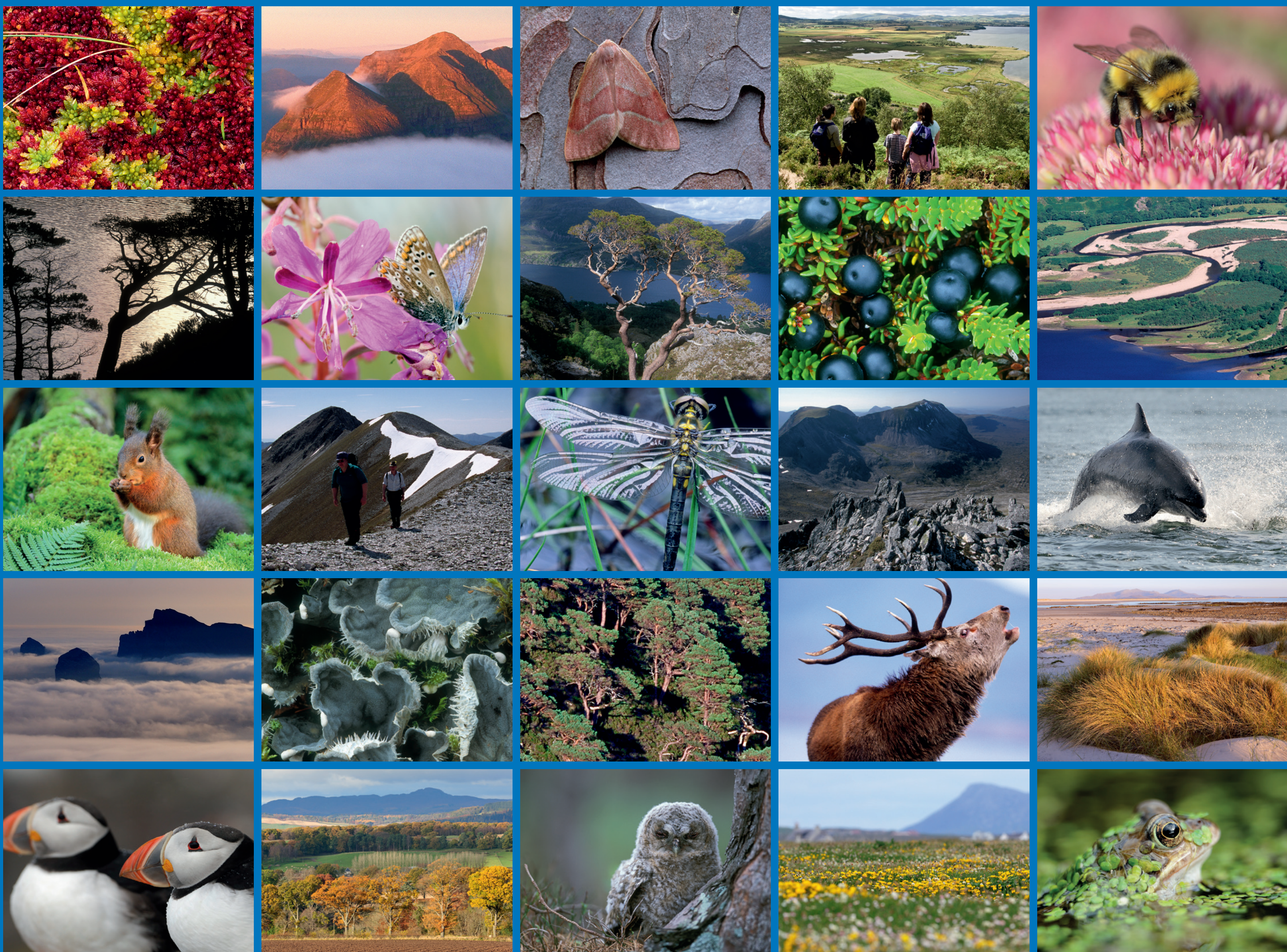
Scottish Natural Heritage
Commissioned Report No. 968

Herbivore Impact Assessment of Ardvar Woodlands SSSI woodland features



C O M M I S S I O N E D   R E P O R T

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COMMISSIONED REPORT

Summary

Herbivore Impact Assessment of Ardvar Woodlands SSSI woodland features

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Keywords

Ardvar; woodland; deer browsing; regeneration.

Background

This survey was commissioned by SNH to provide an assessment of the woodland condition in the Ardvar Woodlands SSSI. In September 2016 a field-based assessment of 122 plots covering 1% of the total woodland area was carried out. The assessment covered tree and shrub seedlings and saplings (i.e. smaller and larger regeneration), woodland structure and overall herbivore impact.

Main findings

- Seedlings and saplings occur across the SSSI at an average of 1,578 stems per hectare, although this varies widely between sample plots. However it is unlikely that the differences in stocking between the woodland compartments is statistically significant.
- 51% of all seedlings and saplings were browsed in the last 12 months, compared to 81%, in a similar but not identical survey in 2007. The majority (82%) of large seedlings had been browsed, inhibiting recruitment into the next life stage.
- Small seedlings occur most frequently (70%), with lower densities of larger seedlings (22%) and especially saplings (8%).
- The diversity of tree species regenerating within the woodland is low. Nearly all the regeneration is either birch (43%) or rowan (49%), with little regeneration of hazel, holly, willow and aspen. Shrubs, and other woodland plants known to be preferentially browsed by deer (e.g. bramble, blaeberry and honeysuckle) are widespread but infrequent, and their abundance is limited by browsing.
- The survey evidence shows that red deer are the dominant herbivore in the woodlands, and likely to be the cause of the current browsing impacts on the trees and shrubs.
- Other factors with the potential to affect or limit woodland regeneration were examined. This showed plots with dense woodland or bracken canopy and/or waterlogging had on average half as many seedlings as plots with no limiting factors. Whilst there are fewer seedlings in plots with limiting factors, substantial numbers are still present and the principle factor preventing their growth is considered to be browsing.

What these findings mean

The number of seedlings is encouraging, indicating the potential for woodland regeneration that exists on Ardvar. However, the high density of seedlings does not continue through to sapling stage and this is a threat to the long-term continuity of the woodland. There is some evidence of a reduction in browsing due to increased deer management in recent years. Nevertheless, the lower density of larger seedlings and saplings indicates a browsing impact of deer which is constraining woodland recovery. A good comparison is with the similar nearby woodland at Loch a' Mhuilinn, where deer numbers are low. Here, seedling numbers are similar to Ardvar, but there are 15 times more saplings, showing how regeneration can progress under lower browsing levels. The impact of selective browsing on more palatable trees, shrubs and other plants is preventing the development of the rich structure and understorey that is natural in these woodlands.

Overall, this survey shows that recovery of the potentially rich diversity of the Ardvar woodlands is being largely prevented by current browsing impacts. It also indicates that adequate reductions in browsing pressure will reverse this situation.

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Acknowledgements

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1. INTRODUCTION

The Ardvar native woodlands are located on the oceanic western rim of Highland Scotland between Drumbeg and Unapool in Sutherland. They fall largely within the Ardvar Woodlands Site of Special Scientific Interest (SSSI) which extends to just over 731ha, and there are areas of similar woodland contiguous with that in the SSSI, forming a wider woodland network. Along with the Loch a' Mhuilinn native woodland to the north, they comprise the Ardvar and Loch a' Mhuilinn Woodlands Special Area of Conservation (SAC).

There is a disjunct distribution of native birch-dominated woodland within and adjacent to the SSSI, in three separate and geographically discrete catchments (1. Nedd/Gleann Learaig; 2. Loch Ardbhair/ Gleann Ardbhair/ Clais Ardbhair; and 3. Kerrachar-Unapool), and oak is present within the site at low density in a few areas. A small area of more mixed deciduous woodland with a rich ground flora occurs in a steep gorge on nutrient-rich rock in the Creag an Spardain part of the site. Together, these woods represent relatively undisturbed relicts of the previously more extensive north-western forests. As such, they have a particularly high nature conservation and scenic value, and are nationally important.

The ownership of the site is shared between four different parties, from west to east, North Assynt Estate, Ardvar Estate, Rientraid Estate and Quinag Estate. Those parts of the SSSI owned by North Assynt and Quinag Estates form part of the wider Nedd Common Grazings in the west and the Unapool Common Grazings in the east.

Little is known of the past history and utilisation of the woodland, although the introduction of wide-scale sheep farming and associated burning following local clearances under the Earls of Sutherland around 1829, most probably resulted in a contraction of the woodland area and possibly some loss of diversity. The "Ancient Woodland Inventory" indicates that the majority of the current woodland is considered to be of "ancient semi-natural origin", suggesting that there has been a continuous history of woodland on the site since sometime before the 1750s.

Sheep were removed from the Ardvar Estate in the early 1970s, and there are scattered small stands of thicket birch approximately 40-45 years old, indicating past localised reductions in browsing/ grazing pressure at this time. Additionally there are small scattered stands of thicket birch approximately 20-25 years old in some areas indicating further localised reductions in browsing pressure during the early 1990s.

Notwithstanding these positive measures, when the condition of the woodland was assessed in 2004 as part of SNH's cyclical monitoring of SSSI sites, it was recorded as being in "Unfavourable Declining" condition due to the canopy of mature woodland being fragmented in many areas and below 50% cover, the dearth of saplings of all species throughout the woodland, and the suppression of the woodland understorey and field layer, as a result of the impacts from browsing and grazing.

More recently deer fenced woodland enclosures have been established at Dubh Leitir (Gleann Ardbhair) and in the Torgawn area (11.5ha) under a Woodland Grant Scheme in 2000, and on Rientraid Estate through the Scottish Forestry Grant Scheme in 2004 (4ha). A Woodland Profile and Herbivore Impact Survey in 2007 (Beck, 2009) concluded that the long-term continuity of both the current woodland extent and structure was threatened by high levels of deer browsing, and consequently a Section 7 Deer Control Agreement was concluded with Ardvar Estate and the John Muir Trust in 2008, to reduce deer occupancy of the woodlands to a level which would allow woodland regeneration.

2. OBJECTIVES

The primary objective of this survey was to assess woodland regeneration, structure and current herbivore impacts on all elements of the woodland ecosystem, including the understorey and the field layer vegetation, and to identify and record factors which may be preventing or suppressing regeneration and the development of optimum woodland biodiversity.

The specific objectives of the survey were:

- To provide a clear picture of the current stocking density of seedling and sapling trees within the three wooded compartments comprising the survey area [see Map 1 for compartments].
- To provide an indication of the type and distribution of woodland regeneration within each compartment.
- To provide information on the current browsing impacts on woodland regeneration and the understorey and field layer vegetation within each compartment.
- To describe and quantify additional impacts which may be factors limiting or suppressing woodland natural regeneration within each compartment.
- To compare these data with similar data collected during the 2007 Woodland Profile and Herbivore Impact survey (Beck, 2009), and the 2008 Loch a' Mhuilinn Woodland Profile survey (Clifford & Clifford, 2008).

3. SURVEY METHODS

3.1 The survey area

The intended total survey area was 620ha, which included all existing woodland within the SSSI, a 50m buffer zone around existing woodland stands, and woodland outside the designated site but within the wider woodland network. In practice this was reduced to approximately 587ha as woodland adjacent to, and contiguous with, the SSSI to the immediate north of Nedd was not surveyed.

3.2 Timing of survey

This survey was carried out in autumn at the end of the growing season. The assessment of seedlings and saplings looked at both the 2016 summer's green growth and the previous season's woody shoots. This assessment of browsing is thus capable of detecting browsing impacts in the full 12 months prior to the 2016 survey, including impacts during winter and spring.

3.3 Number and distribution of plots, and plot size

The survey method followed the plot-distribution protocol used in SNH Woodland Profile Surveys, which is based on Forestry Commission Information Note 45 (Kerr *et al*., 2002) and provides for a systematic grid-based plot sampling method, with the objective of achieving a minimum 1% sample by area.

A 1% sample by area has been tested on a range of Woodland Profile Surveys on behalf of both SNH and the Forestry Commission, and has been shown to provide a representative sample of the variability in woodland regeneration and structure, and the surveyors' opinion is that the plot-based observations in this survey adequately represent the variability in the wider woodland resource. Nevertheless, it is important that the plot-based data are set against the wider woodland context obtained through the associated "walk through" survey between survey plots, where a much greater proportion of the woodland was assessed.

The survey grid was created in ArcGIS which produced a “bounding box” from which a grid was drawn over the entire survey area, and calculated the origin at the most south westerly point of the bounding box.

The result of this process gave a survey grid of 122 circular survey plots located at the intersections on the survey grid, with a spacing of 210m between them, giving a 1.03% sample by area (Map 1). The area of each plot was 0.05ha (12.6m radius), which equates to one twentieth of a hectare. The grid references for the plot centres were then pre-loaded onto a hand-held GPS unit (Garmin GPSMap 60CSx), with an average 4m error margin, which was used in the field to locate the plots.

