient numbers to compile a DBH profile. Figure 13 shows that the majority of trees are mature and the mean DBH is just above the maturity threshold of 15cm (Table 4). The remaining species identified within the plots were too few in number to compile realistic DBH profiles. Limited numbers of hazel, holly, willow and aspen tended to be scattered throughout the woods or occurred as small stands and there was a range of size classes. A few mature goat willow were found and there were also some immature rowan, for example on crags or rock scree.

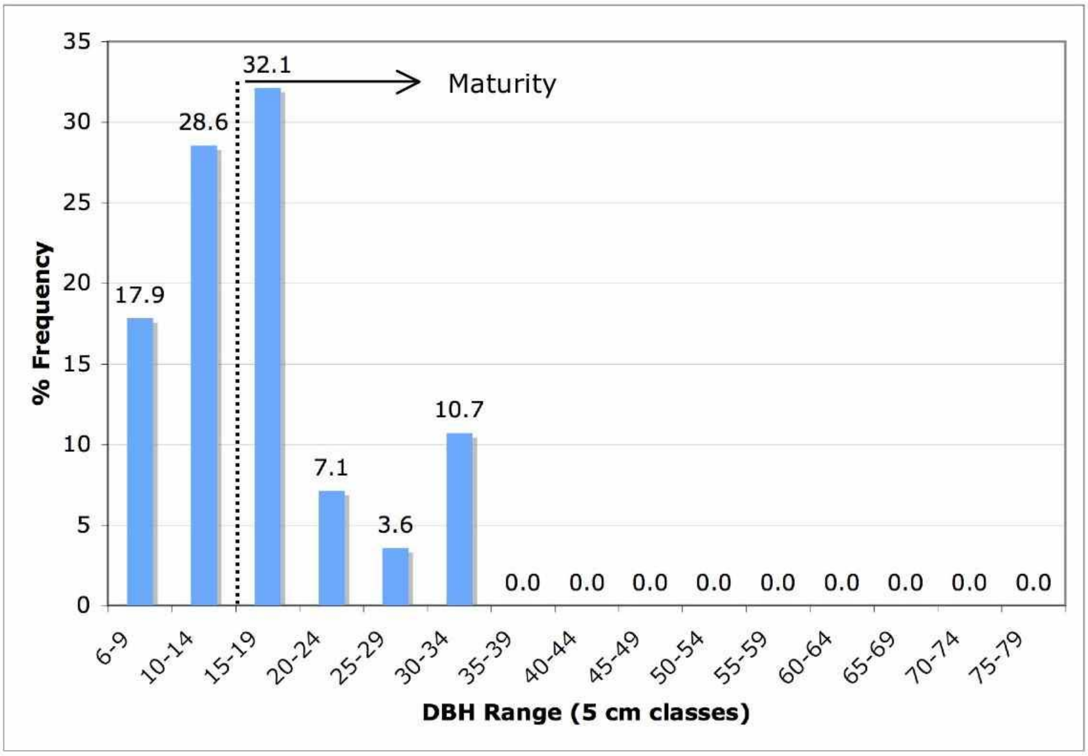

Figure 13 DBH range of rowan trees at Creag na garbh-baid

Basal area data, which provide a volume assessment per hectare based on the measurable trees at each of the four sites, illustrated another difference among the sites. Leitir Mhuiseil possesses a significantly lower basal area than the other sites. As the mean DBH is similar to the overall mean for the whole woodland area the low basal area is due to the greater degree of fragmentation and more open canopy at Leitir Mhuiseil.

4.5 Stocking density

Mean stocking density figures, which includes established canopy trees, established regeneration and non-established regeneration, for the four woodland areas are given in Tables 6 - 9. The canopy trees are based on the measurable stems ≥ 6 cm DBH found in the woodland plots and can thus be linked to the mean DBH (Table 5) and compared to the stocking density guide in Table 2. Stocking density for canopy trees in the four areas ranged from 150 ± 112 to 586 ± 268 stems/ha. Leitir Mhuiseil is thus 'grossly understocked' even when the upper level of the confidence limits are taken into account. Creag na garbh-baid is 'understocked' including accounting for the upper level of the confidence limits. Merkan, with a mean DBH of 15 ± 1.3 cm, just falls outside the "normal" range but with confidence levels considered could be regarded as borderline normal. The stocking density range is wide due to the variability in stocking as the plots included areas of dense birch as well as areas of widely spaced larger trees. Stocking density in the enclosure is also grossly understocked if only the mature trees are considered but with the addition of saplings stocking levels are brought closer to the normal range. Numbers of standing dead trees were not significantly high in any of the woodland areas. Stocking density for the important large sapling life stage was very low in all blocks except the enclosures despite the moderately high numbers of seedlings present in all areas except Merkan.

When all woodland areas are considered as a whole unit stocking density levels for canopy trees are understocked, although clearly there are localised areas where stocking levels fall within the normal range, such as part of Merkan wood and in the enclosures (Table 10). The density of seedlings is good and exceeds the 1100 stems/ha minimum average threshold required by the Forestry Commission as trigger for payment of 'regeneration grant' under previous forestry grant schemes. However, the severely low levels of the next life stage – the sapling size class (3.1) – is a cause for concern in all areas outside of the enclosures.

Table 6 Mean stocking density of all live and standing dead trees at Leitir Mhuiseil

Woodland	Mean stocking density (stems/ha)	Stocking density range (stems/ha)	No. of samples
Canopy trees (≥ 6 cm DBH & ≥ 3.2 life stage class)	150 ± 112	0 - 450	9
Standing dead trees (8.1) *	11	0 - 100	9
Large saplings (3.1) *	6	0 - 50	9
Seedlings (1.1 – 2.1)	2906 ± 2184	50 - 9450	9

Confidence limits are given at the 95% probability level. * Present in only one of the nine sample plots – CL were therefore not reliable.

Table 7 Mean stocking density of all live and standing dead trees at Creag na garbh-baid

Woodland	Mean stocking density (stems/ha)	Stocking density range (stems/ha)	No. of samples
Canopy trees (≥ 6 cm DBH & ≥ 3.2 life stage class)	376 ± 140	0 - 1300	21
Standing dead trees (8.1) *	12	0 - 100	21
Large saplings (3.1) *	26	0 - 400	21
Seedlings (1.1 – 2.1)	4743 ± 2857	750 - 25000	21

Confidence limits are given at the 95% probability level. * Present in only three of the 21 sample plots – CL were therefore not reliable.

Table 8 Mean stocking density of all live and standing dead trees at Merkan

Woodland	Mean stocking density (stems/ha)	Stocking density range (stems/ha)	No. of samples
Canopy trees (≥ 6 cm DBH & ≥ 3.2 life stage class)	586 ± 268	100 - 1200	11
Standing dead trees (8.1)	14	0 - 100	11
Large saplings (3.1) *	23	0 - 100	11
Seedlings (1.1 – 2.1)	718 ± 421	0 - 1800	11

Confidence limits are given at the 95% probability level. * Present in only three of the 11 sample plots – CL were therefore not reliable.

Table 9 Mean stocking density of all live and standing dead trees in Enclosures

Woodland	Mean stocking density (stems/ha)	Stocking density range (stems/ha)	No. of samples
Canopy trees (≥ 6 cm DBH & ≥ 3.2 life stage class) *	172	100 - 1200	9
Standing dead trees (8.1)	None recorded	0	9
Large saplings (3.1) *	389	0 - 2450	9
Seedlings (1.1 – 2.1)	2022 ± 1517	0 - 5300	9

Confidence limits are given at the 95% probability level. * Present in only four (canopy trees) and three (3.1) of the 9 sample plots – CL were therefore not reliable.

Table 10 Mean stocking density of all live and standing dead trees in the total woodland area

Woodland	Mean stocking density (stems/ha)	Stocking density range (stems/ha)	No. of samples
Canopy trees (≥ 6 cm DBH & ≥ 3.2 life stage class)	345 ± 96	0 – 1250	50
Standing dead trees (8.1)	10 ± 8	0 – 100	50
Large saplings (3.1) *	87	0 – 2450	50
Seedlings (1.1 – 2.1)	3037 ± 1295	0 – 25000	50

Confidence limits are given at the 95% probability level.

5.6 Herbivore impacts

5.6.1 Browsing of seedlings and saplings

Browsing impact on the lead shoots was very high for all areas except within the two enclosures and ranged from 82% to 94% of all recorded seedlings and small saplings (Table 11). Virtually all browsing in all areas had taken place prior to the current growing season, most probably between late summer of 2009 and early spring of 2010. As field-work was carried out during June there was no information on the 2010 growing season browsing activity after that month.

All species of seedling recorded during the survey experienced high levels of browsing activity on the lead shoots prior to the current growing season (birch, rowan, hazel, aspen, grey willow, holly, *Rosa* spp. and eared willow) (Figure 17).

The limited numbers of large saplings (life stage 3.1) recorded outside the enclosures were usually above browse height or were on inaccessible locations and did not suffer leader damage. Browse activity, if present, was limited to lateral branches which did not affect tree growth.

Deer and livestock (mainly sheep) were the principal herbivores causing the browse damage to the leader shoots of all species of seedling and small sapling at all unenclosed and accessible areas. It was not possible to separate the leader damage by herbivore species.

Table 11 Leader browsing of seedlings and small saplings (life stages 1.1 to 2.1) - all species combined

Woodland block	Mean % browsed	Sample size	Mean % browsed during current growing season	Mean % browsed prior to current growing season
Leitir Mhuiseil	86 ± 24.8	9	3	97 ± 4.4
Creag na garbh-baid	94 ± 5.9	21	0.1	99.9 ± 0.2
Merkan	82 ± 18.4	10	5	95 ± 11
Enclosures	0	8	-	-

- Sample size refers to the number of plots where seedlings were recorded and assessed.
- Current growing season equates with the period late April to June 2010 (the time of field survey)
- Confidence limits are at 95% probability level. Data without CL are less reliable due to the small sample size

5.6.2 *Browsing of epicormics and basal shoots*

Browsing impacts on the epicormic and basal shoots when present on the larger broadleaved trees was very high for all species in all three unenclosed woodland areas. Levels ranged from 81% to 100% of trees with accessible shoots (Table 12). Again the browsing impact occurred almost entirely prior to the current growing season.

Table 12 Browsing of epicormics and basal shoots (life stages 3.1 to 7.2) – all species combined

Woodland block	Mean % browsed	Sample size	Mean % browsed during current growing season	Mean % browsed prior to current growing season
Leitir Mhuiseil	81 ± 35	7	0	100
Creag na garbh-baid	100	20	1.9	98 ± 2.7
Merkan	89 ± 13	10	0	100
Enclosed	0	3	-	-

- Sample size refers to number of plots where trees with epicormics/basal shoots were recorded.
- Current growing season equates with the period late April to June 2010 (the time of field survey)
- Confidence limits are at 95% probability level. Data without CL are less reliable due to the small sample size

5.6.3 *Bark stripping and fraying*

Recent damage to the bark of young trees and saplings was not recorded on any species in any of the woodland areas. Old bark stripping, probably by roe deer, was recorded in a very small number of birch and goat willow at Leitir Mhuiseil and Creag garbh-baid. In total six trees were damaged by bark stripping – an insignificant number that would have no impact on regeneration and woodland structure development.

5.6.4 *Browsing, trampling and dunging impacts on ground flora and field layer*

The degree of browsing, trampling and dunging on the ground flora and field layer within each plot was assessed according to the guidance in Appendix 5 and the results are displayed graphically in Figures 14 to 16. In the Leitir Mhuiseil wood grazing was recorded in all the plots but the impact was either low (78%) or moderate (22%); deer dung was recorded in all plots but one and sheep dung was recorded in one plot – all at low or moderate levels; trampling was not recorded (Figure 14). At Creag na garbh-baid grazing was recorded in all the plots but the impact was either low (76%) or moderate (24%); deer dung was recorded in 13 of the 21 plots, sheep dung in three plots and cattle dung in one plot (Figure 15). Most of the livestock dung appeared not to be recent. Dunging impact was recorded as low or medium although one plot at the south end of the wood near the public road contained high levels of sheep and cattle dung. Trampling was absent at most plots but was recorded at low or moderate levels in 29% of plots. Most trampling took the form of trails with exposed soil. At Merkan wood all grazing was at low levels, trampling impact was recorded in just one plot and dunging by sheep and deer was at low or moderate levels in 64% of plots and absent in the remainder (Figure 16).

There was no evidence of any herbivore impact in either of the two enclosures.

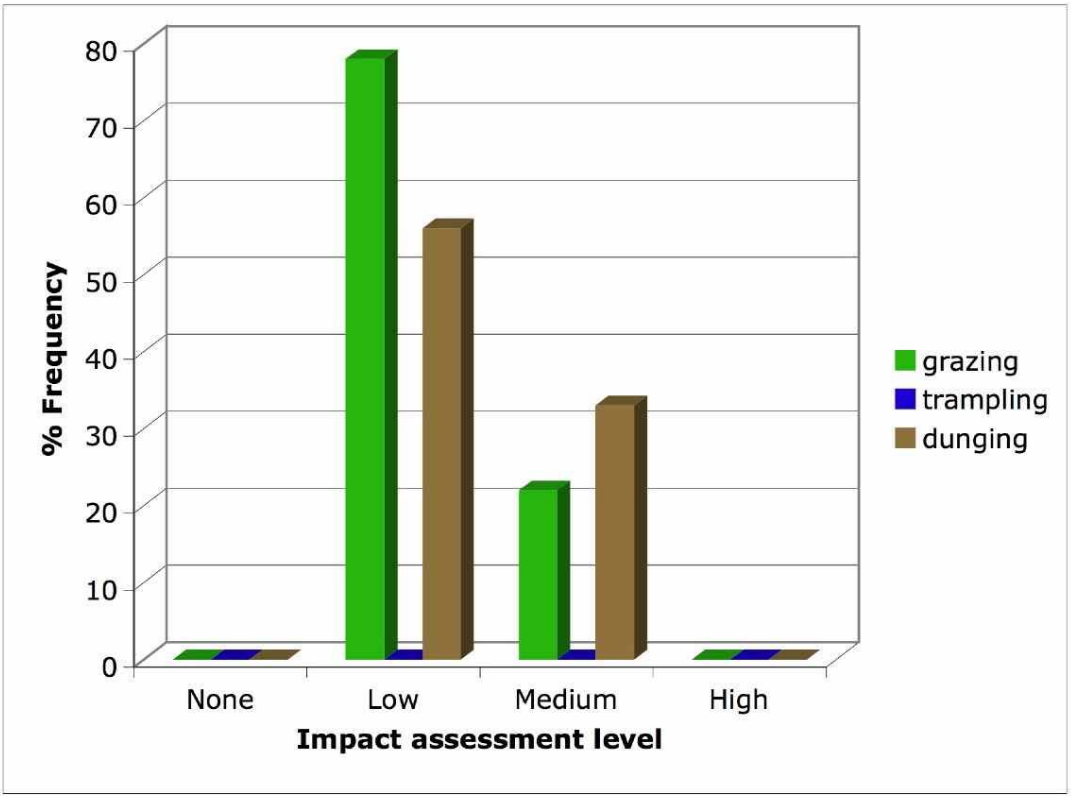

Figure 14 *Grazing, trampling and dunging impacts on the ground flora at Leitir Mhuiseil*

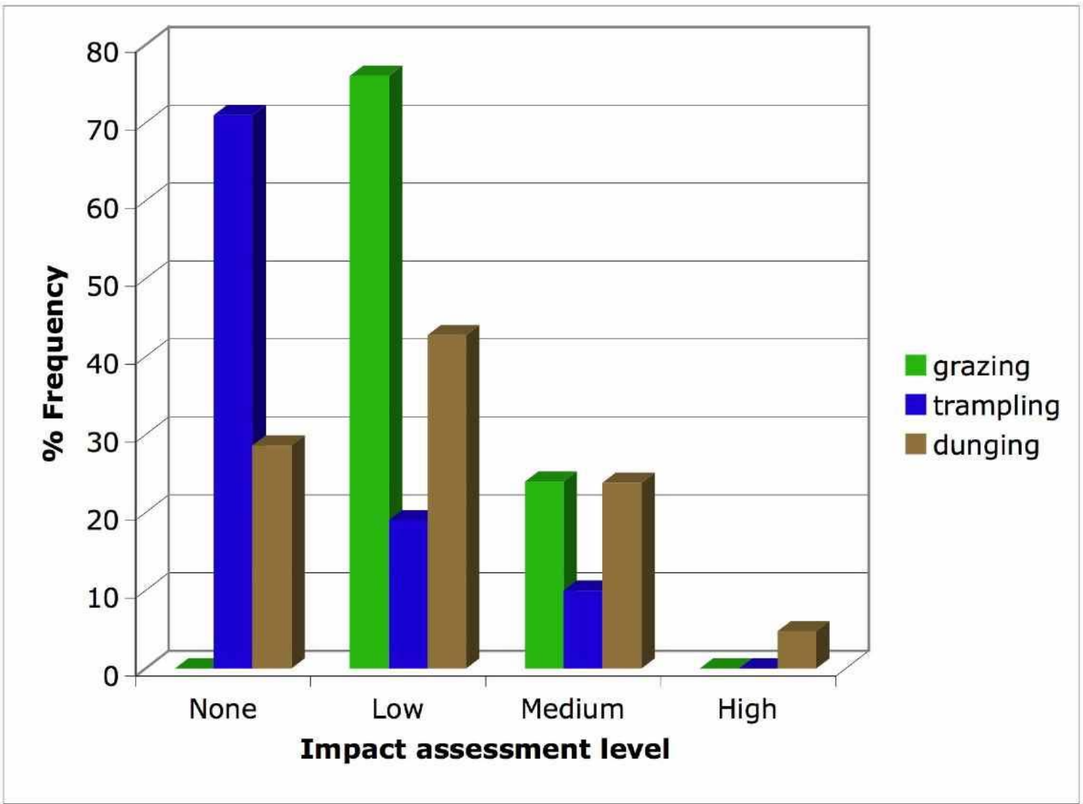

Figure 15 Grazing, trampling and dunging impacts on the ground flora at Creag na garbh-baid

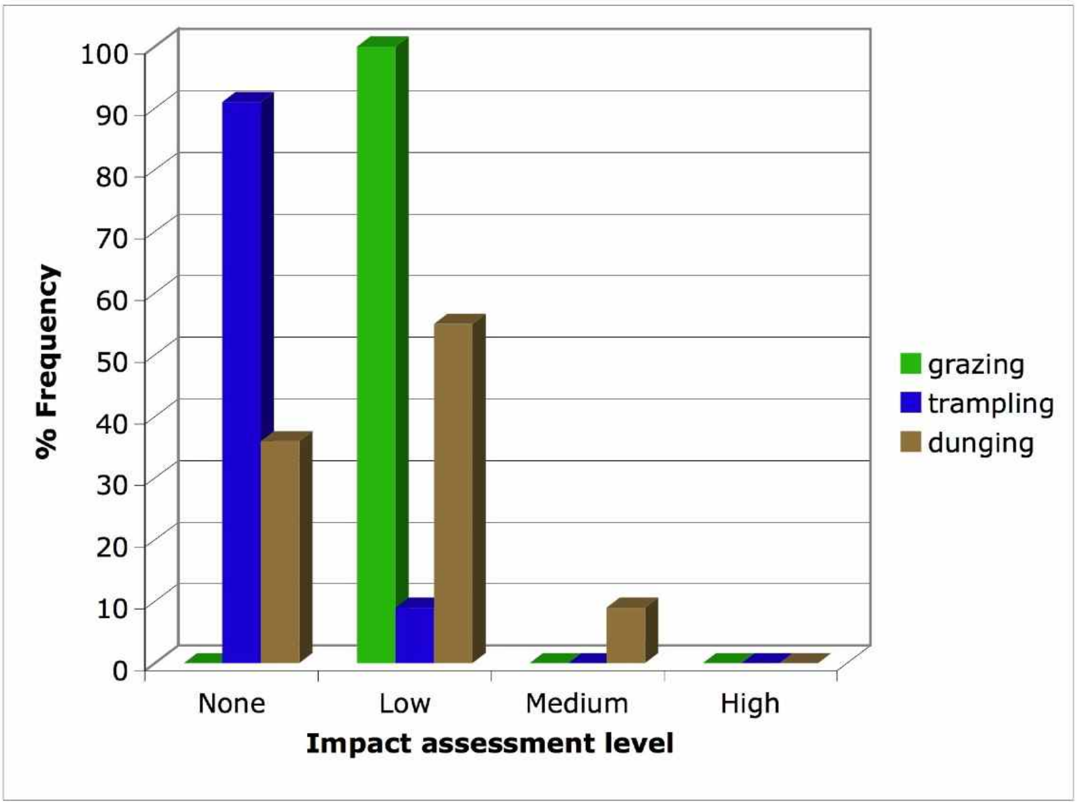

Figure 16 Grazing, trampling and dunging impacts on the ground flora at Merkan

Figure 17 Holly seedling which has been shaped and suppressed by frequent browsing over many years

6. REVIEW OF EXISTING CONSERVATION MANAGEMENT MEASURES

The principal management input into the conservation of the woodlands at Ben Hope SSSI has been the erection of two fenced enclosures designed to encourage the successful regeneration of birch and associated trees and shrubs and restore woodland structure and continuity. Enclosure 1 was a small enclosure of about 2.8 ha (including open ground) and was located at the lower boundary of Leitir Mhuiseil wood. It enclosed about 7% of the current woodland area and included very scattered established mature trees plus areas of open ground beyond the lower woodland edge. The open ground consisted of *Calluna* heath, *Molinia* wet heath and some *Molinia – Myrica* bog. Fences were erected in 1992 and the upper half of the enclosure now contains dense patches of pole sized thicket birch with rowan and willow and extensive areas of large seedlings and saplings. Fence lines were in good condition and there was no evidence of deer or livestock breaching the enclosure.

Enclosure 2 was a larger enclosure of 15 ha located in the northern part of Creag na garbh-baid wood. It enclosed about 19% of the woodland area and included established mature trees and areas of open ground to the north and west. The enclosure was completed in 1992 and now contains dense thickets of birch and rowan amongst the scattered mature trees as well as regeneration extending beyond the original woodland edge. The ground flora under the tree canopy was well developed with carpets of bluebells *Hyacinthoides non-scriptus* and other vascular plants, for example melancholy thistle *Cirsium heterophyllum* and yellow pimpernel *Lysimachia nemorum*, and a rich and luxuriant range of grasses. Honeysuckle *Lonicera periclymenum* was prominent on rocks and cliffs and sometimes growing over saplings. Many of the older trees possessed well-developed epicormic and basal shoot growth all of which was unbrowsed. Fence lines were in good condition and there was no evidence of deer or livestock breaching the enclosure.

Part of the open ground in the Creag na garbh-baid enclosure is blanket bog over deep peat or *Molinia – Myrica* bog and will not develop into woodland although some stunted birch were growing on hummocks of *Molinia caerulae* and *Salix aurita* may regenerate onto some of the flushed areas.

Tree growth is generally relatively slow on exposed upland sites in the north of Scotland and the establishment of new natural regeneration will frequently take twice as long as would be expected on fertile lowland sites. As there were significant numbers of large seedlings and saplings present that are still vulnerable to herbivore damage the fences will have to remain in place for at least another ten to fifteen years.

Although the enclosures have made a successful contribution to the regeneration of the woodlands over the past 18 years, if there was no corresponding reduction in the density of herbivore browsing during the same period, then there may have been an increased browsing impact on the unenclosed woodland areas.