The data from these plots were analysed both as a total dataset and separately by discrete compartments as follows:

- Three geographically separate woodland compartments based on discrete catchments (Table 1 & Map 1):

  Area 1. Nedd/ Gleann Leiraig
  Area 2. Loch Ardbhair/ Gleann Ardbhair/ Clais Ardbhair
  Area 3. Kerrachar to Unapool

Table 1. Number and area of survey plots assessed in the 2016 survey by survey compartment

Survey compartment:	Approx. survey area:	No. survey plots:	Area of survey plots:	Plots as a % of survey area:
1. Nedd/ Gleann Leiraig	201.79 ha	46	2.3 ha	1.14%
2. Loch Ardbhair/ Glen Ardbhair/ Clais Ardbhair	119.25 ha	21	1.05 ha	0.9%
3. Kerrachar to Unapool	265.84 ha	55	2.75 ha	1.03%
Whole survey area	**586.89 ha**	**122**	**6.1 ha**	**1.03%**

- Additionally, some further comparative analyses of regeneration stocking and herbivore browsing were carried out for the main land ownerships;

  1. North Assynt Estate with Nedd Common Grazings
  2. Ardvar Estate/ Rientraid Estate (combined)
  3. Quinag Estate with Unapool Common Grazings (combined)

3.4 Plot measurements

The design of this survey recognises that a "woodland" is not just an "assemblage" or "stand" of trees but is an "ecosystem", a dynamic entity with a range of interlinked and inter-dependant components, communities and populations; and that this system has an optimal potential "biodiversity" in the absence of factors which may function to suppress or reduce this "diversity".

At each plot location the following attributes were measured and recorded within the plot:

- A 10 digit grid reference of the plot centre.
- The number of seedlings and saplings of each tree/ shrub species in each of the life stages shown in Table 2.
- The number of seedlings and saplings in each life stage where the new green and un-lignified growth from the 2016 growing season showed evidence of browsing.
- The number of seedlings and saplings in each life stage where the woody lignified growth established prior to the 2016 growing season showed evidence of browsing. This is used to indicate browsing in the 12 months prior to the 2016 survey, although it is recognised that both non-woody and woody growth may in some cases have been browsed together during the 2016 growing season.
- The tree canopy density as percentage cover of the plot, based on a vertical projection of the canopy onto the plot ground surface, as viewed from the plot centre.
- The average height of the field layer vegetation from 5 measurements.
- The woodland structure class in and immediately adjacent to the survey plot (from FCS "Woodland Grazing Toolbox") shown in Table 3. Where two categories were present in close proximity the primary and minor classes were both recorded.
- An assessment of current herbivore browsing impact using the indicators and scale of severity (Armstrong *et al*., 2014) summarised in Table 4.
- Other signs of herbivore activity and impact (*wallows, tracks, pellet groups, fraying, deer lying up areas; deer seen in or immediately adjacent to plots*).
- The presence of factors other than browsing that may be limiting natural regeneration (*1. woodland canopy; 2. waterlogging/ poor drainage;3. dense bracken cover; 4. distance from a seed source; 5. rock exposure; 6. altitude/ exposure; 7. deep and/ or continuous bryophyte layer; 8. dense vigorous field layer*)
- The predominant BAP/ HAP habitat type and habitat mosaics.
- A digital photograph taken from the plot centre, in a direction that best describes the vegetation and structure of the plot.

The field survey was carried out over two eight day periods in late September and early October 2016. To ensure consistency in the collection of data the surveyors worked together as a two-person team so that agreement was reached on how best to record and score the different survey attributes. Despite the late season all seedlings and saplings had retained their leaves at the time of survey and counts within the plots are therefore considered to be accurate.

Each plot centre was marked with a wooden peg numbered with an aluminium tree tag on the side of the peg, and hammered in so that 10-15cm was above ground as shown in Figure 1.

Figure 1. Sample plot site.

Table 2. Seedling and Sapling life stages

Life stages:	Regeneration category:	Description:
1.1 Small seedling	ADVANCE regeneration	Seedlings at or below the predominant field layer vegetation height, including newly germinated seedlings of the previous year and seedlings long supressed by browsing (all low visibility to deer). Cohort with the potential to provide a new "pulse" of woodland regeneration once released from browsing pressure.
1.2 Large seedling	ESTABLISHED regeneration	Seedlings above the field layer vegetation but <1.3m tall (becoming visible to deer). Mycorrhiza usually developed and good root:shoot ratio.
2.1 Small sapling		Saplings ≥1.3m <3m tall and <7cm DBH (visible to deer)
3.1 Large sapling		Saplings ≥3m ≤5m tall and <7cm DBH (visible to deer)

There is some disagreement about the definition of the term "established". One definition is that trees are "out of the reach of browsing". However, this status can be highly variable; it may depend on individual species which have differing palatability and differential resistance to browsing, and a consistent height threshold is difficult to determine as even large saplings of some species can be susceptible to browsing and particularly bark stripping, and may be killed.

Consequently, in this survey the definition used by the Forestry Commission with regard to the payment of regeneration grant has been adopted. This is based on the assumption that in a healthy looking seedling >45cm tall, the root to shoot ratio of the plant, and the development of mycorrhiza, is likely to be sufficient to indicate potential for longer term survival (albeit not necessarily from future browsing), and the fragile early stage following germination, where many seedlings succumb to damping off and other impacts, has passed. The definition applied in this survey is thus “*seedlings >45cm tall, above the height of the surrounding field layer vegetation”.*

Table 3. Woodland Grazing Toolbox Structure Classes and equivalent Stand Dynamics [after Oliver & Larsen (1996)]

Class No.	WGT woodland structure class description:	Stand dynamics:
1	**Open ground, simple:** open vegetation with a simple low growing structure and little or no regeneration or shrub layer	**No woodland regeneration**
2*	**Open ground, complex:** open ground progressing towards woodland, with some regeneration and/ or low shrub layer	**Stand initiation:** Young trees (seedlings and saplings) regenerating onto non wooded habitat(s)
3	**Dense regeneration:** clumped patches of regeneration up to 3m tall	
4	**Thicket/ stem exclusion:** young woodland >3m in height up to early maturity. Field layer of shade tolerant species	**Stem exclusion:** Tree canopies closing with competition reducing the number of trees. Field layer vegetation shaded.
5*	**Mature woodland with understorey regeneration**: older woodland with small canopy gaps or where competition between trees is minimal, a woody shrub layer, understorey and or tree seedlings & saplings becoming established	**Understorey re-initiation:** The tree canopy opens to varying extent allowing some advance regeneration and the development of saplings where browsing/ grazing is light
6	**Mature woodland with no/ little understorey regeneration:** older woodland with small canopy gaps or where competition between trees is minimal, single storey of mature trees with sparse or absent understorey and regeneration.	**Open canopy simple:** Can result from aborted understorey re-initiation due to heavy browsing/ grazing, also as a result of long-term heavy browsing/ grazing pressure
7*	**Canopy tree mortality complex (established regen in canopy gaps)**: open canopy with dead and dying trees. Field layer and/ or understorey present	**Old growth:** Trees age and begin to die slowly, snags and fallen trees add dead wood habitat. Gaps created by wind throw expose mineral soil; regeneration in gaps where browsing/ grazing is light
8	**Canopy tree mortality simple: canopy gaps with heavy grazing**: open canopy with dead and dying trees. Field layer and understorey sparse and regeneration largely absent	

* A threshold of ≥25 sapling trees ≥1.3 metres tall was required within the survey plot before each of these classes was applied.

Table 4. Woodland Grazing Toolbox Browsing indicators and levels of impact

Browsing indicator:	Level of browsing impact:				
	very high	**high**	**medium**	**low**	**No impact**
Tree basal shoots	Accessible shoots of all species heavily browsed back to trunk	All shoots browsed back except most unpalatable	Palatable shoots browsed short, tips of unpalatable removed	Shoots of palatable species lightly to moderately browsed. Unpalatable not browsed	No evidence of browsing
Tree epicormic shoots	Evidence of recent browse line; few shoots of palatable species below browse line	Clear browse line on palatable species only	Palatable browsed short, tips of unpalatable removed	Abundant shoots below browse line with only tips browsed	No evidence of browsing
Seedlings & saplings	Seedlings either absent, or only newly germinated present. Undamaged saplings only in inaccessible locations, otherwise battered by very heavy browsing	No seedlings of palatable species present; saplings and older seedlings heavily browsed	50-90% growth of moderately palatable species (eg birch) removed	<50% growth of palatable species removed; unpalatable species NOT browsed	No evidence of browsing
Bark stripping & stem breakage	Recent severe stripping on >50% of stems; >20% of live stems on young trees snapped	Recent stripping on 20-50% stems; frequent snapping of stems on young trees	Occasional signs of bark stripping and/or stem breakage on young trees	Bark stripping and stem snapping hard to find	No evidence of bark stripping or stem breakage
Preferentially browsed species	Only present in inaccessible locations	Accessible shoots heavily browsed (>75%)	Accessibe shoots moderately browsed (25-75%)	Accessible shoots lightly browsed (<25%)	No browsing, may be thickets of woodrush or bramble
Sward	Palatable species heavily grazed; unpalatable moderately grazed (25-75%)	Sward short, palatable species heavily grazed, unpalatable moderately browsed	Palatable species moderately grazed >5cm tall; unpalatable <25% grazed	Taller field layer, >10cm where not shaded; unpalatable species ungrazed	Ungrazed tall sward
Ground disturbance	>50% disturbed	Bare ground frequent	Heavy poaching restricted to tracks and feeding sites	Some disturbance on wet sites on tracks and around feeding sites	No signs of disturbance

4. DATA ANALYSIS & INTERPRETATION

4.1 Data presentation and interpretation

Within each of the 122 survey plots two types of recording took place.

The first was actual counts of seedlings and saplings within each life stage by species, together with the numbers browsed. Stocking density per hectare for each plot was obtained by multiplying the count by a factor of 20, as the area of each plot was 1/20th of a hectare, and percentage browsing was obtained by dividing the number browsed by the total number and multiplying the resultant fraction by 100. The overall average stocking for each sub-compartment was then calculated by summing the stocking/ha for each plot and dividing by the total number of plots. Likewise for percentage browsed.

The second was the allocation of the attribute being recorded to one or more of a number of categories (e.g. browsing of the sward or browsing of epicormic shoots, classified as one of 5 categories of browsing impact from "absent" to "very high"). The results for each sub-compartment were then presented as the percent of plots falling within each of the categories.

Additionally, contextual notes were taken on the woodland attributes during the walks between survey plots.

It should be noted that care needs to be taken in the interpretation of the stocking map (Map 2), where plot stocking is presented as one of seven mutually exclusive stocking categories (Table 5), particularly in category 2 (20-240 stems per hectare) where only a single seedling allows a plot to be allocated to this stocking class.

Table 5. Regeneration stocking classes and ranges

Stocking class:	Stocking range:
1	Zero stocking
2	20-240 stems/ha
3	260-500 stems/ha
4	520-1100 stems/ha
5	1120-1600 stems/ha
6	1620-2400 stems/ha
7	>2400 stems/ha

4.2 Statistical tests

In any survey the ideal is to survey/ measure/ count the total target population, to give a wholly accurate answer to the questions posed. However, this is usually impractical in terms of resources/ costs, and a sample is chosen to represent the whole population as closely as possible.

The key is to select a sample that is large enough to represent the population reasonably accurately, and the sample size necessary to achieve this depends on the underlying variability in the population. In addition to properly representing the whole population, the sample must be selected without bias, and can therefore be randomly generated or systematic. Where the sample points are randomly selected, or where the systematic grid start point has not been specifically selected, parametric statistical tests may be used to test the significance of any findings.

The plot sample method utilised in this survey, devised by the Forestry Commission and specified by SNH, provides a systematic grid-based survey sample which has the advantage of preventing the clumping of survey plots often found with random sampling, and is more efficient than random sampling in areas which are heterogeneous with regard to the survey parameters.

Where averages are being calculated based on a systematic sample of the population, as they are for seedling/ sapling stocking density and browsing in this survey, confidence limits of the mean (average) can only be used where each of the following criteria are fulfilled:

1. The sampling grid has a random start point.
2. The sampling grid/ interval doesn't hide/ mask a pattern in the attribute(s) being surveyed.
3. The population being sampled is relatively homogeneous.

If these criteria are fulfilled, each sampling point has a known and equal possibility of selection for the survey sample, which makes it fundamentally similar to random sampling.

However, these criteria were not fulfilled in this survey, as the survey grid start point (applying the Kerr, 2002 methodology) was not randomly selected, and the regeneration being sampled was distinctly clumped. Confidence limits of the mean (average) for seedling/ sapling stocking densities and percentage browsing could not therefore be calculated.

5. RESULTS

5.1 Numbers of seedlings and saplings

The proportion of each species within the survey sample is shown by life stage in Table 6. A total of 8,864 seedlings/ saplings of eight species were assessed and measured. Overall 49% of the sample was rowan and 43% birch, with the other six species making up the remaining 8% of the sample.

With regard to '*established regeneration',* birch comprised 92% of life class 2.1 (small saplings) and 95% of life class 3.1 (large saplings), compared with only 5% and 4% respectively for rowan. Rowan however comprised 62% of the *'advance regeneration*' compared with 28% for birch.