7. EVALUATION

7.1 Evaluation of woodland profile

Oliver & Larsen (1996) recognise four different phases of stand development that would be present over the lifetime of a given area of woodland and these four phases can be used in conjunction with the life stage profiles as a comparison to indicate the current condition of the Ben Hope woods (Table 13). Most large natural woodlands should possess a mosaic of the four phases although the proportion of each phase could vary significantly depending on the age and longevity of the trees, the disturbance history of the site and the actual area of woodland involved. The dynamic processes relating to mortality and recruitment that are involved in the life cycle of a wood will occur over many decades and the changes that may take place may be triggered by a disturbance such as fire or windthrow. In the wet and windy oceanic climate of the north-west of Scotland fire is less likely to be a natural disturbance factor and the more localised impact of windthrow or simply the natural mortality of old trees, often aided by the cumulative impacts of pathogenic fungi are the usual dynamic processes of change. At a landscape scale the theoretical expected age structure in the profile would be the 'reverse J' curve where there is constant recruitment and mortality in the woodland population (Mason *et al*, 2004). In the ancient woods of Ben Hope disturbance factors are more likely to be small and localised and hence there should be a higher proportion of the old growth phase resulting in an ideal curve that is more 'wave-like' in shape.

The profiles for the three unenclosed woodland blocks showed that there were elements of the stand initiation phase (abundant seedlings of a range of species) throughout most of the areas. However, as the sapling elements were largely missing from the three areas the stand initiation phase was incomplete (Table 13). The second phase of stand development, the stem exclusion phase, where young saplings progress to pole stage trees and thickets, was entirely absent from Leitir Mhuiseil and Creag na garbh-baid (except for a few saplings on crags and scree). Thickets of young birch were present on the fringes of part of Merkan wood, for example next to the public road and along the southern edge of the main wood. These thickets appeared to have developed some twenty to twenty-five years ago but there has been very little expansion in recent years. As a result the woodland profiles for Leitir Mhuiseil and Creag na garbh-baid exhibit a truncated bell shape curve with a complete absence of the key sapling stage life class (3.1). Such a curve indicates an aging population, characterised by a low rate of recruitment, but with a serious discontinuity due to the missing younger life stage classes. These omissions mean that there is nothing to replace the mature and over-mature trees, which are significant reservoirs of biodiversity, as they progress towards the end of their life cycle. It is only Merkan wood that has a profile which approaches a wave-like curve albeit with a weak large sapling life stage (see Figure 6).

The majority of the woodland was entering the 'Old growth' phase as it was mature birch that dominated the canopy at Merkan, Creag na garbh-baid and Leitir Mhuiseil. The mean DBH of the birch at 18 cm confirmed the maturity dominance. However, old growth was very poorly developed because in areas where the canopy was open there was no understorey re-initiation phase at any of the three unenclosed sites. Since stocking densities were below normal, and indeed at Leitir Mhuiseil severely abnormal, regeneration should have progressed beyond the early stages of stand initiation into the thickets of stem exclusion as part of the understorey re-initiation phase associated with a well-developed old growth wood. This did begin to happen at Merkan wood sometime in the 1980s (Figure 18) but has not happened elsewhere and further development at Merkan appears to have diminished substantially. Although there were abundant birch and rowan seedlings, and to a lesser extent seedlings of other species, around almost all the woodland edges and in canopy gaps there was no significant sign of established regeneration developing in any of the open ground areas (Figure 19).

The two enclosures were the only parts of the Ben Hope woodlands where there were sufficient numbers of seedlings, saplings and young trees developing as future replacements for the very scattered mature trees. Here, the profile was approaching the ‘reverse J’ type, which indicates a rapidly increasing population, as seedlings and saplings dominated the life stages. The DBH profile was still dominated by mature trees but young trees were present too and as more stems reach a measurable size the profile will become a more wave-like curve.

Figure 18 Natural expansion of birch at Merkan wood

The dead tree component at all sites occupied a moderately low proportion of the woodland profile. As the canopy was very open in some areas, and particularly at Leitir Mhuiseil, dead stems should have been a larger proportion, but the lack of dead wood indicates that there has been no significant recent mortality. Birch and rowan decay at a relatively fast rate compared to tree species such as oak and Scots pine, which suggests canopy decline and fragmentation began many decades ago.

A further concern is the very low basal areas associated with the Ben Hope woodland areas, particularly at Leitir Mhuiseil. Mean DBH and basal area of the combined data for all live measurable trees provides a useful benchmark and guide in a comparison with the same information from upland birchwoods at other northern and western sites (Table 14).

The mean basal area and DBH for the whole wood is very similar to the Letterewe birchwoods which also possessed a poor stocking density. While at Loch a’Mhuilinn, a more extreme coastal oceanic site with similar mean basal area but smaller mean DBH and depressed growth rates, the stocking density is within the normal range - more than double that of Ben Hope.

Figure 19 *Extensive birch regeneration in Leitir Mhuiseil wood. All seedlings (1.1 & 1.2 life stages) have multiple leader branches and all have been suppressed by browsing prior to current growing season.*

Table 13 The four phases of stand development in the woodlands of Ben Hope SSSI (based on Oliver & Larsen, 1996)

Phase	Classification	Life class stage*	Leitir Mhuiseil	Creag na garbh-baid	Merkan	Enclos - ures
1	Stand initiation	1.1 – 3.1	Present but incomplete	Present but incomplete	Present but incomplete	Present
2	Stem exclusion	3.2 – 3.3	Not present	Not present	Present in part of site	Present
3	Understorey re-initiation	Multi-age advance regeneration (2.1 – 3.3) under open canopy of 4.1 - 8	Not present	Not present	Not present	Present in part of site
4	Old growth	4 – 8 (with elements of 1.1 – 3.3)	Present but very poorly developed	Present but poorly developed	Present but poorly developed	Present but limited in area and structure

- See Appendix 5 for details of the life stage classification.

Table 14 Mean DBH and Basal Area (all species) of three native woodlands in the north-west Highlands

Site name	Mean DBH (cm)	Mean Basal Area (m^2/ha)	Stocking density (canopy trees ≥ 6 cm DBH)
Ben Hope birchwoods	18 ± 1	13 ± 3.7	345 ± 96
Letterewe birchwood	19 ± 1	12.5 ± 3.1	321 ± 75
Loch a' Mhuilinn	12.3 ± 0.5	10.3 ± 2.8	886 ± 227

Letterewe and Loch a'Mhuilinn data from MacKenzie & Clifford (2008) and Clifford & Clifford (2008).

7.2 Evaluation of enclosures and browsing levels

The two enclosures have clearly been successful in helping to regenerate tree species and diversify woodland structure but the woodland inside the fences only occupies about 10% of the total woodland area at Ben Hope. The enclosures have thus shown the potential for significant improvements in woodland structure and biodiversity in the absence of browsing.

The enclosures were also benefiting the ground flora, understorey and shrub layer. With the complete absence of browsing and grazing thickets of birch and rowan had developed and epicormics and basal shoots had achieved their full potential. Honeysuckle was developing in Enclosure 2 and there was more luxuriant growth of herbs, grasses and dwarf shrub heaths in both enclosures. In complete contrast to the area outside of the enclosure where there was a distinct browseline, a grazed sward and the absence of understorey vegetation (Figure 20).

Outside of the enclosures grazing, trampling and dunging impacts on the ground vegetation and browsing of tree seedlings and epicormics were not high during the time of the survey. It was, however, evident that browsing levels on tree regeneration, epicormics and undershrubs were high prior to the current season, most probably in the winter or late summer when grasses and herbs begin to lose their nutritional benefits.

Several species such as holly, dog rose, hazel and rowan - the more shade tolerant components of a mature old growth phase, and an important part of the understorey re-initiation phase - were either rare or occasional in frequency levels. A browseline - where all lower branches had been browsed – was also apparent in many parts of the woodland. The lack of saplings and the poor development of undershrubs such as honeysuckle, which is a preferentially targeted species, is a clear indication that browsing by herbivores has reduced the diversity of the woodland habitat and suppressed the regeneration of most of the tree and shrub species.

It was not possible to ascertain whether deer or sheep were the main browsers since the extent of the trails and the signs of both deer and sheep were widespread in and around most unenclosed woodland areas. However, as deer density was moderately high, according to the last deer census, and there are only limited areas of woodland available as shelter in the glen, deer are likely to have a disproportionate impact on native woodland. Although there were signs of cattle in a few areas and roe deer were also observed it is likely that their impact was less significant.

Figure 20 *The contrast in tree regeneration, understorey and browseline between unenclosed woodland and Enclosure 2*

8. ASSESSMENT OF RISK TO CONSERVATION OBJECTIVES

The principal conservation objectives for the Ben Hope SSSI woodlands are to ensure that there is a continuous presence of mature trees across the majority of the site and that the biodiversity of the habitat is maintained in a favourable condition. In order to carry out these objectives sufficient established regeneration of all the relevant tree and shrub species must be distributed across the three woodland blocks. This will guarantee that:

- Minimum areas of mature woodland will be formed in the future.
- Future mature woodland will reflect the current distribution of the woodland.
- Future mature woodland areas will not be mutually isolated.

Many species have limited dispersal ability and in order to ensure continuity when the large old host trees die the regenerating replacement trees should be located nearby and of a similar size. This means therefore that it is important to have sufficient successful regeneration early enough so that the replacement trees reach maturity before the existing mature woodland becomes moribund. Such regeneration should be distributed across the site to prevent woodland fragmentation or loss of the current distribution of the existing habitat.

The conservation objectives, targets and achievements for the Ben Hope SSSI woodlands are summarised in Table 15. The present woodland profile survey has assisted in identifying areas where the objectives have in part been achieved and also in highlighting those areas where objectives have not yet been achieved.

The boundaries of the three woodland areas have not changed much since the late 19th century but the woodland canopy is considerably more open that it once was, especially at Leitir Mhuiseil (Figure 21). Apart from the pockets of birch regeneration that occurred at Merkan some years ago and more recently in the two enclosures there has been no significant amounts of internal regeneration in canopy gaps or any expansion of the native woodland adjacent to the existing boundaries. Thus the risks to the current extent and distribution of the birchwoods lie in the eventual increased fragmentation due to windthrow, natural mortality and the shrinkage of the woodland areas due to the lack of regeneration. As mature trees dominated the woodland and stocking densities were low, stand mortality can increase exponentially as old trees become vulnerable to disease and to disturbances such as windthrow (Peterken, 1996). When gaps in the canopy are created by windthrow or by the natural death of old trees and there are no immediate replacements regenerating in the gaps then the remaining woodland becomes vulnerable to premature demise should any unpredictable disturbance occur. The very open canopy of Leitir Mhuiseil makes it especially vulnerable to further deterioration in the short term and with a serious risk of long-term habitat loss. At the other sites there was insufficient regeneration of trees and shrubs to compensate for losses and avoid further deterioration in the habitat.

In addition to the poor structural diversity there was also limited species diversity in parts of the woodlands. Rowan, which should be a common component throughout the woods, was recorded as established trees in less than a third of the total plots and was not recorded in any plots at Merkan despite abundant seedlings. Seed trees for some species were actually quite rare. Holly, hazel and aspen were only recorded as established trees in two plots respectively and the willow species in one plot. The rock whitebeam seedling, which was recorded below its usual habitat on the crags, suggests it should be more widely distributed.

Figure 21 The open canopy and fragmented boundaries of Leitir Mhuiseil wood

The small stands of aspen possessed a very limited age range and there was a shortage of dead wood, which puts at risk the very specific and characteristic fauna and flora associated with aspen. There is therefore an urgent need to encourage successful regeneration before some of the less common species become rare.

The poor frequency levels of the preferentially browsed species such as bramble and honeysuckle were also an indication of the reduced diversity and the impact of sustained heavy grazing over many decades (Rodwell, 1991). Such species were rarely recorded in the plots, their abundance levels were very low and growth was generally suppressed to below the height of the ground flora. Bracken was recorded at high density in several plots and may be a local barrier to tree regeneration at a few locations but was not the main obstacle to woodland rejuvenation. Rowan seedlings were recorded in all the plots and hazel and birch in most of the plots containing dense bracken while within Enclosure 2 the successful growth of saplings of several tree species was not affected by bracken. It is unlikely that bracken would prevent the woodland achieving its conservation objectives, provided the level of herbivore browsing was reduced. Bracken control should not therefore be necessary.

Although the enclosures have been analysed separately in the relevant tables both are in fact a part of either Leitir Mhuisil or Creag na garbh-baid woodland areas. The fenced areas have been successful in improving structural and species diversity in the tree layer and in the ground flora. However, the enclosures by themselves will not provide sufficient measures to ensure the conservation objectives are achieved for the two woods. At Leitir Mhuiseil Enclosure 1 has only provided about 6% instead of the required 25% of 'young reproductive' life stages, does not reflect the current distribution of the woodland and could lead to mutually isolated woodland areas. Conservation objectives 1, 2 and 4 have thus not been achieved. Enclosure 1 does provide a single minimum 1 hectare patch size and therefore achieves part of conservation objective 2 but further patches elsewhere will be required to fully meet this target. At Creag na garbh-baid wood Enclosure 2 provided about 19% instead of the required 25% of 'young reproductive' life stages. It has contributed to an extensive patch of new regeneration extending to about 8 ha which benefited the northern part of the wood. However, the remaining woodland areas will continue to be at risk from the impact of browsing herbivores and the rarer components of the woodland - holly, hazel, aspen and rock whitebeam - will be at risk of local extinction.

Without reductions in browsing levels and an expansion in the area of established regeneration of all tree and shrub species the risk to the conservation of objectives will be continued canopy decline, which will lead to further fragmentation, isolation of stands and eventual possible disappearance of the woodland.

Table 15 *Summary of conservation objectives, targets and achievements for woodland continuity in Ben Hope SSSI*

	Conservation objective	Measurement	Target	Achievement & Risk			
				Leitir Mhuiseil	Creag na garbh-baid	Merkan	Enclosures
1	Ensure sufficient regeneration succeeding to maturity before the existing mature trees senesce and die	Area of woodland up to 'young reproductive' life stage, as a % of woodland	25% of each woodland block	Not achieved (Lack of established regeneration, very low stocking density & fragmented canopy will eventually lead to further losses of mature trees)	Not achieved (Lack of established regeneration & low stocking density will eventually lead to further losses of mature trees)	Part achieved (Has 14% 'young reproductive' – but insufficient to meet target, thus some loss of mature trees)	Achieved (Has sufficient "young reproductive' to replace mature trees)
		Life stage at which regeneration becomes necessary to ensure continuity	Regeneration initiated when woodland enters 'mature reproductive' phase	Not achieved (Mature trees are dominant & regeneration has been initiated but is being suppressed by browsing)	Not achieved (Mature trees are dominant & regeneration has been initiated but is being suppressed by browsing)	Not achieved (Mature trees are dominant & regeneration has been initiated but is being suppressed by browsing)	Achieved (Regeneration has been initiated)
2	Suitable minimum areas of future mature woodland are formed	Minimum patch size of regeneration	Most patches at least 1 hectare	Not achieved (Patches of established regeneration ≥ 1ha are absent. There is no future mature woodland being formed)	Not achieved (Patches of established regeneration ≥ 1ha are absent. There is no future mature woodland being formed)	Not achieved (Patches of established regeneration ≥ 1ha are absent. Recent future mature woodland is scarce)	Achieved (Patches of established regeneration > 1ha are present)
3	The future mature woodland will reflect the current distribution of the existing habitat	Assess life stages at 50 samples spread across the site	Evidence of successful regeneration pulses in adjacent sample plots	Not achieved (As there is no future mature woodland being formed across the site the current distribution of habitat is at risk)	Not achieved (As there is no future mature woodland being formed across the site the current distribution of habitat is at risk)	Part achieved (Some future mature woodland was formed 20 years ago but only reflects current distribution in two areas. Risk of mutual isolation)	Almost Achieved (Future mature woodland is being formed)
4	Future mature woodland areas will not be mutually isolated	Sample area sizes limited to ensure average distances between future old growth areas reflect dispersal ability of characteristic biodiversity					

9. CONCLUSIONS & RECOMMENDATIONS

In order to meet the conservation objectives and the targets for achieving favourable condition in the Ben Hope SSSI woodlands the herbivore browsing impacts will have to be reduced to a level that will improve and sustain the woodland habitat and its associated species. Some browsing is always beneficial in helping to maintain structural diversity and by the creation of open habitats but when high levels are sustained over many years the impact is invariably a negative one. The browsing evidence from the current survey has indicated that the majority of the impact occurred prior to the 2010 growing season as most of the current season's leader growth of seedlings, basal shoots and epicormics was unbrowsed at the time of the survey (June). This could suggest that browsing took place either during the previous winter months, in early spring 2010 or in the late summer or autumn of 2009. One can only speculate on the annual regularity of this or on the ratio of browsing between deer and sheep, but certainly a high incidence of browsing has happened with sufficient frequency to prevent any regeneration of seedlings and understorey shrubs throughout the unenclosed woodland areas.

Large herbivores generally have a very significant impact on the ecosystem function of natural woodland, particularly when predation is absent, and management of the deer population and other herbivores have different objectives. Deer, sheep and cattle selectively browse on tree seedlings, shrubs and herbs and over many decades the composition and structure of the vegetation changes as the understorey and shrub layer are lost. This has cascading and negative effects on birds, invertebrates and small mammals as nest sites, food plants and shelter become rare and predation risk is increased (Gill & Fuller, 2007). Then there is also the long-term impact on future generations of epiphytic lichens and bryophytes that are dependent on the continuity of old and veteran trees being present. The lack of the early successional stages of woodland, the rarity of some tree species, the absence of the understorey trees and shrubs and the restricted distribution of species such as bramble and honeysuckle confirm that the impact of herbivores on ecosystem structure and function has been considerable over many years. Since the complete range of life stages in the woodlands is not present there is effectively a break in the continuity of the woodland habitat. This has the potential to eliminate species that may be dependent on that continuity of habitat and some may be unable to return when the habitat is eventually restored (Peterken, 1996), for example the very specific and specialised invertebrate fauna of pole stage and mature aspen.

The success of the Ben Hope enclosures has shown the value of the removal of browsing pressure to aid woodland regeneration. The enclosures have also shown the potential of the ground flora to be more luxuriant compared to outside the fences where the same species were being suppressed by grazing. However, in the long term the complete elimination of all browsing may lead to the deterioration of small mosaics of flushed grassland habitats although these were very small scale areas in relation to the overall extent of the woodland. The ideal solution to ensure the long-term continuity of the Ben Hope woodlands and to achieve the site's conservation objectives would be to reduce browsing pressure to a level that will sustain habitats and maintain favourable condition across all woodland areas. Some browsing is generally necessary to aid in the structural diversity of the woodland and to help to maintain open ground habitats but parts of the woodland were very small, open and fragmented and may require an initial period of very minimal or zero browsing to restore species and structural diversity.

In order to reduce browsing impact and improve the woodland habitat at Ben Hope there are two possible management options that could be considered.

1. Deer control and the exclusion of livestock

The ideal permanent solution to restore the missing life stage classes and improve the habitat would be to increase the red deer cull and exclude sheep (and cattle) from the wood with the use of stock fencing. Although livestock numbers have already been reduced by the removal of significant numbers of sheep in 2009 it is too early to determine what impact this has had on the vegetation. The herbivore impact results from this survey have shown that browse levels have remained high. Deer control will therefore be required but how high the cull should be will be dependent on the response of the habitat and not on the absolute density or numbers of deer. Monitoring of browsing impact (using the marked tree seedlings) would thus be required in order to ascertain the response of the vegetation to the reduced browse levels. Vegetation monitoring should also focus on overall tree regeneration and key indicator plants (eg bramble and honeysuckle) and could either be by the use of fixed-point photography, by semi-quantitative assessments using the methodology of Thompson (2007) or use plot based quantitative measurements.

There are difficulties with this option because of the small amount of woodland within a very extensive area of moorland and hill ground, much of which is part of the same deer range. A reduction of the deer population that impacted on the woodland part of the SSSI would inevitably involve a reduction in numbers over a much wider area. The SSSI is under three different ownerships with different management objectives that include agriculture, forestry and sport shooting and the specific requirements of some of these may conflict with the conservation objectives of the site. For example, a drastic change in the red deer population might have serious consequences for the viability of sport shooting.

2. Complete exclusion with deer fencing

Erecting a deer proof fence around the perimeters of Merkan and Leitir Mhuiseil woods would be a feasible option and the minimum area needed to restore and safeguard the woodland habitat. A large enclosure is more beneficial to biodiversity and the proper functioning of the woodland ecosystem. The smallest patch of woodland habitat in which all the dynamic states persist, known as the Minimum Dynamic Area, is likely to be at least 20 hectares for mixed broadleaved woods in Scotland (Peterken *et al*, 1995) while Yapp (1980) also considered 20 ha to be the minimum area of woodland habitat that would be required for the full representation of breeding bird species. As the current areas of Merkan and Leitir Mhuiseil are each below 20 ha a perimeter fence incorporating some open ground is therefore considered to be the minimum viable single “patch” of woodland in terms of providing true woodland interior conditions and the full compliment of associated species.

Creag na garbh-baid, although larger in extent at about 42 ha, would also benefit from a perimeter fence around the site or at least on three sides and utilising cliffs to effect the upper barrier.

A system of rotational enclosures could be considered; although only at Creag na garbh-baid as the other sites are too small. The disadvantage of this option is that smaller deer-proof enclosures would be less satisfactory as this can create ‘islands’ of regeneration, exacerbate the deterioration of the unenclosed woodland and thereby lead to mutually isolated mature stands – conservation objectives 3 and 4 would not be fully achievable (Table 15). However, provided there was a corresponding increase in the deer cull, the woodland habitat did not deteriorate outside the enclosures, and monitoring of the vegetation was carried out in order to ascertain change, then this option is feasible.

There were also a number of very small patches of native woodland between the main blocks, particularly between Creag na garbh-baid and Merkan wood. It would be beneficial to biodiversity interests to improve the habitat links between the three woodland areas by encouraging regeneration between the woodlands, especially as there is already extensive birch regeneration outside the SSSI in the enclosure between the road and the shore of Loch Hope. As a first step an enclosure could be considered around some of these small fragments to prevent further deterioration and maintain the existing seed source.

The disadvantage of any enclosure is that it is still only a temporary measure designed to aid the replacement of the missing life stage classes and improve habitat and structural diversity. The woodland will continue to be in a dynamic state and if, at the end of the lifetime of a fence, the browsing pressure remains unchanged then either the fence will have to be replaced or a new long-term, more sustainable, strategy to reduce herbivore impact will be required.

Currently there is an urgent need to restore the missing life stage classes and improve the structural and species diversity of the Ben Hope woods, particularly at Leitir Mhuiseil. The lengthy period required to develop old growth characters and maintain the continuity of the mature and veteran trees means that management solutions need to be put in place as soon as possible. While another consideration is that climate change may bring further uncertainty as it is possible that an increased incidence of storms, drought or tree disease could accelerate windthrow and mortality (Fuller *et al*, 2007). As much of the open ground is suited to woodland expansion there is an opportunity to restore the long lost linkages between the fragments of woodland. There is also great potential for re-instating a natural treeline, for example above Merkan wood and in areas below the crags where trees are currently missing.