Table 6. Number of seedlings and samplings by life stage. Percentages show the percentage of each species within each life stage, except for the final line which shows each life stage as a percentage of the total.

Species	Life Stage								All life stages:	
	1.1		1.2		2.1		3.1			
	Advance regeneration		*Established regeneration*							
	No.	%	No.	%	No.	%	No.	%	No.	%
Birch	1746	28%	1374	70%	511	92%	150	95%	**3781**	**43%**
Rowan	3812	62%	466	24%	25	5%	7	4%	**4310**	**49%**
Hazel	201	3%	18	0.9%	0	0%	0	0%	**219**	**2%**
Holly	6	0.1%	23	1%	2	0.4%	0	0%	**31**	**0.4%**
Willow	408	7%	60	3%	6	1%	0	0%	**474**	**5%**
Aspen	9	0.2%	12	0.6%	2	0.4%	0	0%	**23**	**0.3%**
Oak	3	0.05%	0	0%	0	0%	0	0%	**3**	**0.03%**
Dog rose	5	0.08%	10	0.5%	7	1%	1	0.6%	**23**	**0.3%**
ALL spp :	**6190**	**70%**	**1963**	**22%**	**553**	**6%**	**158**	**2%**	**8864**	**100%**

5.2 Average stocking density of seedlings and saplings

The data on average stocking density are presented as a total dataset combining the whole survey area, and additionally by discrete woodland compartment (Map 1) and separately by land ownerships.

5.2.1 Average stocking for the whole survey area and component woodland compartments

The breakdown of stocking density is shown by woodland compartments and species in Table 7. Taking the site as a whole, the overall average stocking of seedlings and saplings combined is 1578 stems/ha, with birch and rowan comprising most of the stocking at 671 stems/ha on average (43%) and 760 stems/ha on average (49%) respectively. The overall stocking density was similar in all three woodland compartments albeit slightly higher in sub-compartment 3 (Kerrachar to Unapool).

The highest average stocking density of rowan occurred in compartment 2 (Loch Ardbhair/Gleann Ardbhair/ Clais Ardbhair) where it comprised 53% of the overall stocking, whilst the highest stocking of birch was recorded in compartment 3 (48%). Oak was only recorded in compartment 1 (Nedd/ Gleann Leiraig) where very occasional individual mature and semi-mature oak were encountered. Hazel, willow and holly were recorded in all three compartments, with aspen only recorded in compartments 1 and 2.

Table 7. Overall average stocking of natural regeneration for all life stages combined

Compt	Overall average stocking:	S. DEV	Average stocking by species (stems/ha)							
			Birch	Rowan	Hazel	Willow	Aspen	Holly	Oak	Dog rose
1	**1548/ha**	1909	605/ha	697/ha	83/ha	130/ha	27/ha	3/ha	1/ha	0/ha
2	**1535/ha**	1328	594/ha	842/ha	34/ha	36ha	6/ha	20/ha	0/ha	3/ha
3	**1620/ha**	3019	755/ha	781/ha	3/ha	72/ha	0/ha	2/ha	0/ha	7/ha
ALL	**1578/ha**	**2391**	**671/ha**	**760/ha**	**39/ha**	**88/ha**	**11/ha**	**6ha**	**<1/ha**	**4/ha**

S.DEV = standard deviation

Compartment 1 also contained the highest average stocking density of hazel (83 stems/ ha, 5%), willow (130 stems/ ha, 8%) and aspen (27 stems/ ha, 2%), whilst the highest stocking of holly was recorded in compartment 2 (20 stems/ ha, 1%). The distribution of all these “minor” species is extremely localised, none occurring throughout the woodland, and with aspen restricted to inaccessible cliff or crag refugia.

Standard Deviation (SD) shows how much variation or "dispersion” exists from the average (mean value) for a measured variable. A low standard deviation indicates that the data points tend to be very close to the mean whilst a high standard deviation indicates that the data points are spread out over a wide range of values. The very high standard deviation figures shown in Table 7 confirm the wide variability in overall average stocking density, both at the scale of the overall survey area and within each survey compartment, and suggest that it is unlikely that the differences in stocking between the woodland compartments is statistically significant.

5.2.2 Woodland structure

Table 8 shows the number and percentage of survey plots falling within each of the eight woodland structure classes, together with the associated average overall stocking density. The distribution of structure classes by survey plots is shown on Map 5 and the corresponding plot stocking density on Map 2.

40% of all survey plots were located in open ground “buffer zone” habitats (OG, with <5% woodland canopy); dry heath comprised 34% of OG plots, wet heath 34% of OG plots, W25 Bracken 15% of OG plots, blanket bog/ mire 11% of OG plots, Molinia grassland/ flush 4% of OG plots, and bog/ flush mosaic 2% of OG plots. Of these “buffer zone” plots, 51% were located in habitats with generally impeded drainage. Whilst it might be concluded that these habitats are suboptimal for woodland regeneration 96% of wet heath plots, 75% of blanket bog plots and 100% of Molinia flush/ grassland plots contained seedlings and/ or saplings. Furthermore, the NVC W4 woodland community clearly demonstrates that birch (and also alder and willow species) will regenerate onto areas dominated by Molinia over a peat substrate where drainage is impeded.

Table 8 demonstrates that woodland regeneration was recorded in all eight structure classes. A high proportion of the regeneration recorded in categories 1 (open ground simple), 4 (thicket/stem exclusion), 6 (mature woodland with no/ little understorey regeneration) and 8 (Canopy tree mortality simple: canopy gaps with heavy grazing) was advance regeneration (not yet established).

Table 8. Number and percentage of plots in each woodland structure class and associated average stocking (all species, life stages and compartments combined)

Structure class	Description	No. of plots	% of plots	Average overall stocking of regeneration (stems/ha)
1	**Open ground, simple:** open vegetation with a simple low growing structure and little or no regeneration or shrub layer	49	40%	824/ha
2	**Open ground, complex:** open ground progressing towards woodland with some regeneration and/or low shrub layer	7	6%	2403/ha
3	**Dense regeneration:** clumped patches of regeneration up to 3m tall	6	5%	3150/ha
4	**Thicket/stem exclusion:** young woodland >3m in height up to early maturity. Field layer shade tolerant species	3	2%	240/ha
5	**Mature woodland with understorey regeneration**: older woodland with small canopy gaps or where competition between trees is minimal, a woody shrub layer, understorey and or tree seedlings & saplings becoming established	5	4%	3992/ha
6	**Mature woodland with no/little understorey regeneration:** older woodland with small canopy gaps or where competition between trees is minimal, single storey of mature trees with sparse or absent understorey and regeneration.	39	32%	1934/ha
7	**Canopy tree mortality complex (established regen in canopy gaps)**: open canopy with dead and dying trees, field layer and/or understorey present	3	2%	1600/ha
8	**Canopy tree mortality simple**: **canopy gaps with heavy grazing**: open canopy with dead and dying trees. Field layer and understorey sparse and regeneration largely absent	10	8%	1550/ha

Oliver & Larsen (1996) recognise four distinct phases of woodland stand development [*1. stand initiation; 2. stem exclusion; 3. understorey re-initiation and 4. mature/ old-growth*], and Mason *et al*. (2004) use a simple fire frequency model for a Scots pine ecosystem (Seymour & Hunter, 1999), which suggests that, with a variation in the return period of disturbance events of between 50-150 years, the ideal relative proportions of the four different stand development phases would lie within the following ranges; *12-33% stand initiation, 29-46% stem exclusion, 15-22% understorey re-initiation, and 6-37% mature/old growth*. As birch is a light demanding species like Scots pine, with a similar strategy for perpetuation, it seems reasonable to assume that these proportions are appropriate to use for Ardvar.

Table 9 compares the percentage of plots in each of the woodland structure classes from Table 8, with the equivalent stand development phases described above, and shows that the *stand initiation, stem exclusion, and understorey re-initiation* phases are under-represented in the plot sample with only the mature/ old growth phase fully represented. The under-represented stand development phases are the drivers for the continuity of woodland, suggesting that the long-term extent and distribution of woodland at the site is currently at risk.

Table 9. Comparison between the percentage of plot figures for woodland structure classes at Ardvar with the ideal relative proportions of the four different stand development phases described by Seymour & Hunter (1999).

Stand development phase	Ideal proportion of the woodland resource	Equivalent Woodland structure classes	% of plots with woodland structure class	Total percentage of plots with woodland structure classes[1]
Stand initiation	12-33%	2. Open ground, complex	6%	11%
		3. Dense regeneration	5%	
Stem exclusion	29 - 46%	4. Thicket/ stem exclusion	2%	2%
Understorey re-initiation	15 - 22%	5. Mature woodland with understorey regeneration	4%	6%
		7. Canopy tree mortality with established regeneration in canopy gaps	2%	
Mature/old growth	6 - 37%	6. Mature woodland with little/ no regeneration	32%	40%
		8. Canopy tree mortality, canopy gaps with heavy grazing	8%	

5.2.3 Factors potentially limiting to woodland regeneration

Within each survey plot, a range of eight discrete factors with the potential to limit/ suppress natural regeneration, were recorded where they impacted ≥25% of the plot area. These were woodland canopy, waterlogging/ poor drainage, dense/ vigorous bracken cover, distance

[1] This column does not add up to 100%, because 40% of the plots were classed as structure class 1, which is not included in the stand development phase classification.

from a seed source, rock exposure, altitude/ exposure, deep and/ or continuous bryophyte layer and dense vigorous field layer vegetation.

Table 10 shows the number and percentage of survey plots where each potentially limiting factor was recorded, and the associated average stocking of seedlings and saplings combined. At the scale of the whole survey area, 58 out of the 122 survey plots (48%) contained at least one factor with the potential to limit or suppress natural regeneration.

Of the eight possible factors, distance from a seed source and rock exposure were not recorded as limiting factors and deep and/or continuous bryophyte layer, altitude exposure and dense/ vigorous field layer vegetation were less frequently recorded than woodland canopy cover, waterlogging/ poor drainage and dense/ vigorous bracken.

At the scale of the whole survey area, the most commonly encountered potentially limiting factor was woodland canopy, which was recorded in 26% of the 122 survey plots, followed by dense vigorous bracken canopy recorded in 15% of the plots and waterlogging/ poor drainage recorded in 9% of the plots. The first two factors were recorded together in only 7 of the survey plots (6%), with woodland canopy and waterlogging/ poor drainage occurring together in less than 1% of the survey plots (1 plot).

Overall the average mature woodland canopy across the whole woodland resource was relatively light (26%) but this masks a wide range, from 0% to 80% canopy cover. 39% of plots had a tree canopy of 0 to <5%, 13% a canopy of ≥5 <20%, 23% a canopy of ≥20 <50% and 25% a canopy of ≥50%. Only canopies within the last of these classes would be likely to have any suppressing effect on rowan (a partially shade tolerant species) and other more shade-tolerant species such as holly would be likely to regenerate successfully under these more dense canopies. However, canopies within both the ≥50% and ≥20 <50% classes would be likely to have some suppressant effect on the light-demanding birch.

Bracken canopy was also highly variable and below a threshold density of approximately 20 fronds /m^2 (Marrs and Watt, 2006), where ambient light was sufficient for seed germination and subsequent photosynthesis and growth, appeared to have a “protective” role reducing browsing impact on small “unestablished” seedlings (life stage 1.1). This was particularly evident with hazel seedlings many of which were found underneath quite dense bracken canopy.

Table 10. Number & percentage of plots with each factor potentially limiting to natural regeneration, with associated average stocking (all species, life stages and compartments combined).

Potentially limiting factor	Description	No. of plots	% of plots	Average overall stocking of regeneration	
				Limiting factor present	Limiting factor absent
1	Woodland canopy/low ambient light level (for birch regeneration)	32	26%	1123/ha	1747/ha
2	Waterlogging/poor drainage	11	9%	593/ha	1668/ha
3	Dense vigorous bracken canopy	18	15%	728/ha	1694/ha
4	Distance from a seed source	0	0%	-	-
5	Rock exposure	0	0%	-	-
6	Deep and/or continuous bryophyte layer	1	1%	80/ha*	-
7	Altitude/exposure	6	5%	760/ha	1632/ha
8	Dense vigorous field layer vegetation	2	2%	181/ha	1601/ha

* 1 plot, no average stocking

Table 10 indicates that when a comparison is made between the average stocking density of plots with potentially limiting factors and those without any limiting factors, the plots without potentially limiting factors have higher average stocking density in all cases. At the overall scale, plots without any limiting factors have an average stocking density more than twice as high as those with a limiting factor (2098 stems/ha vs 975 stems/ha).

There are no exact data on what threshold stocking densities are necessary for any particular species, to ensure that seedlings and saplings recruit in sufficient numbers to subsequent life stages and ultimately attain maturity. Essentially only one seedling needs to progress through the consecutive life stages and reach maturity for each existing mature tree in order to maintain the current woodland cover. However, the Forestry Commission "rule of thumb" for payment of grant for natural regeneration is that an average of 1100 stems/ha above approximately 50cm height should be present. Whilst the average stocking densities shown in Table 10 do not differentiate between the regeneration life stages, the data suggest that this threshold is more likely to be met in plots without limiting factors.