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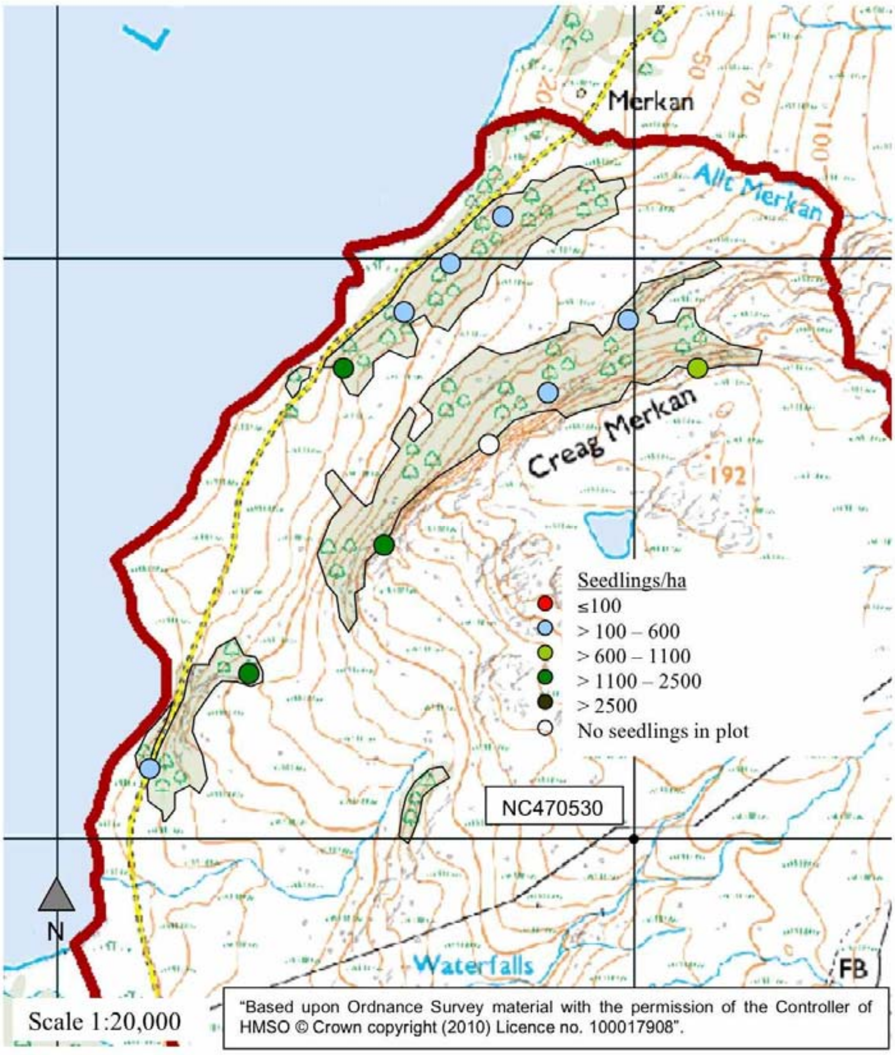

Figure 22 *Stocking densities of seedlings (1.1 & 1.2 life stage classes) within each of the 11 plots in Merkan wood*

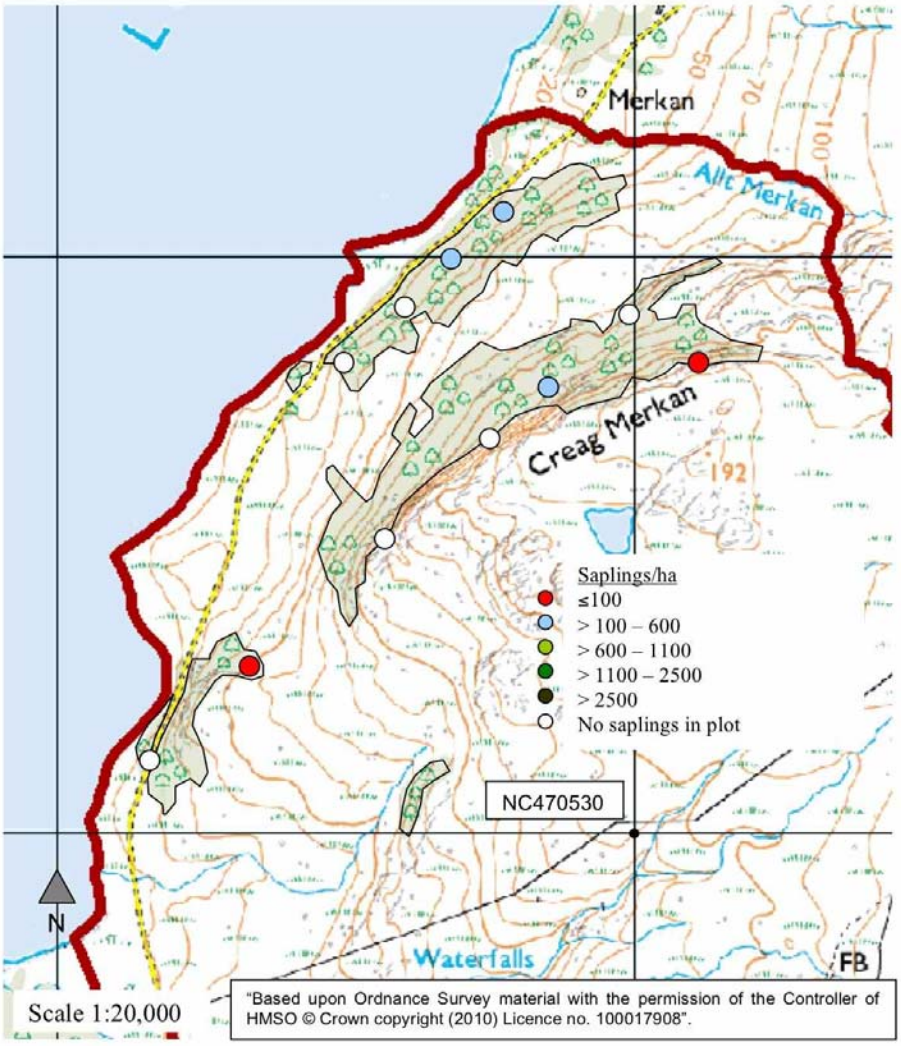

Figure 23 *Stocking densities of saplings (2.1 & 3.1 life stage classes) within each of the 11 plots in Merkan wood*

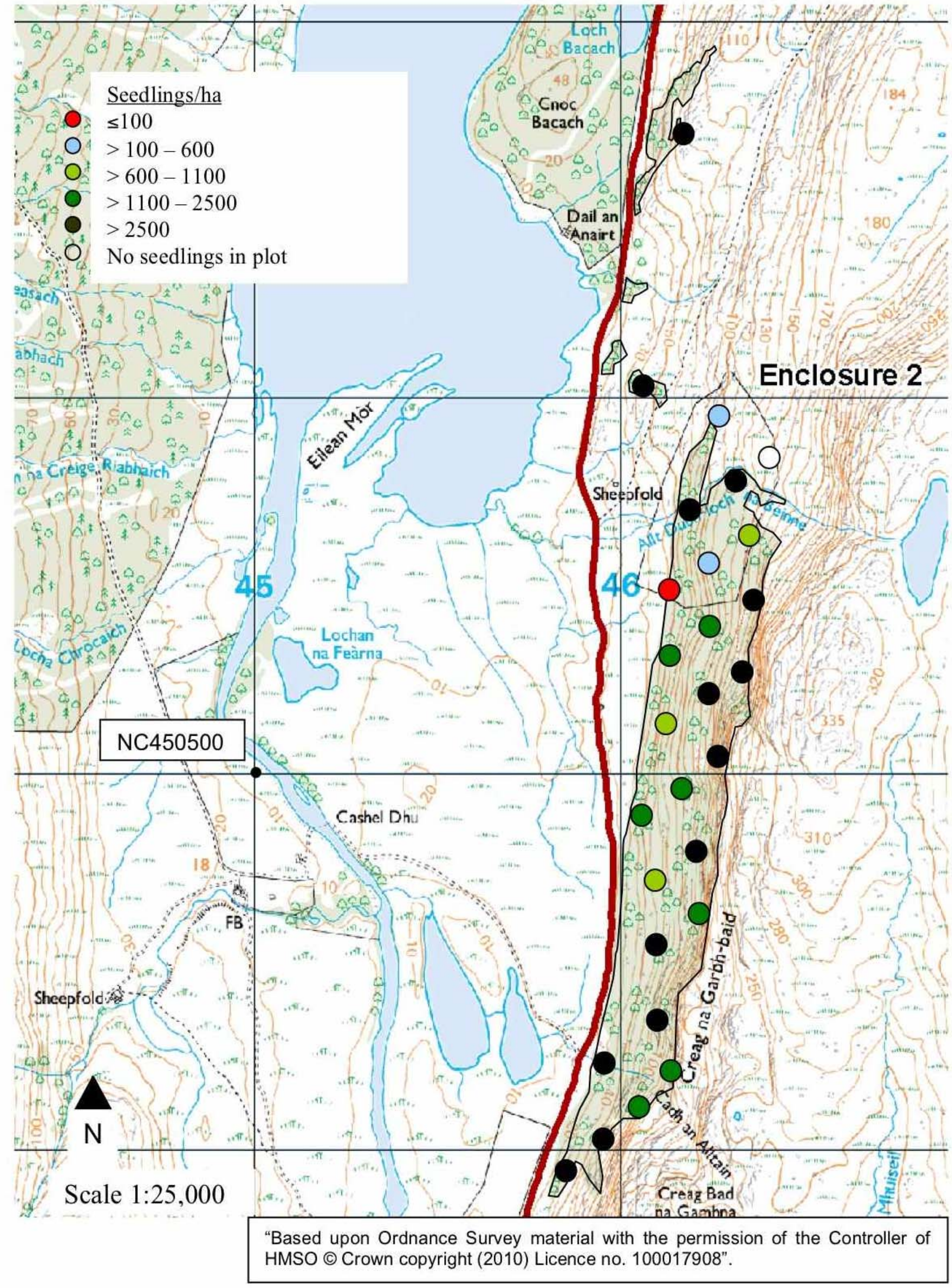

Figure 24 *Stocking densities of seedlings (1.1 & 1.2 life stage classes) within each of the 28 plots in Creag na garbh-baid wood (includes 7 plots in Enclosure 2)*