The relationships between 'woodland canopy vs stocking density', and 'average field layer vegetation height vs stocking density' were investigated by means of scatter diagrams, and tested by means of "correlation coefficient [r]" ,and no significant correlation was found between either set of paired variables (see Figures 1 and 2 in Annex 2). However, it should be noted that there may be other interacting factors obscuring the relationships between the paired variables.

5.2.4 Average stocking density by survey compartment, species and life stage

The average stocking density by species, life stage and woodland compartment is shown in Table 11.

A cohort of *advance regeneration* of seedlings below the height of the field layer vegetation awaiting a release from browsing pressure before potentially establishing and becoming large seedlings and saplings represents the "capital" for the next pulse of woodland regeneration, and is important for the long term continuity of mature canopy trees.

The dominance of rowan *advance regeneration* in each of the three compartments is evident and equates to 58% of all *advance regeneration* in compartment 1, 68% in compartment 2 and 64% in compartment 3. The equivalent figures for birch are 25%, 26% and 29% respectively by compartment.

Table 11. Overall average stocking density (stems/ha) by species and life stage for the whole survey area & woodland compartments

Species	Average stocking (stems/ha)											
	Compartment 1				Compartment 2				Compartment 3			
	1.1	1.2	2.1	3.1	1.1	1.2	2.1	3.1	1.1	1.2	2.1	3.1
	Adv regen	*Established regeneration*			*Adv regen*	*Established regeneration*			*Adv regen*	*Established regeneration*		
Birch	284	228	77	16	287	214	59	34	299	313	112	30
Rowan	663	30	3	2	745	95	2	0	661	112	6	1
Hazel	77	6	0	0	31	3	0	0	3	0	0	0
Willow	97	30	3	0	30	7	0	0	61	10	1	0
Aspen	16	10	1	0	0	6	0	0	0	0	0	0
Holly	2	1	0.4	0	5	15	0	0	0	1	0.4	0
Oak	1	0	0	0	0	0	0	0	0	0	0	0
Dog rose	0	0	0	0	0	3	0	0	1	3	3	0.4
ALL Spp	**1140**	**305**	**85**	**18**	**1097**	**343**	**61**	**34**	**1026**	**440**	**123**	**31**
		408 combined				**438 combined**				**594 combined**		
ALL life stages	**1548**				**1535**				**1620**			
Overall	**1578**											

Adv regen = Advance regeneration

Rowan is not a major component of the canopy of forest types in the Scottish Highlands, other than in totally deer/stock proof enclosures, as herbivores in unenclosed woodland habitats act as an "ecological sieve" (sensu Silvertown, 1982) preferentially browsing seedlings of this species so that only a proportion pass through the sieve to develop as established saplings. As a less preferred deer browse species, more birch are likely to pass through the sieve than rowan. In terms of the overall average stocking densities of advance regeneration shown in Table 11 for each compartment the figures do not therefore represent the true potential for recruitment to the sapling life stage, which is likely to be lower under current browsing levels. This also applies to other preferentially browsed species such as willow and holly, and to a lesser extent hazel, which are important components of a diverse woodland understorey.

Table 11 also clearly illustrates the much lower average stocking density of established regeneration, compared with advance regeneration, in each of the woodland compartments (408 compared to 1140 stems/ha in compartment 1, 438 compared to 1097 stems/ ha in compartment 2, and 594 compared to 1026 stems/ ha in compartment 3), and the large decrease in numbers of subsequent life stages within the established regeneration category. The large sapling life stage (≥3m ≤5m tall and <7cm DBH) is the only stage where the impact of deer browsing is unlikely to be significant, as the trees are largely above browsing height, but this life stage is poorly represented in the survey plots (Table 12) and, from general observation, in the wider woodland. Across the whole survey area, only 20% of survey plots contain large saplings, with a similar proportion within the individual compartments (15% of plots in compartment 1, and 24% in each of compartments 2 and 3, contained large saplings). Table 6 shows that only 158 of the 8864 seedlings/ saplings recorded (1.7% of the total) were large saplings. This data therefore indicates that an important life stage, which should contribute to the maintenance of the current extent and distribution of mature upland birch woodland within the site, is significantly under-represented.

Additionally, the stocking of species with the potential to form a shrub/understorey layer (hazel, willow, holly), which is an important structural component of the woodland, is extremely low, and their distribution is limited and distinctly local (Map 6), preventing the full expression of potential woodland biodiversity.

Table 12. Percentage of survey plots with each life stage (all species combined)

Compartment	No. of survey plots	Life stages			
		1.1	**1.2**	**2.1**	**3.1**
		Advance regen	***Established regeneration***		
1	46	93%	63%	43%	15%
2	21	95%	90%	43%	24%
3	55	96%	96%	29%	24%
ALL	**122**	**96%**	**83%**	**39%**	**20%**
			86% combined		

Table 13 shows the percentage of survey plots where the average stocking of advance and established regeneration exceeds illustrative thresholds of 500 stems/ha and 1100 stems/ha respectively. The stocking density necessary to deliver woodland regeneration objectives is not a set figure and depends of site objectives and management. However, for comparison, the current Forestry Grant Scheme requirement for the successful establishment of natural regeneration is for a stocking density of at least 400 established trees/ha.

Map 2 provides complementary information on the spatial distribution of regeneration by stocking classes within the survey plots, and shows that stocking >1120 stems/ha is widespread, with the most significant area in the North western section of compartment 1 (Nedd/Gleann Leiraig).

Table 13. Percentage of survey plots with average stocking >500 and >1100 stems/ha by land ownership (all species combined)

Compartment	No. of survey plots	Life stage 1.1 [*Advance regeneration*]		Life stages 1.2, 2.1 & 3.1 combined [*Established regeneration*]	
		% of plots with >500 stems/ha	% of plots with >1100 stems/ha	% of plots with >500 stems/ha	% of plots with >1100 stems/ha
1	46	59%	33%	22%	11%
2	21	57%	43%	19%	10%
3	55	47%	24%	25%	15%
ALL	**122**	**52%**	**30%**	**23%**	**12%**

The percentage of survey plots with advance regeneration exceeding the two stocking thresholds is markedly higher than the percentage of established regeneration both at the scales of the overall survey area and the woodland compartments.

5.2.5 Average stocking by land ownership, species and life stage

Table 14 shows the overall average stocking, for all life stages combined, by land ownerships. The plot samples for both Reintraid Estate and the area of Unapool Common Grazings (UCG) outside the JMT ownership were too small to warrant separate analysis. The Reintraid data have therefore been combined with the Ardvar Estate data, and the Unapool Common Grazings data with that from the JMT owned Quinag Estate.

The overall average stocking was slightly higher for plots on Ardvar Estate; the average stocking of birch was highest in the JMT/UCG ownership, and that of rowan on Ardvar Estate. The lowest average stocking of rowan was recorded in the JMT/UCG ownership, where the “minor’ species aspen, holly and oak were not recorded in the survey plots.

However, the standard deviations for overall average stocking in each of the three “ownerships” are high, indicating the wide variability in the plot stocking density, and suggesting that the differences are unlikely to be statistically significant.

Table 14. Overall average stocking of natural regeneration for all life stages combined

Owner	Overall stocking:		Average stocking by species (stems/ha)							
	Mean	S. DEV	Birch	Rowan	Hazel	Willow	Aspen	Holly	Oak	Dog rose
NAT	**1562/ha**	2244	641/ha	700/ha	46ha	122ha	50/ha	34ha	<1/ha	0/ha
ARD	**1605/ha**	2601	617/ha	852/ha	42/ha	82/ha	1/ha	7/ha	<1/ha	4/ha
JMT	**1444/ha**	1104	1044/ha	320/ha	7/ha	63/ha	0/ha	0/ha	0/ha	10/ha
ALL	**1578/ha**	**2391**	**671/ha**	**760/ha**	**39/ha**	**88/ha**	**11/ha**	**6/ha**	**<1/ha**	**4/ha**

S.DEV = standard deviation,
NAT = North Assynt Trust & Nedd Common Grazings; ARD = Ardvar & Reintraid Estates (combined); JMT = John Muir Trust Quinag Estate & Unapool Common Grazings [UCG] (combined)

The average stocking density by species, life stage and woodland ownership is shown in Table 15, and Table 16 shows the percentage of survey plots containing each life stage. These Tables support the observations made for the three woodland compartments described above, and show that rowan is a significant component of the advance regeneration at the scale of the different ownerships, with the average stocking of this species exceeding that of all the other species combined for the North Assynt Trust/Nedd CG, and for the combined Ardvar and Reintraid Estates ownerships, although the average stocking of birch advance regeneration slightly exceeds that of rowan on the JMT/UCG owned area.

When all species are considered together at the scale of the three different ownerships the average stocking of advance regeneration is more than twice that of established regeneration at North Assynt Trust/Nedd CG and the combined Ardvar and Reintraid Estates.

However, for the JMT/UCG owned area the situation is reversed, with the average stocking of established regeneration being almost twice that of advance regeneration. The explanation for this is the comparatively high stocking of large seedlings (life stage 1.2) and small saplings (life stage 2.1) here compared with the other two ownerships. The percentage of plots containing large saplings (life stage 3.1), and the average stocking density of this life class is also higher for this area.

Table 15. Overall average stocking by species & life stage for the whole survey area & separate ownerships

Species	Average stocking (stems/ha)											
	North Assent Trust & Nedd common grazings				Ardvar Estate & Rientraid Estate combined				JMT & Unapool Common Grazings combined			
	1.1	**1.2**	**2.1**	**3.1**	**1.1**	**1.2**	**2.1**	**3.1**	**1.1**	**1.2**	**2.1**	**3.1**
	Adv regen	***Established regeneration***			***Adv regen***	***Established regeneration***			***Adv regen***	***Established regeneration***		
Birch	210	320	94	16	319	224	47	27	271	401	336	36
Rowan	666	29	3	2	758	90	4	0	214	97	4	4
Hazel	46	0	0	0	38	4	0	0	6	2	0	0
Willow	68	47	6	0	73	9	0	0	49	10	4	0
Aspen	29	19	2	0	0	1	0	0	0	0	0	0
Holly	3	1	0	0	1	5	1	0	0	0	0	0
Oak	1	0	0	0	1	0	0	0	0	0	0	0
Dog rose	0	0	0	0	1	2	1	0	3	0	6	1
ALL spp	**1022**	**416**	**105**	**18**	**1190**	**335**	**53**	**27**	**543**	**510**	**350**	**41**
		540 combined				**415 combined**				**901 combined**		
All life stages	**1562**				**1605**				**1444**			
Overall	**1578**											

Table 16. Percentage of survey plots within each life stage (all species combined)

Land ownership	No. of survey plots	Life stages			
		1.1	1.2	2.1	3.1
		Advance regen		*Established regeneration*	
North Assynt Trust & Nedd Common Grazings	25	92%	56%	32%	16%
Ardvar & Reintraid Estates combined	83	95%	88%	40%	20%
JMT & Unapool Common grazings combined	14	100%	100%	43%	29%
ALL	**122**	**96%**	**83%**	**39%**	**20%**

Table 17 shows the percentage of survey plots where the average stocking of advance and established regeneration exceeds the thresholds of 500 stems/ha and 1100 stems/ha.

The JMT/UCG combined ownership has the highest percentage of plots with established regeneration above both the 500 stems/ha and 1100 stems/ha thresholds (36% and 29% respectively) and the lowest percentage of plots with advance regeneration above these thresholds, although it should be noted that the sample size for this ownership is small.

Table 17. Percentage of survey plots with stocking >500 and >1100 stems/ha by land ownership (all species combined)

Land ownership	No. of survey plots	Life stage 1.1 [*Advance regeneration*]		Life stages 1.2, 2.1 & 3.1 combined [*Established regeneration*]	
		% of plots with >500 stems/ha	% of plots with >1100 stems/ha	% of plots with >500 stems/ha	% of plots with >1100 stems/ha
North Assynt Trust & Nedd Common Grazings	25	56%	28%	28%	16%
Ardvar & Reintraid Estates combined	83	53%	34%	19%	8%
JMT & Unapool Common grazings combined	14	43%	7%	36%	29%
ALL	**122**	**52%**	**30%**	**23%**	**12%**

5.2.6 Average stocking density within deer fenced enclosures

As only three of the 122 survey plots were located within deer fenced areas, and in one of these (at Reintraid) no seedlings or saplings were recorded, it is not possible to give a detailed numerical account of average stocking density. However, in the Torgawn enclosure, where most of the regeneration is rowan, almost 60% of the trees recorded within the plot were life stage 1.2 (large seedlings) which qualifies as established regeneration, with a stocking density of 420 stems/ha, and in open areas adjacent to the plot there was patchy regeneration of small sapling rowan (life stage 2.1). There was also a single unbrowsed large seedling holly (a preferentially browsed species) adjacent to the plot.

The beneficial effects of enclosure were particularly well demonstrated in the survey plot in the deer proof enclosure above Kerrachar. Here honeysuckle was unbrowsed and well developed, and 99% of the regeneration was established, at a stocking density of over 2000 stems/ha.

5.2.7 Overall evaluation of stocking density

The overall average stocking of seedlings and saplings combined within the whole survey area exceeds 1500 stems/ha, and this is also the case within each of the catchments which comprise the woodland survey compartments, and also within the North Assynt Trust/Nedd CG and the combined Ardvar & Reintraid ownerships. The overall average stocking for the JMT/UCG ownership is slightly lower at just over 1400 stems/ha. This regeneration is distributed across 95% of the 122 survey plots, as shown in Map 2.

A high proportion of this average stocking comprises advance regeneration (seedlings at or below the height of the surrounding field layer vegetation), with average stocking density exceeding 1000 stems/ha for the whole survey area, the woodland compartments and the woodland ownerships other than the JMT/UCG ownership, where the average stocking is just over half this value.

Of the total stocking, 49% of this is rowan, a preferentially deer browsed species, many of which are therefore unlikely to survive and recruit to the sapling life stages. So whilst the small seedling "capital" available for recruitment to the sapling life stages is high, the proportion that will be recruited to become established regeneration is likely to be less than the stocking density figures for advance regeneration suggest, as a result of browsing.

The current stocking density of large saplings is low, and an essential life stage in the structure of the woodland is therefore under-represented, compromising the future structure, extent and distribution of mature upland birch woodland within the site. Likewise, the relatively low stocking of shrubs such as willow, hazel and holly, and their localised distribution, is likely to compromise the development of an extensive woodland understorey layer.

With regard to factors with the potential to prevent or suppress woodland regeneration (other than browsing), plots without these factors have seedling/sapling densities double those where a limiting factor is present. This indicates that these factors have a suppressive influence, particularly with regard to woodland canopy/ low ambient light level (for birch regeneration), waterlogging/ poor drainage and dense vigorous bracken canopy, each of which is present in >10% of survey plots. However, bracken canopy below a threshold density seems to protect small seedlings from the impacts of browsing. Whilst there are significantly fewer seedlings in plots with limiting factors, substantial numbers are still present and the principle factor preventing them from becoming established is considered to be browsing (see section 5.3).

The overall indication is that there is significant potential for a pulse of woodland regeneration, expansion, and the development of a more complex structure across much of the woodland, although it should be noted that the regeneration would have a clumped rather than continuous distribution.

5.3 Herbivore signs, impacts and browsing levels

5.3.1 Herbivore browsing

It was not possible to reliably differentiate between deer and sheep browsing or grazing impacts. However, it was possible to differentiate between red deer, roe deer and sheep pellet groups with reasonable confidence (Bang & Dahlstrom, 2001). Additionally sheep were cleared from Ardvar Estate in 1974, and whilst there may be occasional marauders from neighbouring estates, their impact is likely to be small compared to that of red deer in this area.

Table 18 shows our assessment of the number and percentage of plots containing one or more pellet groups of each of these three herbivores, and gives a clear indication that red deer are likely to be the primary browser across the whole site.

Table 18. Number and percentage of plots with herbivore pellet groups (PG)

Compt	Total No plots	Red deer			Roe deer			Sheep		
		No. plots	% plots	Average PG per plot	No. plots	% plots	Average PG per plot	No. plots	% plots	Average PG per plot
1	46	23	50%	1.2	1	2%	0.02	1	2%	0.02
2	21	11	52%	0.6	1	1%	0.05	0	-	-
3	55	21	38%	1.1	0	-	-	0	-	-
ALL	**122**	**55**	**45%**	**1.04**	**1**	**1%**	**0.1**	**1**	**1%**	**0.1**

5.3.1.1 Herbivore browsing by survey compartment & land ownership, all life stages and species combined

Tables 19 and 20 show the percentage of all seedlings and saplings (combined) browsed by herbivores (mainly deer) both during the 2016 growing season (browsing of green shoots) and in the 12 months prior to the 2016 survey (browsing of woody shoots), by woodland compartment (catchment) and land ownership.

Table 19. Percentage of all seedlings & saplings combined browsed by herbivores during the 2016 growing season, and in the 12 months prior to the 2016 survey, (by survey compartment)

Compartment	No. of survey plots	% of all seedlings/saplings browsed by herbivores	
		2016 growing season (green shoots)	During 12 months prior to the 2016 survey (woody shoots)
1	46	10%	65%
2	21	8%	41%
3	55	5%	45%
ALL	**122**	**7%**	**51%**

Table 20. Percentage of all seedlings & saplings combined browsed by herbivores <u>during the 2016 growing season</u>, and in the 12 months prior to the 2016 survey, (by land ownership)

Land ownership	No. of survey plots	% of all seedlings/saplings browsed by herbivores	
		2016 growing season (green shoots)	During 12 months prior to the 2016 survey (woody shoots)
North Assynt Trust & Nedd Common Grazings	25	13%	68%
Ardvar & Reintraid Estates combined	83	6%	48%
JMT & Unapool Common grazings combined	14	5%	43%
ALL	**122**	**7%**	**51%**

It is evident that the levels of browsing during the 2016 growing season are consistently lower across woodland compartments and land ownerships (7% overall) compared with browsing levels in the 12 months prior to the 2016 survey (51% overall). The percentage of seedlings/saplings with green shoots browsed during the 2016 growing season was highest in Compartment 1, as was the percentage with woody shoots browsed during the 12 months prior to the 2016 survey. When the individual land ownerships are considered, the lowest percentage browsing of both green and woody shoots was recorded in the John Muir Trust & Unapool Common Grazings combined ownership, and the highest in the North Assynt Trust & Nedd Common Grazings combined ownership for both green and woody shoots.

It is not possible to determine with any certainty in which season or seasons the damage from deer browsing is heaviest. However, the browsing of the 2016 growing seasons' "green shoots" is low compared with the browsing of woody shoots in the full 12 months prior to the survey. It is suggested that this is the result of deer returning to the wooded areas in early winter for shelter and feeding once the upland vegetation has senesced and the weather has deteriorated, having spent a large part of the growing season on higher ground to avoid the flies and midges and exploit the upland grazing.

There was no significant correlation between average field layer vegetation height and the percentage of seedlings browsed, either woody shoots in the 12 months prior to the 2016 survey, or green shoots during the 2016 growing season (see Figures 3 & 4 in Annex 2). However, it should be noted that other interacting factors may be obscuring the relationship.

5.3.1.2 Herbivore browsing by survey compartment & life stage, all species combined

Tables 21 and 22 show the number and percentage of seedlings/saplings browsed by life stage within each survey compartment and for the whole survey area.

Table 21. Overall herbivore browsing during the 2016 growing season (green shoots), by survey compartment and life stage, all species combined

Compartment & sample size	Life stages							
	1.1 small seedling		1.2 large seedling		2.1 small sapling		3.1 large sapling	
	Total #	# and % browsed	Total #	# and % browsed	Total #	# and % browsed	Total #	# and % browsed
1 [n = 46]	2231	127 (6%)	515	146 (28%)	168	12 (7%)	36	0 (0%)
2 [n = 21]	1152	35 (3%)	360	94 (26%)	64	1 (2%)	36	0 (0%)
3 **[n = 55]**	2807	82 (3%)	1089	137 (13%)	320	8 (3%)	86	3 (3%)
ALL [n =122]	**6190**	**224 (4%)**	**1964**	**377 (19%)**	**552**	**21 (4%)**	**158**	**3 (2%)**

Table 22. Overall herbivore browsing during the 12 months prior to the survey (woody shoots), by survey compartment and life stage, all species combined

Compartment & sample size	Life stages							
	1.1 small seedling		1.2 large seedling		2.1 small sapling		3.1 large sapling	
	Total #	# and % browsed	Total #	# and % browsed	Total #	# and % browsed	Total #	# and % browsed
1 [n = 46]	2231	1252 (56%)	515	476 (92%)	168	150 (89%)	36	28 (78%)
2 [n = 21]	1152	326 (28%)	360	308 (86%)	64	24 (38%)	36	5 (14%)
3 [n = 55]	2807	995 (35%)	1089	823 (76%)	320	96 (30%)	86	16 (19%)
ALL [n =122]	**6190**	**2573 (42%)**	**1964**	**1607 (82%)**	**552**	**270 (49%)**	**158**	**49 (31%)**

A comparison of the data between Tables 21 and 22 clearly shows the increased browsing levels on *woody shoots* compared with *green shoots* across all life stages and all survey compartments. At the scale of the whole survey area approximately ten times the number of *small seedlings* (life stage 1.1) displayed browsed woody shoots compared with *green shoots* browsed. The comparable figures for large seedlings (life stage1.2), small saplings (life stage 2.1) and *large saplings* (life stage 3.1) were approximately x4, x10 and x16 respectively.

The highest percentage browsing of both *woody shoots* and *green shoots* was recorded in survey compartment 1. This was the case for all life stages with regard to *woody shoot* browsing, and life stages 1.1, 1.2 and 2.1. for *green shoot* browsing, but not for life stage 3.1 which were unbrowsed.

For both *green shoots* browsed during the 2016 growing season and *woody shoots* browsed in the 12 months prior to the survey the higher browsing of *large seedlings* (life stage 1.2) compared with *small seedlings* (life stage 1.1) is evident. This is likely to reflect the increased visibility to deer of large seedlings emerging from the protection of the field layer vegetation.

5.3.1.3 Herbivore browsing by land ownership & life stage, all species combined

Tables 23 and 24 show the same data broken down by land ownership where similar patterns apply.

A comparison of the data between Tables 23 and 24 again clearly shows the increased browsing levels on woody shoots compared with green shoots across all life stages and all ownerships, although the browsing levels for large saplings (life stage 3.1) on the JMT/UCG ownership was comparatively low for both woody and green shoots.

The increased browsing of large seedlings compared with small seedlings is also again evident for each ownership as they emerge from the protection of the field layer vegetation.

The highest percentage browsing of both woody shoots and green shoots was recorded in the North Assynt Trust/ Nedd Common grazings ownership. This was the case for all life stages with regard to woody shoot browsing, and life stages 1.1, 1.2 and 2.1 for green shoot browsing, but not for life stage 3.1 which were unbrowsed.

Table 23. Overall herbivore browsing during the 2016 growing season (green shoots), by land ownership and life stage, all species combined

Land ownership & sample size	Life stages							
	1.1 small seedling		1.2 large seedling		2.1 small sapling		3.1 large sapling	
	Total #	# and % browsed	Total #	# and % browsed	Total #	# and % browsed	Total #	# and % browsed
North Assynt Trust & Nedd Common Grazings [n = 25]	911	66 (7%)	334	100 (30%)	105	8 (8%)	18	0 (0%)
Ardvar & Reintraid Estates combined [n = 83]	4899	167 (3%)	1273	240 (19%)	202	10 (5%)	111	1 (1%)
JMT & Unapool Common grazings combined [n = 14]	380	1 (3%)	357	37 (10%)	245	3 (1%)	29	2 (7%)
ALL [n = 122]	**6190**	**224 (4%)**	**1964**	**377 (19%)**	**552**	**21 (4%)**	**158**	**3 (2%)**

Table 24. Overall herbivore browsing during the 12 months prior to the survey (woody shoots), by land ownership and life stage, all species combined

Land ownership & sample size	**Life stages**							
	1.1 small seedling		**1.2 large seedling**		**2.1 small sapling**		**3.1 large sapling**	
	Total #	**# and % browsed**	**Total #**	**# and % browsed**	**Total #**	**# and % browsed**	**Total #**	**# and % browsed**
North Assynt Trust & Nedd Common Grazings [n = 25]	911	514 (56%)	334	316 (95%)	105	87 (83%)	18	14 (78%)
Ardvar & Reintraid Estates combined [n = 83]	4899	1879 (38%)	1273	1083 (85%)	202	136 (67%)	111	33 (30%)
JMT & Unapool Common grazings combined [n = 14]	380	180 (47%)	357	208 (58%)	245	47 (19%)	29	2 (7%)
ALL [n = 122]	**6190**	**2573 (42%)**	**1964**	**1607 (82%)**	**552**	**270 (49%)**	**158**	**49 (31%)**

The percentage browsing of both woody and green shoots for the whole survey area is shown for each species in Table 25, and the corresponding information for each survey compartment in Tables 26, 27 and 28.

Table 25 indicates that holly and aspen have the highest percentage browsing overall for both woody shoots (87% and 83% respectively) and also green shoots (77% and 48% respectively), followed by willow for woody shoots only (76%). These results are not unexpected as these species are highly preferred deer browse species. However, surprisingly rowan, a preferred deer browse species, has the lowest percentage browsing of woody shoots (almost half that of birch) and the second lowest for green shoots (again approximately half that of birch). The reason for this may be that a high proportion of rowan 1.1 (small seedlings) and 1.2 (large seedlings) were tiny, growing very close to the ground, many of the 1.2 seedlings growing within a very low field layer vegetation or areas where there was only a low bryophyte layer. This would make them more difficult for deer, a browser rather than a grazer, to exploit.