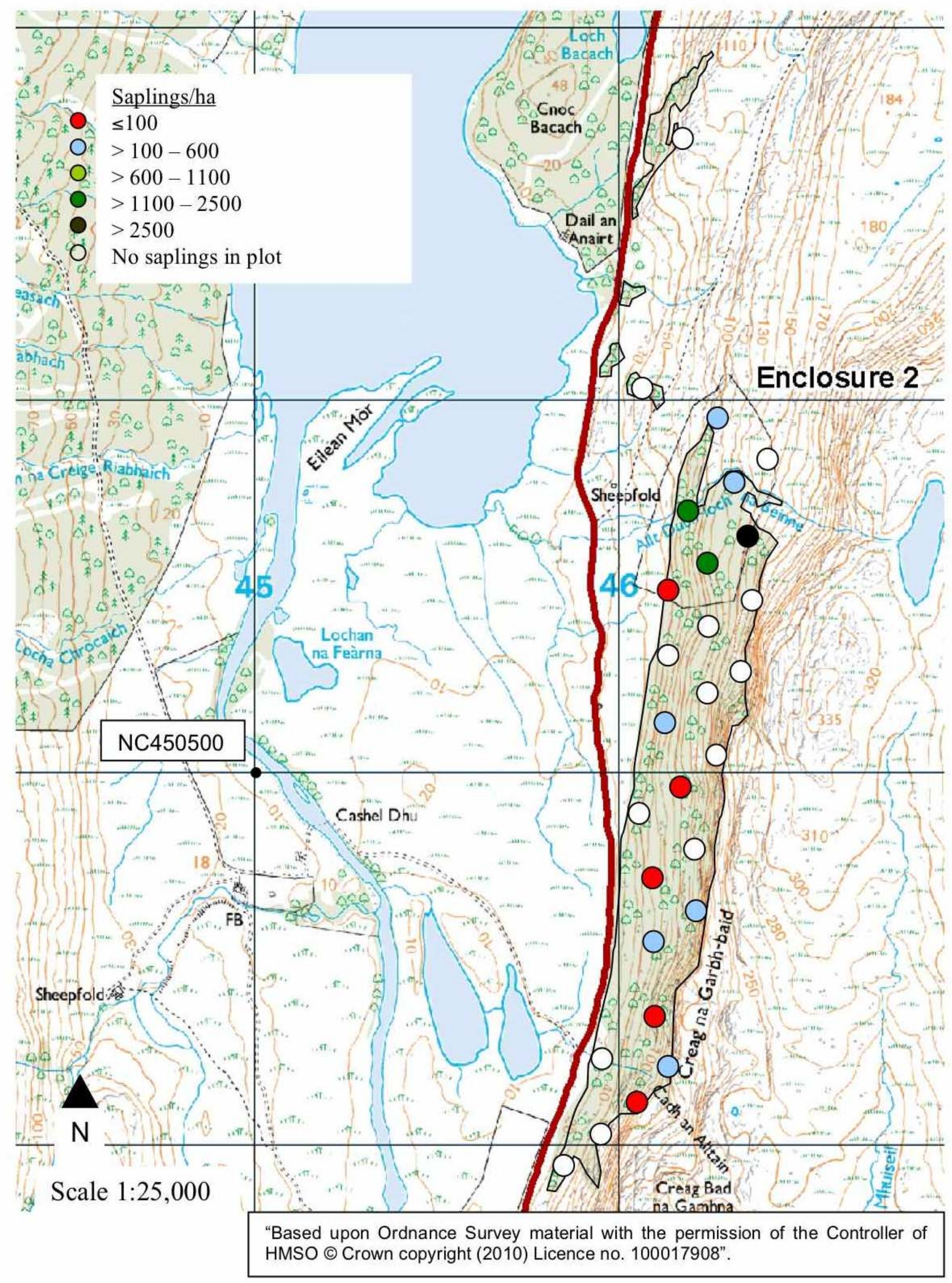

Figure 25 *Stocking densities of saplings (2.1 & 3.1 life stage classes) within each of the 28 plots in Creag na garbh-baid wood (includes 7 plots in Enclosure 2)*

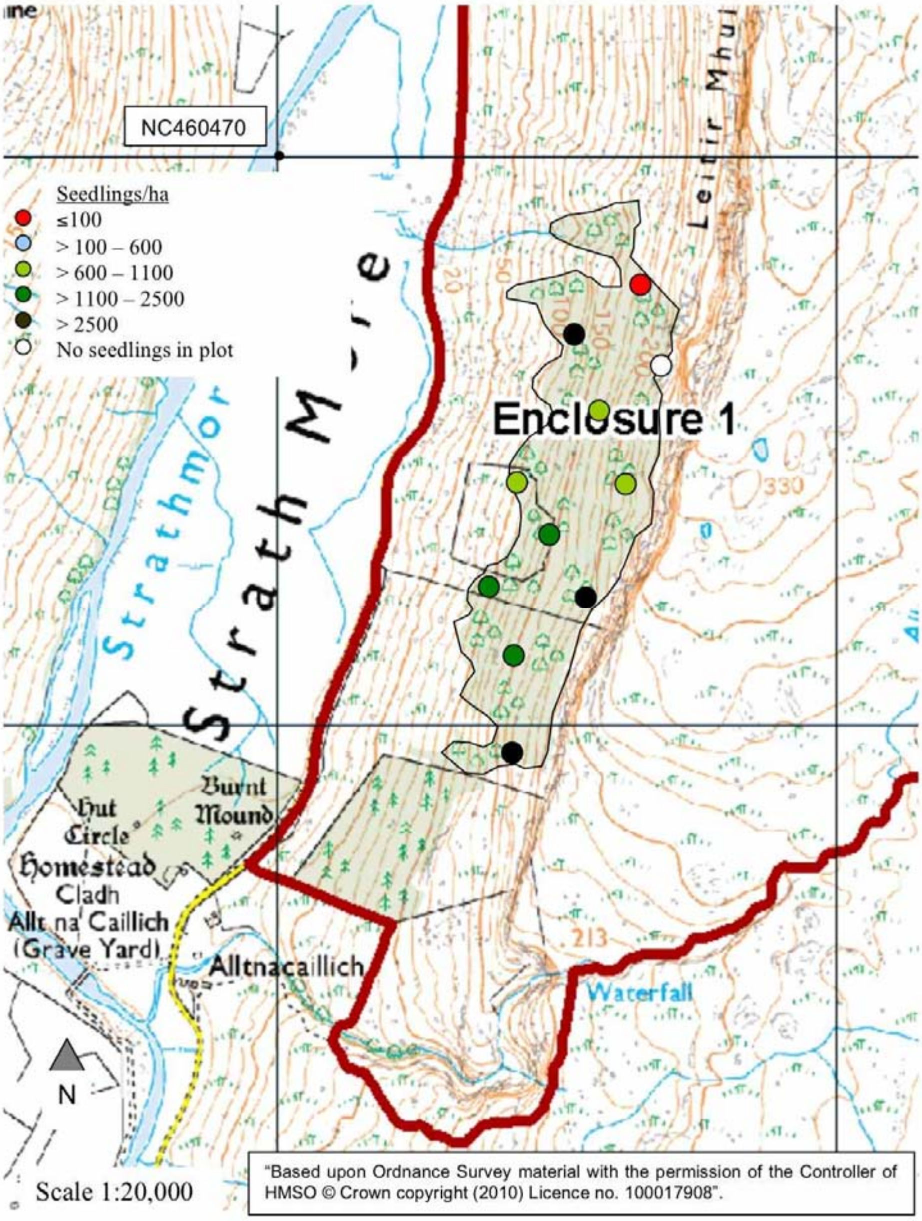

Figure 26 *Stocking densities of seedlings (1.1 & 1.2 life stage classes) within each of the 11 plots in Leitir Mhuiseil (includes 2 plots in Enclosure 1)*

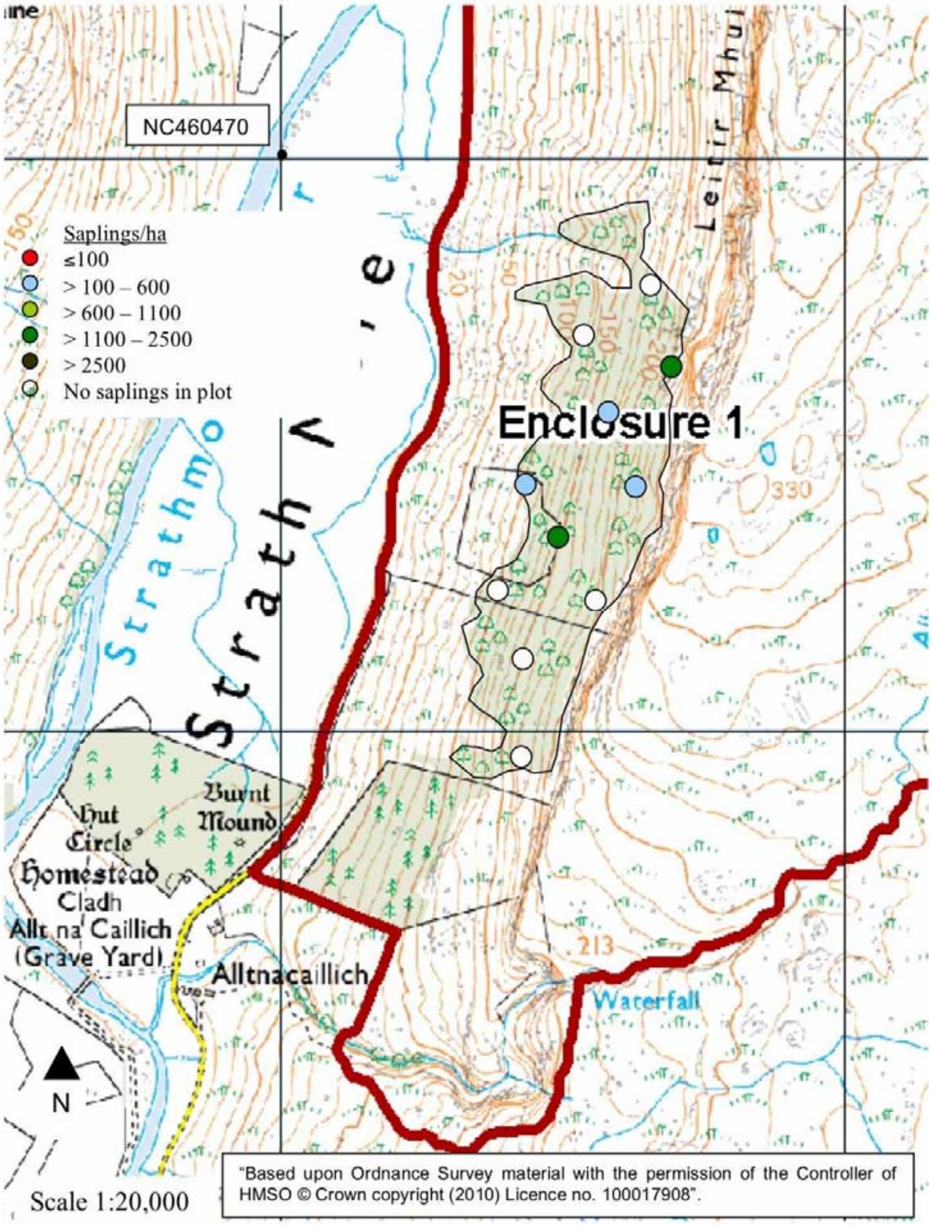

Figure 27 *Stocking densities of saplings (2.1 & 3.1 life stage classes) within each of the 11 plots in Leitir Mhuiseil (includes 2 plots in Enclosure 1)*

Appendix 1 Ben Hope plot data - location and habitats

Plot ID	Grid ref.	Photo ID	Direction of photo	Woodland HAP type	Woodland NVC type	Field layer	Notes
1	NC 46416,45950	benhope001.jpg	S	Upland birch	W11 & open heath	Grasses, Molinia, bracken, hard fern, Calluna, primrose	Leitir Mhuiseil. Woodland edge with very open canopy anc mature birch. Seedlings multi-stemmed and bushy.
2	NC 46519,46195	benhope002.jpg	N	Upland birch	W17	Calluna, Vaccinium, mosses, hard fern	Leitir Mhuiseil. Boulder field with very scattered mature bir Vaccinium well cropped ; flowers browsed.
3	NC 46411,46106	benhope003.jpg	W	Upland birch	wet heath	Calluna, Molinia	Leitir Mhuiseil. Open area of wet heath at woodland edge.
4	NC 46386,46241	benhope004.jpg	S	Wet wood	W4	Molinia with sparse Calluna	Leitir Mhuiseil. Very sparse canopy of mature birch
5	NC 46486,46335	benhope005.jpg	N	Upland birch	Heath	Calluna and sparse Molinia	Leitir Mhuiseil (Enclosed) Dense thickets of young birch a extensive patches of large seedlings.
6	NC 46593,46412	benhope006.jpg	WSW	Upland birch	Heath & scree	Calluna, Vaccinium, mosses	Leitir Mhuiseil. Scattered mature birch with occasional row boulder scree slope. Patchy saplings among scree.
7	NC 46604,46474	benhope007.jpg	SW	Upland birch	W17	Calluna, Vaccinium, mosses, boulders	Leitir Mhuiseil. Boulder scree with open canopy woodland rowan. Plot moved 80m to south due to cliffs and scree.
8	NC 46533,46529	benhope008.jpg	N	Upland birch	W11/W17	Calluna, Molinia, wood sorrel, Lonicera, bracken	Leitir Mhuiseil. Area of boulder scree with open canopy of and rowan.
9	NC 46415,46430	benhope009.jpg	SE	Blanket bog	Blanket bog	Molinia, Myrica, Calluna	Leitir Mhuiseil (Enclosed). Birch and rowan seedlings grov Molinia tussocks at edge of dense young birch and rowan

Appendix 1 Ben Hope plot data - location and habitats

Plot ID	Grid ref.	Photo ID	Direction of photo	Woodland HAP type	Woodland NVC type	Field layer	Notes
10	NC 46533,46694	benhope010.jpg	W	Upland birch	W11	Grasses, bracken, mosses, primrose	Leitir Mhuiseil. Open canopy of very mature birch.
11	NC 46634,46772	benhope011.jpg	S	heath & grassland	heath & grassland	Grasses, bracken, wood sorrel, bluebells etc	Leitir Mhuiseil. Woodland edge/very open and scattered tr trees in or near plot and seedlings uncommon.
12	NC 45837,48961	benhope012.jpg	NE	Upland birch	W17	Calluna, Molinia, sparse bracken	Creag na garbh-baid. Woodland edge/very scattered tree mature birch. Plot moved 14m to east away from bog.
13	NC 45932,49070	benhope013.jpg	N	Upland birch	W17	Molinia, bracken,rushes, bluebell, Vaccinium	Creag na garbh-baid. Canopy of mature birch. Pine marte
14	NC 46036,49154	benhope014.jpg	W	Upland birch	W17	Molinia, bracken, ferns, Calluna, Vaccinium	Creag na garbh-baid. Good canopy of trees with a range o including small stand of aspen just outside plot with sucke Rock whitebeam preset here.
15	NC 46094,49237	benhope015.jpg	N	Upland birch	W17	Calluna, Vaccinium, bracken, grasses, hard fern	Creag na garbh-baid. Rich diversity of tree species includi holly on cliffs. Plot moved 30m west due to cliff.
16							Creag na garbh-baid. Plot not surveyed - above cliff.
17	NC 46060,49368	benhope017.jpg	S	Upland birch	W17	Calluna, Vaccinium, bracken, Molinia	Creag na garbh-baid. Boulder field with canopy of stunted rowan.
18	NC 45928,49250	benhope018.jpg	SW	Upland birch	W17	Calluna, Vaccinium, Molinia, Myrica, bracken	Creag na garbh-baid. Woodland edge/blanket bog. Sparse birch.

Appendix 1 Ben Hope plot data - location and habitats

Plot ID	Grid ref.	Photo ID	Direction of photo	Woodland HAP type	Woodland NVC type	Field layer	Notes
19	NC 46067,49549	benhope019.jpg	SW	Upland birch	W17	Vaccinium, bracken, wood sorrel, mosses, boulders	Creag na garbh-baid. Good canopy of stunted birch and r Saplings on large boulders inaccessible to herbivores.
20	NC 46174,49644	benhope020.jpg	SSW	Upland birch	W17	Calluna, Vaccinium, bracken	Creag na garbh-baid. Patchy birch cover. Very steep and below cliffs at top of wood.
21							Creag na garbh-baid. Plot too inaccesible.
22	NC 46175,49836	benhope022.jpg	S	Upland birch	W17	Calluna, Vaccinium, bracken, wood sorrel, mossy boulders	Creag na garbh-baid. Very steep with small crags and clif birch with rowan.
23	NC 46071,49747	benhope023.jpg	S	Wet wood	W11/W4	Molinia, sparse bracken, Calluna, Lonicera	Creag na garbh-baid. Small wet area within mature birchw
24	NC 46044,49895	benhope024.jpg	S	Upland birch	W11	Grasses, bracken, wood sorrel, bluebell, pignut	Creag na garbh-baid. Good canopy of mature birch; no ur clear browseline
25	NC 46139,49986	benhope025.jpg	S	Upland birch	W17	Calluna, Vaccinium, bracken	Creag na garbh-baid. Open canopy of mature birch trees. Vaccinium well grazed; flowers browsed.
26	NC 46229,50071	benhope026.jpg	S	Upland birch	W11	Grasses, bracken, Calluna, bluebell, primrose, tormentil, heath bedstraw	Creag na garbh-baid. Very open and scattered mature bir rowan; some scree and rock.

Appendix 1 Ben Hope plot data - location and habitats

Plot ID	Grid ref.	Photo ID	Direction of photo	Woodland HAP type	Woodland NVC type	Field layer	Notes
27	NC 46297,50334	benhope027.jpg	NE	Upland birch	W17	Calluna, Vaccinium, moss, boulder scree	Creag na garbh-baid. Very open and scattered mature bi unstable boulder scree. Vaccinium heavily grazed. Plot m NW due to scree.
28	NC 46239,50239	benhope028.jpg	E	Upland birch	W17	Vaccinium, bracken, wood sorrel, tormentil, bluebell, mosses, boulders	Creag na garbh-baid. Mature birch with rowan growing an covered boulders. Vaccinium flowers grazed.
29	NC 46119,50142	benhope029.jpg	N	Upland birch	W11/W17	Bracken, Molinia, Vaccinium	Creag na garbh-baid. Open canopy of mature birch. Birch cliff.
30	NC 46139,50324	benhope030.jpg	N	Upland birch	W11	Bracken, rocks, moss, wood sorrel, hard fern	Creag na garbh-baid. Mature birch canopy at lower edge Dense bracken though rowan seedlings common.
31	NC 46230,50383	benhope031.jpg	W	Upland birch	W11	Bracken, grasses, wood sorrel, primrose, bluebell, Vaccinium, beech fern	Creag na garbh-baid. Open canopy of mature birch. Patch bracken but birch, rowan and hazel seedlings common. P m to south to avoid enclosure fence.
32	NC 46345,50492	benhope032.jpg	NNE	Upland birch	W11	Molinia, wood sorrel, grasses, Vaccinium, moss, sparse bracken	Creag na garbh-baid. Open canopy of mature birch adjac scree.
33	NC 46332,50676	benhope033.jpg	E	Upland birch	W11	Grasses, bracken, bluebell, yellow pimpernell, sparse Calluna	Creag na garbh-baid (Enclosed). Scattered mature birch a dense thickets of birch and rowan. Well developed groun shoots and understorey. No browseline here.

Appendix 1 Ben Hope plot data - location and habitats

Plot ID	Grid ref.	Photo ID	Direction of photo	Woodland HAP type	Woodland NVC type	Field layer	Notes
34	NC 46131,50509	benhope034.jpg	SE	Bog	Bog	Molinia, Myrica, Calluna, Phragmites	Creag na garbh-baid (Enclosed). Flushed Molinia - Myrica to woodland edge of dense birch and rowan. A few birch seedlings present.
35	NC 46184,50572	benhope035.jpg	NNE	Upland birch	W11	Bracken, bluebells, Lonicera,	Creag na garbh-baid (Enclosed). Scattered mature birch a saplings of birch, rowan, hazel and dog rose. Honeysuckle Plot moved west due to cliff.
36	NC 46172,50721	benhope036.jpg	SSW	Upland birch	W11/W17	Calluna, Vaccinium, bracken, grasses	Creag na garbh-baid (Enclosed). Scattered mature birch w rowan and birch saplings. Holly present.
37	NC 46274,50809	benhope037.jpg	SW	Upland birch	Heath	Calluna, Molinia	Creag na garbh-baid (Enclosed). Woodland edge with ext regeneration on Calluna heath. Large holly next to burn, a crags above plot.
38	NC 46378,50892	benhope038.jpg	N	Blanket bog	Blanket bog	Calluna, Molinia, Myrica	Creag na garbh-baid (Enclosed). No trees or seedlings; ur tree growth except Eared willowand some stunted birch w present out of plot.
39	NC 46251,50961	benhope039.jpg	W	Upland birch	Blanket bog	Calluna, Molinia, Myrica	Creag na garbh-baid (Enclosed). Adjacent to woodland ec birch thickets. Bog with scattered birch, rowan and Eared edge of bog.
40	NC 46037,51047	benhope040.jpg	W	Upland birch	W11	Grasses, sparse bracken, wood sorrel, bluebell, heath bedstraw, primrose, pignut	Creag na garbh-baid. Open canopy of mature birch. No ur Clear browseline. Small birch thicket out of plot.
41	NC 46126,51728	benhope041.jpg	S	Upland birch	W11	Moss, Molinia, wood sorrel, bracken	Creag na garbh-baid. Mature birch near woodland edge.
42	NC 47073,53818	benhope042.jpg	W	Upland birch	W11	Grasses, bracken, ferns, wood sorrel, Calluna, foxglove	Merkan. Patchy canopy of mature birch on steep slope.

Appendix 1 Ben Hope plot data - location and habitats

Plot ID	Grid ref.	Photo ID	Direction of photo	Woodland HAP type	Woodland NVC type	Field layer	Notes
43	NC 46987,53904	benhope043.jpg	ENE	Upland birch	W11	Bracken, grasses, Molinia, wood sorrel, rushes	Merkan. Very open birch canopy at lower woodland edge.
44	NC 46836,53778	benhope044.jpg	SW	Upland birch	W11/W4	Molinia, bracken, wood sorrel, moss	Merkan. Moderately good canopy of mature birch. Seedli saplings severely browsed.
45	NC 46741,53685	benhope045.jpg	ENE	Upland birch	W11	Grasses, wood sorrel, bracken, bluebell, hard fern	Merkan. Moderately open canopy of mature birch. No see adjacent to plot.
46	NC 46556,53539	benhope046.jpg	NE	Upland birch	W11	Grasses, bracken, wood sorrel, primrose, bluebell, lemon scented fern	Merkan. Mature canopy of birch below crags with aspen. I 30m to NW due to crag.
47	NC 46328,53286	benhope047.jpg	SSW	Upland birch	W11	Bracken, grasses, wood sorrel, bluebell	Merkan. Mature birch and rowan canopy. Browseline pres
48	NC 46149,53124	benhope048.jpg	S	Upland birch	W11	Dense bracken, wood sorrel, bluebell	Merkan. Mature birch and rowan canopy. Seedlings of rov present but rare in dense bracken.

Appendix 1 Ben Hope plot data - location and habitats

Plot ID	Grid ref.	Photo ID	Direction of photo	Woodland HAP type	Woodland NVC type	Field layer	Notes
49	NC 46781,54094	benhope049.jpg	S	Upland birch	W4	Molinia, Myrica, moss	Merkan. Wet area with mature multi-stemmed birch trees a branched and browsed large seedlings.
50	NC 46677,54001	benhope050.jpg	S	Upland birch	W11	Dense bracken, wood sorrel, bluebell, hard fern	Merkan. Open canopy of mature birch over dense bracken occur but rare under bracken.
51	NC 46585,53905	benhope051.jpg	NE	Upland birch	W11	Bracken, wood sorrel, bluebell, hard fern, primrose	Merkan. Open canopy of mature birch over dense bracken rowan seedlings under bracken.
52	NC 46483,53812	benhope052.jpg	SW	Upland birch	W11	Bracken, grasses, ferns, wood sorrel, bluebell	Merkan. Very open canopy of stunted birch.