The heaviest browsing of birch, rowan, hazel, willow, aspen and dog rose was recorded for the 1.2 (large seedling) life stage, for both woody and green shoots. Again, this reflects their increased visibility to deer of these seedlings after they have emerged from the protective field layer vegetation.

Table 25. <u>ALL SURVEY COMPARTMENTS combined</u> - Percentage herbivore browsing by species and life stage during the 2016 growing season (green shoots) & during the 12 months prior to the survey (woody shoots)

Life stage	**Period***	**Percentage browsing per species**								
		Birch	**Rowan**	**Hazel**	**Willow**	**Aspen**	**Holly**	**Oak**	**Dog rose**	**ALL spp**
1.1	**1**	4%	3%	8%	11%	22%	33%	0%	20%	**4%**
	2	51%	33%	52%	74%	78%	50%	67%	60%	**42%**
1.2	**1**	17%	17%	61%	33%	100%	88%	-	30%	**19%**
	2	85%	70%	83%	82%	100%	96%	-	100%	**82%**
2.1	**1**	3%	4%	-	0%	-	100%	-	71%	**4%**
	2	48%	40%	-	100%	-	100%	-	865	**49%**
3.1	**1**	1%	14%	-	-	-	-	-	-	**2%**
	2	31%	29%	-	-	-	-	-	-	**31%**
All life stages	**1**	**8%**	**4%**	**13%**	**14%**	**48%**	**77%**	**0%**	**39%**	**7%**
	2	**62%**	**37%**	**55%**	**76%**	**83%**	**87%**	**67%**	**83%**	**51%**

* 1 = browsing during the 2016 growing season (green shoots); 2 = browsing during the 12 months prior to the survey (woody shoots).
NB. Aspen, holly, oak and dog rose have very low sample sizes in each life stage.

This pattern repeats itself in the three woodland survey compartments (Tables 26-28), with higher browsing of 1.2 (large seedlings) compared with 1.1 (small seedlings) for all species, and the browsing of both woody shoots and green shoots of rowan being markedly less than that of birch, in all three compartments. Additionally hazel shows relatively high levels of browsing, particularly of woody shoots of 1.2 (large seedlings) in each compartment.

Table 26. <u>SURVEY COMPARTMENT 1</u> - Percentage herbivore browsing by species and life stage during the 2016 growing season (green shoots) & during the 12 months prior to the survey (woody shoots)

Life stage	Period*	Percentage browsing per species								
		Birch	**Rowan**	**Hazel**	**Willow**	**Aspen**	**Holly**	**Oak**	**Dog rose**	**ALL spp**
1.1	**1**	5%	4%	10%	16%	22%	0%	0%	100%	**6%**
	2	59%	50%	60%	75%	78%	100%	67%	100%	**56%**
1.2	**1**	24%	33%	64%	44%	100%	67%	-	-	**28%**
	2	96%	75%	86%	78%	100%	100%	-	-	**92%**
2.1	**1**	6%	17%	-	0%	0%	100%	-	-	**7%**
	2	92%	50%	-	100%	0%	100%	-	-	**89%**
3.1	**1**	0%	0%	-	-	-	-	-	-	**0%**
	2	84%	25%	-	-	-	-	-	-	**78%**
All life stages	**1**	**11%**	**5%**	**14%**	**19%**	**47%**	**60%**	**0%**	**100%**	**10%**
	2	**76%**	**52%**	**62%**	**76%**	**76%**	**100%**	**67%**	**100%**	**65%**

* 1 = browsing during the 2016 growing season (green shoots); 2 = browsing during the 12 months prior to the survey (woody shoots).
NB. Aspen, holly, oak and dog rose have very low sample sizes in each life stage.

Table 27. SURVEY COMPARTMENT 2 - Percentage herbivore browsing by species and life stage during the 2016 growing season (green shoots) & during the 12 months prior to the survey (woody shoots)

Life stage	Period*	Percentage browsing per species								
		Birch	**Rowan**	**Hazel**	**Willow**	**Aspen**	**Holly**	**Oak**	**Dog rose**	**ALL spp**
1.1	**1**	6%	1%	3%	10%	-	40%	-	-	**3%**
	2	32%	25%	15%	81%	-	40%	-	-	**28%**
1.2	**1**	25%	14%	67%	43%	50%	94%	-	0%	**26%**
	2	87%	83%	67%	43%	100%	100%	-	100%	**86%**
2.1	**1**	3%	0%	-	-	-	-	-	-	**2%**
	2	35%	100%	-	-	-	-	-	-	**38%**
3.1	**1**	0%	-	-	-	-	-	-	-	**0%**
	2	14%	-	-	-	-	-	-	-	**14%**
All life stages	**1**	**12%**	**3%**	**8%**	**16%**	**50%**	**81%**	**-**	**0%**	**8%**
	2	**51%**	**32%**	**19%**	**74%**	**100%**	**86%**	**-**	**100%**	**41%**

* 1 = browsing during the 2016 growing season (green shoots); 2 = browsing during the 12 months prior to the survey (woody shoots).

NB. Aspen, holly, oak and dog rose have very low sample sizes in each life stage.

Table 28. <u>SURVEY COMPARTMENT 3</u> - Percentage herbivore browsing by species and life stage during the 2016 growing season (green shoots) & during the 12 months prior to the survey (woody shoots)

Life stage	Period*	Percentage browsing per species								
		Birch	Rowan	Hazel	Willow	Aspen	Holly	Oak	Dog rose	ALL spp
1.1	1	2%	3%	0%	5%	-	-	-	0%	**3%**
	2	51%	25%	43%	72%	-	-	-	50%	**35%**
1.2	1	11%	14%	0%	19%	-	80%	-	43%	**13%**
	2	79%	65%	100%	96%	-	80%	-	100%	**76%**
2.1	1	1%	0%	-	0%	-	-	-	71%	**3%**
	2	28%	29%	-	100%	-	-	-	86%	**30%**
3.1	1	2%	33%	-	-	-	-	-	-	**3%**
	2	18%	33%	-	-	-	-	-	-	**19%**
All life stages	1	**5%**	**5%**	**0%**	**7%**	**-**	**80%**	**-**	**42%**	**5%**
	2	**57%**	**31%**	**50%**	**76%**	**-**	**80%**	**-**	**79%**	**45%**

* 1 = browsing during the 2016 growing season (green shoots); 2 = browsing during the 12 months prior to the survey (woody shoots).
NB. Aspen, holly, oak and dog rose have very low sample sizes in each life stage.

5.3.2 Herbivore signs

Table 29 shows the percentage of plots where one or more of six indicators of deer occupancy were recorded during the survey.

Table 29. Percentage of survey plots with one or more signs of recent herbivore occupancy (by compartment)

Compartment	No. of survey plots	% of survey plots with each herbivore sign					
		Tracks, black with regular use	Tracks, green with light use	Wallows and/or obvious poaching	Pellet groups	Lying up areas	Herbivore prints (lighter than poaching)
1	46	57%	11%	7%	52%*	2%	9%
2	21	67%	29%	5%	52%	5%	33%
3	55	33%	25%	0%	38%	4%	29%
ALL	**122**	**48%**	**20%**	**3%**	**46%***	**3%**	**22%**

* Includes one plot with a single sheep pellet group and no deer pellet groups

The most common indicators recorded within the survey plots were tracks black with regular use (48% of plots) and deer pellet groups, recorded in 46% of plots. The frequency of wallows or obvious poaching due to very heavy occupancy was very low (3% of plots) as was the frequency of herbivore lying up areas (3%).

5.3.3 Herbivore impacts

Tables 30 - 33 show the percentage of survey plots where seven indicators of browsing and occupancy were recorded by degree of severity, in addition to the relative overall score for each impact level within each survey compartment. All impacts likely to have occurred during the 12 months prior to the date of survey were included but obviously older impacts were not recorded.

For each survey plot the relative score for each impact level was calculated as a proportion of the total number of browsing indicators present in the plot. So for example if all seven browsing indicators were present in a plot and three were classed as having very high impact the score for that impact level within the plot would be 3 divided by 7 or 0.423. The total of the scores for impact levels for each plot would therefore add up to 1, so each score would be a proportion of 1. These scores were then averaged for each impact level by summing them for all plots and dividing the total by the number of survey plots to give an overall relative score for each impact level at the scales of the whole survey area and each component survey compartment.

Table 30. Whole survey area: percentage of survey plots with different level of herbivore impact

Browsing indicator	No. of plots where indicator present	% of survey plots with impact level				
		Impact Very high	Impact high	Impact medium	Impact low	No impact
Tree basal shoots browsed	83	22%	48%	18%	10%	2%
Tree epicormic shoots browsed	75	13%	48%	27%	7%	5%
Seedlings & saplings browsed	116	1%	57%	30%	8%	4%
Bark stripping & stem breakage	87	1%	0%	25%	42%	31%
Preferentially browsed species browsed	99	0%	1%	10%	63%	26%
Sward browsed/grazed	121*	0%	7%	21%	65%	7%
Ground disturbance	121*	0%	2%	22%	63%	13%
Overall relative score for each impact level (from a maximum score of 1.00):		**0.037**	**0.211**	**0.209**	**0.406**	**0.138**

* Herbivore impact was not recorded for one survey plot so the total sample is 121 plots for this attribute.

Table 31. COMPARTMENT 1: percentage of survey plots with different level of herbivore impact

Browsing indicator	No. of plots where indicator present	% of survey plots with impact level				
		Impact Very high	Impact high	Impact medium	Impact low	No impact
Tree basal shoots browsed	32	16%	47%	22%	13%	3%
Tree epicormic shoots browsed	25	12%	52%	20%	8%	8%
Seedlings & saplings browsed	43	0%	60%	23%	12%	5%
Bark stripping & stem breakage	33	3%	0%	30%	39%	27%
Preferentially browsed species browsed	35	0%	0%	20%	63%	17%
Sward browsed/grazed	46	0%	11%	22%	63%	4%
Ground disturbance	46	0%	2%	39%	54%	4%
Overall relative score for each impact level (from a maximum score of 1.00):		**0.032**	**0.218**	**0.250**	**0.406**	**0.095**

Table 32. COMPARTMENT 2: percentage of survey plots with different level of herbivore impact

Browsing indicator	No. of plots where indicator present	% of survey plots with impact level				
		Impact Very high	Impact high	Impact medium	Impact low	No impact
Tree basal shoots browsed	17	35%	41%	18%	0%	6%
Tree epicormic shoots browsed	17	24%	35%	35%	0%	6%
Seedlings & saplings browsed	20	0%	45%	55%	0%	0%
Bark stripping & stem breakage	18	0%	0%	44%	33%	22%
Preferentially browsed species browsed	18	0%	0%	11%	72%	17%
Sward browsed/grazed	21	0%	5%	33%	57%	5%
Ground disturbance	21	0%	5%	19%	76%	0%
Overall relative score for each impact level (from a maximum score of 1.00):		**0.068**	**0.185**	**0.288**	**0.386**	**0.074**

Table 33. COMPARTMENT 3: percentage of survey plots with different level of herbivore impact

Browsing indicator	No. of plots where indicator present	% of survey plots with impact level				
		Impact Very high	Impact high	Impact medium	Impact low	No impact
Tree basal shoots browsed	34	21%	53%	15%	12%	0%
Tree epicormic shoots browsed	33	9%	52%	27%	9%	3%
Seedlings & saplings browsed	53	2%	58%	26%	8%	6%
Bark stripping & stem breakage	36	0%	0%	11%	50%	39%
Preferentially browsed species browsed	46	0%	2%	2%	59%	37%
Sward browsed/grazed	54*	0%	4%	15%	70%	11%
Ground disturbance	54*	0%	0%	9%	65%	26%
Overall relative score for each impact level (from a maximum score of 1.00):		**0.029**	**0.214**	**0.143**	**0.414**	**0.200**

* Herbivore impact was not recorded for one survey plot so the total sample is 54 plots for this attribute.

At all scales the overall relative scores give an indication of the proportional influence of each level of impact on the woodland structure and composition. Tables 30 to 33 show that *low impact* has the highest score for the whole survey area and for each component survey compartment, and that the combined scores for *low impact* and *no impact* are higher than the combined scores for *medium, high* and *very high* impacts combined in all cases other than survey compartment 2. These data would therefore suggest that herbivore browsing impact should be described as 'low', if each of the seven indicators were of equal importance.

The most frequently recorded browsing indicators with a *high* or *very high'* impact were b*rowsing of tree basal shoots*, *browsing of tree epicormic shoots* and *browsing of seedlings or saplings. Bark stripping or stem breakage, browsing of preferentially browsed field layer species, browsing of the sward* and *ground disturbance* were infrequently recorded as having a *high* or *very high* impact. The *browsing of seedlings and saplings* was the most frequently recorded browsing indicator with a *high* impact. This pattern was repeated across each of the woodland compartments (catchments) and ownerships.

The field layer vegetation can include a number of species which are preferentially browsed by deer and sheep (see the Woodland Grazing Toolbox). These can therefore be used to indicate the severity of browsing and grazing impacts. Such species present at Ardvar include: *blaeberry, bramble, greater woodrush, ivy, honeysuckle, bog myrtle* and *ferns (other than bracken).* Additionally their presence and growth status gives an indication of the condition and potential diversity of the field layer vegetation.