APPENDIX 2 Ben Hope plot data - Species Life stage class and stocking density per plot (0.02 ha)

Plot ID	Tree species	1.1	1.2	2.1	3.1	3.2	3.3	4.1	5.1	5.2	6.1	7.1	7.2	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2
1	birch	38	106				1											
	rowan	20	24															
	eared willow		2															
2	birch	6	12					2										
	rowan	31	30															
3	birch		31															
	rowan	7	4															
	eared willow		4															
	Salix spp.	4																
4	birch	10	5					3										
	rowan	6	6															
5	birch		26	18														
	rowan		10	7														
6	birch		4	9														
	rowan	5	4				2		1									
7	birch			4			2	1				1						
	rowan			23			2								1	1		
8	birch	1	8	3			2	1			1	1						
	rowan	17	2	6	1						1							
	goat willow							3										
9	birch	1	4															
	rowan	1	5	3														
	grey willow		1															
10	birch	71	12										3					
	rowan	10																
11	rowan	1																
12	birch	5																
	rowan	2																
	aspen	30	24															
13	birch		14				1	4										
	rowan	33	29															
14	birch		3	1			2	6	1									3

APPENDIX 2 Ben Hope plot data - Species Life stage class and stocking density per plot (0.02 ha)

Plot ID	Tree species	1.1	1.2	2.1	3.1	3.2	3.3	4.1	5.1	5.2	6.1	7.1	7.2	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2
	rowan	14	20		1													
	goat willow				1													
	grey willow		1															
	holly				1													
	rock whitebeam		1															
15	birch	2	1				3	4										
	rowan	23	5		5		7											
	aspen				2		1											
	holly						1											
	hazel	1					10											
	Rosa spp.			1	1													
17	birch		5	1			1	4										
	rowan	43	12						1									
18	birch	28	14				1										1	1
	rowan	24	1															
	holly	1																
19	birch	1	4	1			4	8		1								2
	rowan	29	34	2			1	1	1	2								
20	birch	1	12	3				3			2	1						
	rowan	26	8						1									
22	birch	25	1									1	1					
	rowan	42	2				2		1									
	hazel	2																
23	birch						1	6										
	rowan	8	3	1									1					
	holly	1	1	1														
24	birch						1	11					2				1	
	rowan	19	2															

APPENDIX 2 Ben Hope plot data - Species Life stage class and stocking density per plot (0.02 ha)

Plot ID	Tree species	1.1	1.2	2.1	3.1	3.2	3.3	4.1	5.1	5.2	6.1	7.1	7.2	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2
	hazel	3																
25	birch	2	1				5	3										
	rowan	30	3															
	holly			1														
	hazel	2																
26	birch	34	4					1										
	rowan	35	1						1									
27	birch	17						1										1
	rowan	400	5							2								
28	birch	2	1					2					2			1		
	rowan	120	2					1	1				4			1		
29	birch			1	1		6	1										
	rowan	16	2				1											
	hazel			1														
30	birch							9										
	rowan	28	16										1					
31	birch		2					3										
	rowan	13	5															
	hazel	5	1															
32	birch	12						2					1					
	rowan	40																
	hazel	2																
33	birch		3	4	4	1		9					1					
	rowan	4	5	28	45	3	1											
34	birch		1															
	rowan		1	1														
35	birch												1					
	rowan		3	16	7	2												
	hazel			3				4										
	Rosa spp.		1	1														
36	birch		4	1				3					1					
	rowan	4	57	30	1													

APPENDIX 2 Ben Hope plot data - Species Life stage class and stocking density per plot (0.02 ha)

Plot ID	Tree species	1.1	1.2	2.1	3.1	3.2	3.3	4.1	5.1	5.2	6.1	7.1	7.2	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2
	holly							2										
37	birch	2	89	5														
	rowan	5	3															
	eared willow		2															
38	none																	
39	birch	2		5	1													
	rowan			2														
	eared willow	1	3															
40	birch	100	10					2	1						1	1		
	rowan	5																
41	birch	100						9			1		1					2
	rowan	400																
42	birch	6	1	1			2											1
43	birch	2						3			1		1	1	1			
	rowan	5																
44	birch		1	7		2	6	8					1					2
	rowan	4																
45	birch							11					10					
46	birch						3	3			3		2		1		1	
	aspen	27	5				2											
47	birch				1		7	8					7					
	rowan	39																
48	birch							4										
	rowan	1																
	hazel	1																
49	birch	1	2	6			13	11										
	rowan	5	2															
50	birch	1			2		3	5					2				1	
	rowan	1																
51	birch						1	1			6							
	rowan	7																
52	birch	10	3				2		2								1	

APPENDIX 2 Ben Hope plot data - Species Life stage class and stocking density per plot (0.02 ha)

Plot ID	Tree species	1.1	1.2	2.1	3.1	3.2	3.3	4.1	5.1	5.2	6.1	7.1	7.2	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2
	rowan	13																
	goat willow	1																

APPENDIX 3 HERBIVORE IMPACT ON GROUND FLORA AND FIELD LAYER OF BEN HOPE SSSI WOODLAND (PLOT DATA)

Plot ID	Grazing & browsing impact on ground flora & sub-shrubs	Trampling impact	Dunging impact	Evidence of herbivore type
1	Medium	None	Medium	Sheep & red deer dung; 3 red seen
2	Medium	None	Medium	Red deer dung
3	Low	None	None	
4	Low	None	Low	Red deer dung
6	Low	None	Low	Red deer dung
7	Low	None	Medium	Red deer dung; 1 red seen
8	Low	None	Low	Red deer dung
10	Low	None	Low	Red deer dung
11	Low	None	Low	Red deer dung
12	Low	None	Medium	Sheep dung
13	Low	Low	None	Cattle tracks
14	Low	None	Medium	Sheep & red deer dung
15	Low	None	Low	Red deer dung
17	Low	None	Low	Red deer dung
18	Low	Medium	High	Sheep & cattle dung
19	Low	None	None	
20	Low	None	None	
22	Low	None	None	
23	Low	None	None	
24	Low	None	Low	Red deer dung
25	Medium	Low	Medium	Red deer dung
26	Low	None	Low	Red deer dung
27	Medium	None	Low	Red deer dung
28	Medium	Low	Low	Red deer dung
29	Low	None	Low	Red deer dung
30	Low	None	None	
31	Low	None	Low	Red deer dung
32	Medium	Medium	Medium	Red deer dung
40	Low	none	Low	Red deer dung
41	Medium	Low	Medium	Red deer dung
42	Low	None	Low	Red & roe deer dung
43	Low	None	Low	Sheep dung
44	Low	None	Medium	Sheep & red deer dung
45	Low	Low	Low	Sheep dung; red deer tracks
46	Low	None	Low	Sheep dung
47	Low	None	None	
48	Low	None	None	
49	Low	None	Low	Sheep dung
50	Low	None	Low	Sheep wool
51	Low	None	None	
52	Low	None	None	

Excludes plots within Enclosures – no evidence of herbivore impacts.

APPENDIX 4 LIFE STAGE CLASSES FOR BROADLEAVED TREES

Life Stage:	Tree sub-class:	Descriptor:	Stand type/conditions:	Biodiversity characteristics:	Stand process:
1. Seedling	1.1 Small seedling	All seedlings **at or below the predominant field layer vegetation height,** Includes newly germinated seedlings of the previous year	Open woodland, gaps, woodland edges and under canopy	Generally high biodiversity in sheltered canopy gaps with increased woodland edge habitat, particularly birds and Lepidoptera. Biodiversity generally reduced on exposed woodland edges.	**Stand initiation/regeneration**
	1.2 Large seedling	Seedlings above the field layer vegetation height, **but still < 1.3m tall**	Open woodland, gaps & woodland edges		
2. Juvenile non-reproductive	2.1 Small sapling	Small saplings **1.3m - 3m height, and < 7 cm dbh;** not yet producing **significant** quantities of seed	Both dense drifts & scattered individuals in canopy gaps & at stand edges		
3. Young reproductive	3.1 Large sapling	Large saplings **3m - 5m in height but DBH < 7 cm.** Birch will usually be seed-producing but other species may not yet.	May be dense patches but with branches of established trees not yet fully interlocking, or may be small patches or scattered individuals		
	3.2 Young reproductive - thicket	Seed-producing small trees **(> 1.3 m tall and > 7 cm dbh), usually over 5m in height** where canopy has closed **DBH range 7 – 20 cm**	Dense stands & patches with fully interlocking branches	1. Low light levels, declining biodiversity; 2. some deadwood formation through self thinning	**Stem exclusion**
	3.3 Young reproductive – non thicket		Lone trees & small groups in canopy gaps & at stand edges		
4. Mature reproductive	4.1 Mature	Seed-producing trees (> 1.3 m tall and > 7 cm dbh) **usually over 5m height & >20cm DBH**, not falling into the preceding or following classes May be **canopy die-back up to 10%** due to competition for light	1. Scattered open-crowned individuals <u>or</u> 2. closer grown stands, sometimes around "pioneer trees"	1. Some deadwood habitat from self-thinning; 2. Canopy provides nesting & feeding sites for birds & invertebrates; 3. Mosses, lichens on bark (but greater development on overmature trees	**Dynamic Equilibrium**
5. Over-mature	5.1 Early canopy decline	Trees **usually over 5m**; **Canopy 10-20% dead** with reduced seed production [Any reduction likely to be proportional to crown size]	Usually more open conditions, where wind has begun to de-limb trees	1. Increase in standing and fallen deadwood; 2. Torn branches & broken limbs; 3. rot-holes developing on tree & saprophytic fungi fruiting 4. Crown dieback → increased light to bole → more opportunities for epiphytes!	**Canopy break-up**

6. Senescent post-reproductive	6.1 Heavy canopy decline	Trees **usually over 5m** height, with spreading canopy much ravaged by wind & pathogens; **Canopy 50-99% dead** with markedly reduced seed production proportional to loss of canopy	Often [but not always] very open stand with large canopy gaps, with or without recent regeneration	As above sub-class with significant increase in standing deadwood habitat on each tree	
7. Phoenix	7.1 Main bole dead	Fallen but still rooted tree, has sent up vertical shoots from trunk. The new trunks may have established their own root systems by now and the original tree died off.	Open stands – phoenixing generally occurs when trees fall in open or scattered canopy.	Can allow a certain amount of vegetative regeneration to occur even with heavy grazing, but can't be relied on to maintain woodland cover.	
	7.2 Main bole procumbent	Fallen but still rooted tree, sending up vertical shoots from trunk.			
8. Dead	8.1 Standing dead		Often degrading fragmented stands of large old trees with significant windthrow; but: includes smaller specimens resulting from competitive exclusion in dense stands and: Steep scree slopes with a mobile substrate where trees have been uprooted	Bio-diversity likely to be high for recently dead trees [bark still on tree] with larger stem diameters, which are more typical of fragmented open stands. Birch rots very quickly, so dead wood volumes are likely to be relatively low compared with other upland woodland types.	**Death, decay and nutrient cycling**
	8.2 Fallen dead				
	8.3 Stumps with no fallen trunk/bole evident				

From: Clifford, T., Collier, L., & Clifford, B. (2004) *Woodland Profile Survey, Zone 1 - Feshie Catchment Section 7 Control Agreement Area.* A Report to the Deer Commission for Scotland. Inverness.

Appendix 5 Guidance indicators for browsing, trampling and dunging impacts on ground flora

Assessment	Impact of grazing
High	Absence of shrubs Browsing induced topiary effects of remaining shrubs. Browse line on mature trees. Ground vegetation <10 cm tall, mostly grasses and mosses. All herbs obviously heavily cropped, non-flowering. Only *Luzula* is likely to be abundant.
Moderate	Patchy shrubs showing evidence of pruning or a browse line. Ground vegetation to 30 cm, as a mixture of grasses, herbs or heaths. Localised close-cropped lawns where there is a concentration of grazing. Some herbs partially cropped or ungrazed, sparsely flowering.
Low or none	Well developed shrub layer without obvious browse line. Lush ground vegetation, where shrub layer is not too dense (i.e. 30-50% cover), dominated by grazing sensitive species. Ground mosses uncommon. Many herbs only partially cropped or ungrazed. Some species abundant and flowering.

Assessment	Impact of trampling and dunging
High	Abundant dung from grazing animals, evidence of tracks and poaching.
Moderate	Patches of bare soil rare and small scattered dung present.
Low or none	Few signs of trampling or dung.

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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

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