Table 34 shows the number and percentage of plots containing each preferentially browsed species for each woodland compartment, and at the scale of the whole woodland. The Table indicates that *Blaeberry* was not recorded in any of the plots in compartment 1, *greater woodrush w*as not recorded in any plots in compartments 1 and 2, and *Ivy* was not recorded in any plots in compartments 2 and 3.

Ferns other than bracken were the most frequently recorded group in all compartments; 61% of plots in compartment 1, 76% in compartments 2 and 3, and 70% of all plots. More than 80% of these records were hard fern (*Blechnum spicant*). Other than in compartment 1, *blaeberry* was the next most frequently recorded species at 14% of plots in compartment 2 and 20% in compartment 3, followed by *honeysuckle* at 11% of plots in compartment 1, 5% in compartment 2, 9% in compartment 3, and 9% overall. *Bramble* was recorded in 11% of plots in compartment 1 and 14% of plots in compartment 2 although it was infrequently recorded in compartment 3. *Ivy, greater woodrush* and *bog myrtle* were infrequently recorded in the plots in all compartments.

The data therefore suggest that the distribution of preferentially browsed species, other than ferns, is currently limited at Ardvar, particularly with regard to *greater woodrush* and *ivy*. *Bog myrtle* also appears to have a limited distribution but this only applies to the woodland habitat and its immediate regeneration zone. General observations indicate that it is fairly widespread in other open habitats with impeded drainage. The comparison with Loch a' Mhuilinn shows that there is a wider distribution of *bramble, greater woodrush*, *ivy* and *honeysuckle* at this site whereas f*erns* (other than bracken) and blaeberry are more widely distributed at Ardvar.

Table 34. The number & percentage of plots with each preferentially browsed species at Ardvar, compared with Loch a' Mhuilinn

Pref browsed species	Ardvar								Loch a' Mhuilinn	
	Compartment 1 (n = 46)		Compartment 2 (n = 21)		Compartmen t 3 (n = 55)		All compartments (n= 122)		Ring fenced area (n = 35)	
	No. plots	% plots	No. plots	% plots	No. plots	% plots	No. plots	% plots	No. plots	% plots
Blaeberry	0	0%	3	14%	11	20%	**14**	**11%**	**1**	**3%**
Bramble	5	11%	3	14%	1	2%	**9**	**7%**	**8**	**23%**
Greater woodrush	0	0%	0	0%	1	2%	**1**	**<1%**	**8**	**23%**
Ivy	1	2%	0	0%	0	0%	**1**	**1%**	**5**	**14%**
Honeysuckle	5	11%	1	5%	5	9%	**11**	**9%**	**24**	**69%**
Bog myrtle	1	2%	0	0%	2	4%	**3**	**2%**	**1**	**3%**
Ferns*	28	61%	16	76%	42	76%	**86**	**70%**	**20**	**57%**
No & % of plots with 1 or more species **	**34**	**74%**	**19**	**90%**	**44**	**80%**	**99**	**80%**		

(* excluding bracken; **figures include plots with >1 preferentially browsed species recorded)

The percentage of plots where at least one preferentially browsed species was recorded was high in each woodland compartment, at 74% in compartment 1, 90% in compartment 2 and 80% in compartment 3.

5.3.4 Overall evaluation of herbivore impacts

The overall relative scores in Tables 30-33 are highest for the 'low' impact level. However, that does not mean that the overall impact is low, because the methodology requires that the final conclusion about the overall impact level needs to consider the relative priorities of each of the browsing indicators. In other words, the seven indicators are not of equal importance, and in these woods the indicator *'browsing of seedlings and saplings'* is of primary importance. Taking this priority into account, the overall result should be classed as 'medium', noting the following points:

- 7% of all seedlings/saplings combined were browsed during the 2016 growing season (*green shoots*) and 51% were browsed in the 12 months prior to the survey (*woody shoots*).
- Herbivore tracks black with regular use (predominantly red deer) were recorded in 48% of plots and herbivore pellet groups in 46% of plots suggesting that, whilst deer densities may be low (as indicated by an average 1 PG/plot), they are widely distributed within the woodland areas.
- The assessments of the indicator *browsing of seedlings and saplings were dominated by the 'High' category*.

- Those species with the potential to develop a woodland understorey, which is currently largely missing, including holly, willow and hazel have a relatively high overall incidence of browsing of both woody and green shoots, limiting the full expression of this component of the woodland structure.
- The marked reduction in the stocking of saplings of both classes (*established regeneration*) compared with the stocking of *advance regeneration,* together with the incidence of browsing observed, suggests that herbivore browsing is currently limiting the progression of small seedlings through the subsequent life stages.

Whilst it is not possible to determine with any certainty in which season or seasons damage from deer browsing is heaviest, the fact that the browsing of the 2016 growing season's *green shoots* is relatively low compared with the browsing of *woody shoots* in the full 12 months before the survey date, suggests that "winter/ early spring" may be the time of heaviest impact. This conclusion would seem logical as deer are likely to return to the best areas of shelter and feeding within the woodland, as the weather deteriorates in late autumn, and the upland vegetation senesces and loses food value (Clutton-Brock and Albon, 1989).

If this is the case, "winter" deer browsing is still at a level which is preventing the large cohort of small seedlings from recruiting as large seedlings and saplings at any significant scale, although there are localised patches of recent, predominantly birch, regeneration on lower lying areas.

It was hypothesised that deer browsing impacts may be higher in areas where seedling/sapling stocking density was the greatest, and therefore provided better feeding for deer. However when this was examined by means of scatter diagrams, and tested using the correlation coefficient [r] there was no statistically significant correlation between plot stocking density and either browsing impact on *green shoots* during the 2016 growing season, or on *woody shoots* during the 12 months prior to the survey (see Figures 5 and 6 in Annex 2). Although again it must be acknowledged that there may be other interacting factors obscuring the relationship.

6. COMPARISONS WITH THE 2008 LOCH A' MHUILINN WOODLAND PROFILE SURVEY, THE 2007 ARDVAR WOODLAND PROFILE SURVEY & HERBIVORE IMPACT SURVEY (2008), AND THE "WOODS OF ASSYNT" REPORT TO THE ASSYNT CROFTERS TRUST (2000)

The existence of data from the first two surveys described above allows both temporal and spatial comparisons of the 2016 Ardvar data with similar data collected for the Ardvar woodlands in 2007 (Beck, 2009), and with data collected in 2008 for the Loch a' Mhuilinn woodland (Clifford & Clifford, 2008). Additionally, as the Loch a' Mhuilinn woods were ring-fenced against stock and deer in 1978, following the removal of sheep in 1974, this also allows a comparison between management "treatments" as the Ardvar woodlands are largely unfenced.

Additionally the report on the "Woods of Assynt" (Noble, 2000) provides a useful qualitative account of the history of the woods, which gives the context against which the results of the current survey can be considered.

6.1 Stocking density of seedlings & saplings

6.1.1 Ardvar Woodlands in 2016 vs 2007

The 2007 Woodland Profile and Herbivore Impact Survey within the Ardvar Woodlands SSSI, was based on a similar systematic grid-based one percent sample (Beck, 2009), and reported that 58% of all stems/ha comprised *small seedlings* (life stage 1.1), and only 7% *large seedlings* (life stage 1.2). However, as her data also included all tree life stages from *young reproductive trees >7cm DBH* up to *over-mature senescent trees,* it is not directly comparable with the 2016 Ardvar survey data. It was, however, reported that "*the proportion of established seedlings throughout the woodland is low compared to the prolific regeneration of small seedlings".*

Table 35 compares the numbers and percentages of seedlings and saplings of each life stage, and the percentage browsed, from the 2007 survey with similar data from the 2016 survey. The 2007 survey data sheets lump *large* and *small saplings* together, and the report does not specify the period over which browsing was assessed. Nevertheless broad comparisons can be made.

Table 35. Comparison between the numbers & percentages of seedlings and saplings recorded within each life stage in the 2007 and 2016 surveys at Ardvar Woodlands SSSI, and the numbers and percentages browsed.

Life stage	Ardvar 2007 survey		Ardvar 2016 Survey		
	Total # and % of all life stages	# and % browsed	Total # and % of all life stages	# and % browsed *(green shoots)*	# and % browsed *(woody shoots)*
1.1 Small seedlings	4024 (87%)	3273 (81%)	6190 (70%)	244 (4%)	2573 (42%)
1.2 Large seedlings	461 (10%)	341 (74%)	1964 (22%)	377 (19%)	1608 (82%)
2.1 Small saplings	145 (3%)	65 (45%)	552 (6%)	21 (4%)	270 (49%)
3.1 Large saplings			157 (2%)	3 (2%)	49 (31%)
ALL:	**4630**	**3679 (79%)**	**8864**	**645 (7%)**	**4499 (51%)**

The Table shows that, whilst the sample size, and hence the percentage area covered by the plots was similar in both surveys, overall almost twice as many *seedlings/saplings* were recorded in the 2016 survey. Additionally, whilst the percentage of *small seedlings* (advance regeneration) recorded in the 2016 survey was lower than the percentage recorded in 2007

(70% *vs* 87%), the percentage of *large seedlings, small saplings* and *large saplings* combined (established regeneration) was markedly higher (30% *vs* 13%).

The percentage of small and large saplings combined was also higher in the 2016 survey (8% *vs* 3%). However, caution must be used in making direct comparisons between the two surveys, as the 2007 survey did not include a 50 metre regeneration zone around woodland stands, unlike the 2016 survey, although woodland edge plots were included. As a result of this, some areas of regeneration onto open ground beyond the immediate woodland edge may have been missed in the 2007 survey. Nevertheless the data suggest that there may have been an increase in the overall numbers of seedlings/saplings and the percentages of recorded in each life stage since 2007.

A comparison between the browsing data for the two surveys requires even more caution as the 2007 survey does not specify the period for which browsing was recorded. Despite these limitations, it is evident that *small seedlings* were present in high numbers and *large seedlings, small saplings* and *large saplings* in low numbers in both 2007 and 2016, and that the incidence of browsing was high across all life stages in the 2007 survey and moderate in the 2016 survey.

6.1.2 Ardvar woodlands in 2016 vs Loch a' Mhuilinn woodlands in 2008

Like the Ardvar woodland, the Loch a'Mhuilinn native woodland is highly oceanic and located on similar Lewisian Gneiss geology, with a similar range of soils and pattern of open ground and woodland habitats, and is a component part of the same SAC.

Environmental conditions at the two sites are therefore similar and differences in stocking density are likely to be primarily the result of levels of browsing. The ring-fenced area at Loch a' Mhuilinn (first fenced in 1978) is not completely deer free, as there is a resident population of mainly roe deer that is variable but generally low. The two small experimental deer proof enclosures (monitoring plots) erected in 2003 to demonstrate the full potential for the restoration of the woodland structure and associated biodiversity are, however, completely deer free as they are very small (approximately 0.121 ha and 0.125 ha).

Table 36 compares the average stocking density of each life stage and each species in 2016 at Ardvar with similar data collected at Loch a' Mhuilin woodland in 2008.

The Table shows that the overall average stocking density in the ring-fenced area at Loch a' Mhuilinn is twice as high as at Ardvar woodlands, and six times higher in the small deer free experimental enclosures. However, the ring-fenced woodland at Loch a' Mhuilinn provides a more realistic demonstration of the potential at Ardvar than the experimental enclosures due to their very small size. It comprises a similar woodland structure and proportion of open habitats, in combination with low deer density.

A comparison between the average stocking density in this area with that at Ardvar shows that it is approximately the same for *1.1 and 1.2 seedlings* of all species combined, but that it is almost eleven times higher at Loch a'Mhuilinn for *2.1 (small saplings)* and over thirty times higher for *3.1 (large saplings).*

Table 36. Comparative average stocking density between Ardvar & Loch a' Mhuilinn woodlands, and the % contribution each species makes to each life stage at each site

Species	Average stocking (stems/ha)											
	Ardvar woodland 2016 [unenclosed woodland]				Loch a' Mhuilinn woodland 2008 [ring -fenced area]				Loch a' Mhuilinn woodland 2008 [2 small 'experimental enclosures]			
	1.1	1.2	2.1	3.1	1.1	1.2	2.1	3.1	1.1	1.2	2.1	3.1
	Adv regen	***Established regeneration***			***Adv regen***	***Established regeneration***			***Adv regen***	***Established regeneration***		
Birch	291 *(27%)*	264 *(71%)*	90 *(92%)*	25 *(93%)*	99 *(10%)*	237 *(77%)*	589 *(56%)*	700 (82%)	40 *(5%)*	120 *(3%)*	270 *(10%)*	1100 *(42%)*
Rowan	677 *(63%)*	78 *(21%)*	4 *(4%)*	1 *(4%)*	680 *(65%)*	24 *(8%)*	27 *(3%)*	33 *(4%)*	530 *(69%)*	2560 *(69%)*	1410 *(55%)*	40 *(2%)*
Hazel	36 *(3%)*	3 *(1%)*	0	0	182 *(17%)*	23 *(7%)*	33 *(3%)*	76 *(9%)*	200 *(26%)*	1070 *(28%)*	900 *(35%)*	1500 (56%)
Willow	69 *(6%)*	17 *(5%)*	2 *(2%)*	0	9 *(1%)*	17 *(6%)*	399 *(38%)*	31 *(4%)*	0	0	0	0
Aspen	6 *(1%)*	*5 (1%)*	<1 *(<1%)*	0	64 *(6%)*	1 *(<1%)*	1 *(<1%)*	0	0	0	0	0
Holly	1 *(<1%)*	4 *(1%)*	<1 *(<1%)*	0	0	0	0	0	0	0	0	0
Oak	1 *(<1%)*	0	0	0	7 *(1%)*	7 *(2%)*	0	9 *(1%)*	0	0	0	0
ALL spp	**1081**	**372**	**98**	**27**	**1041**	**309**	**1049**	**849**	**770**	**3750**	**2580**	**2640**
All life stages	**1578**				**3248**				**9740**			

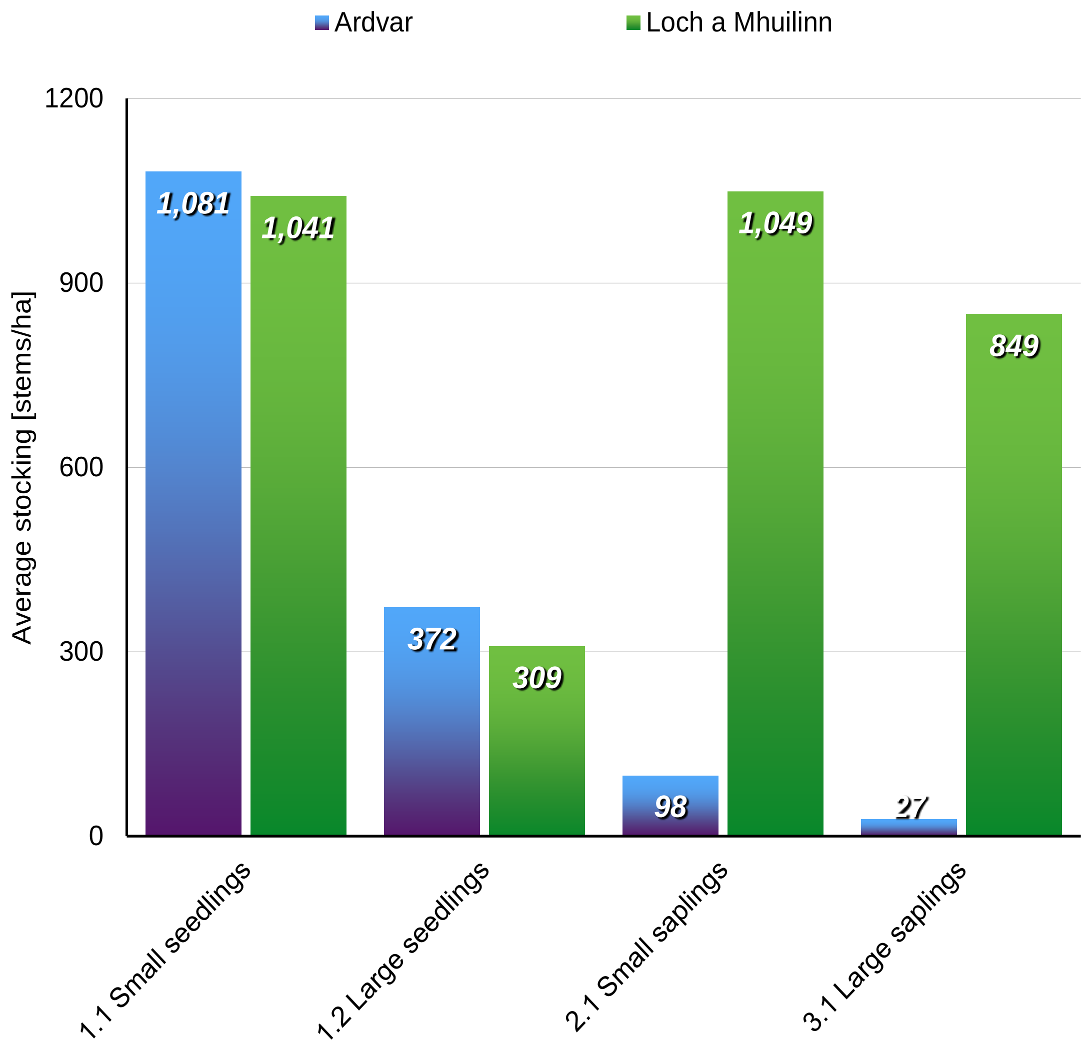

Figure 2. Seedling and sampling life stages

The comparison between the average stocking density of each life stage at Ardvar woodlands with that within the ring-fenced woodland at Loch a' Mhuilinn, which has a small resident roe deer population but only infrequent marauding red deer which are shot out, is graphically illustrated in the figure above. The different shapes of the histograms is striking and clearly demonstrates the potential for improvement in the structure of woodland regeneration over the long term at Ardvar, and consequently in the overall structure, extent and continuity of mature woodland on the site. It also demonstrates the weak large seedling life stage at Ardvar, suggesting that seedlings there are sustaining increased levels of browsing as they rise above the height of the surrounding field lawyer vegetation and become visible to deer.

6.1.3 Ardvar woodlands in 2016 vs the historical context

Robin Noble's (2000) report on the Woods of Assynt provides a useful historical context against which the results of the 2016 survey results can be considered.

The report makes the following historical observations that apply to the Ardvar woodlands:

- According to Home's 1774 Survey of Assynt, oak was more common at that time, losing its dominance on the south facing slopes of Creag Dharaich and Gleann Leiraig as a result of an increasing local population around 1800.
- A period of renewed regeneration, of mainly birch, began about 65 years ago, without any evidence of a real reduction in sheep. He hypothesises that this may have been due to the coming of electricity in 1952 when cutting of wood for fuel ceased and horses were removed from around the crofts.

And the following observations about the deer population:

- Forty years ago (1960) there were very few red deer present in coastal Assynt, (although some roe deer were present), except for a "small herd" in and around the Gleann Leiraig woods.
- Since then the population has increased, "t*here are signs everywhere*", and the population is now too high to permit regeneration, especially in remote parts away from habitation.
- Woods in upper Gleann Leiraig are now senescent due to too many deer, and some deer induced erosion is present on the steeper slopes.

His conclusion was that, if the deer population remains at 2000 levels, the diversity of the woodland structure will decline, bracken will invade areas suitable for woodland regeneration and woodland fragmentation will increase.

6.2 Herbivore impacts

Beck (2009) found that 81% of all *seedlings* were damaged by browsing in the 12 month period prior to the 2007 survey at Ardvar, which compares to the figure of 51% recorded in the 2016 survey for the equivalent period, suggesting reduced deer impact since 2007.

Beck (2009) also stated that *"tracking and dunging by red deer was found throughout the unenclosed areas of woodland"* in 2007, whereas the 2016 survey found that regularly used deer tracks occurred in 48% of the survey plots and red deer pellet groups were found in only 46% of plots. These figures support the conclusion that there has been a marked decrease in deer occupancy within and adjacent to the Ardvar woodland, although this doesn't yet appear to have translated into any significant recruitment of seedlings into the sapling life stages.

7. RISKS TO THE CONSERVATION OBJECTIVES

7.1 Risks to the SAC Conservation Objectives

The SAC Conservation Objectives are based on the requirements of the Habitats Directive [02/43/EEC], which obliges the Scottish Government to ensure the implementation of measures to *'avoid deterioration'* of natural habitats and the habitats of species within Special Areas of Conservation (SAC), as well as disturbance of species for which the site has been designated, and to ensure that the qualifying habitats are maintained in *'favourable condition'*. Table 37 shows the SAC Conservation Objectives and the current risks to these objectives.

Table 37. Risks to the SAC Conservation Objectives

Conservation Objectives: **To ensure that the following attributes are maintained for the qualifying habitat in the long term:**	**Risks:**
Extent of the habitat on the site	The current area of *established regeneration* on the site (1.2 *large seedlings*, 2.1 *small saplings* and 3.1 l*arge saplings*) is well below the 20-25% area of "young" woodland recommended by Stone (2005), and the 12-35% *stand initiation* phase recommended by Seymour & Hunter (1999), and is therefore currently insufficient to replace the existing area of mature and over-mature woodland.
Distribution of the habitat within the site	Areas of woodland stand fragmentation and isolation already exist within the site where the canopy is becoming fragmented, and over-mature trees are not being replaced. The small scale, and patchy distribution of *established regeneration,* is not sufficient to maintain the current distribution of woodland across the site.
Structure and function of the habitat	The full range of woodland life classes are not represented within the site at any significant scale, and the woodland as a whole does not display a "reverse-J" structure where there is a steady movement of all component species through the different life stages from *small seedling* to *over-mature* tree. The under representation of *large saplings* is of particular concern and represents a significant break in woodland continuity, with implications for the continued existence of over-mature and veteran trees within the woodland, which are significant reservoirs of biodiversity. A fully developed woodland understorey of more shade tolerant species such as hazel, holly and rowan is missing from the woodland due to current levels of deer browsing, which is also suppressing the development of the full diversity of the field layer vegetation.
Processes supporting the habitat	The free movement of the existing large cohort of *advance regeneration* through all the woodland life stages up to *over-mature* trees is currently being prevented over most of the site due to browsing (Table 19-22). There may consequently be a risk to the species associated with each tree/shrub life stage, and the continuity and volume of dead wood habitat and its component species over the long term.

Conservation Objectives: **To ensure that the following attributes are maintained for the qualifying habitat in the long term:**	**Risks:**
Distribution of typical species of the habitat	Holly and oak currently have a very restricted distribution within the site, and the distribution of some preferentially browsed field layer species such as bramble, ivy, greater woodrush and honeysuckle is limited. These field layer species may exist more widely but current levels of browsing could be rendering them more or less invisible.
Viability of typical species of the habitat.	In the absence of regeneration and recruitment from one life stage to the next, the long term continuity of holly, aspen and oak, and their associated faunas on the site, is at risk.
No significant disturbance of typical species of the habitat	Browsing is a disturbance factor affecting the extent and distribution of typical species across the site. It is the primary but not the only factor potentially limiting regeneration. The NW Highlands is subject to extremes of weather and the occurrence of winter and equinoctial storms is increasing. A significant number of wind thrown mature trees already exist within the woodland and these are not currently being replaced (personal observations from walk through survey covering a high percentage of the woodland).

7.2 Risks to the SSSI Conservation Objectives

The SSSI Conservation Objectives underpin the SAC Objectives and the specific conservation objectives for the Ardvar Woodlands SSSI woodland therefore encompass woodland extent and distribution, in addition to structure, function and typical species. Table 38 shows the overall management aim, and specific management objectives for the site, along with the current risks to these objectives.

Table 38. Ardvar Woodlands SSSI Conservation Objectives/targets and Risks

Aim: To enhance the extent, structure & function, and distribution of the Upland Birchwood habitat and its typical species.	
Specific objectives/ targets to achieve favourable condition :	**Risks:**
1. The woodland habitat should have a range of typical tree & shrub species, in addition to a full range of age classes/ life stages including seedlings, saplings, young trees, mature reproductive trees and senescent/ veteran trees. Standing and fallen dead wood should also be present.	Whilst the woodland is varied in both pattern and structure, the representative component trees and shrubs are present and *advance regeneration (small seedling life stage)* occurs at high stocking density across much of the site, *established regeneration* of the full range of tree and shrub species is under represented, particularly the l*arge sapling* life stage. The woodland age/ life stage structure is therefore currently compromised by the limited proportion of *small* and *large saplings* of all species.

Aim: To enhance the extent, structure & function, and distribution of the Upland Birchwood habitat and its typical species.	
Specific objectives/ targets to achieve favourable condition :	**Risks:**
2. The woodland should have a fully developed understorey/ shub layer	Within the woodland there is a complete absence of a well-developed shrub/ understorey layer with holly, willow and to a lesser extent hazel sustaining a relatively high incidence of browsing (particularly of *woody* shoots). Consequently an important structural component is missing from the woodland. Whilst it would not be expected that birch, as a pioneer species, would regenerate under its own canopy, more shade tolerant species such as rowan, holly, and hazel have the potential to form a woodland understorey but are at present too heavily browsed back, preventing the full expression of potential woodland biodiversity.
3. The woodland ground flora/ field layer should be able to express its maximum potential diversity and structure	The proportion of survey plots where *browsing of the sward* was recorded as *low* or *no impact* was high (65% & 7% respectively) [Table 30]. This was also the case with preferentially browsed species, with *low* or *no impact*, recorded for 61% and 26% of plots respectively [Table 30]. This suggests that the current level of browsing poses a low to moderate risk to the ground flora/ field layer. However, other than ferns which occurred in 70% of the survey plots, the other preferentially browsed species, *honeysuckle, blaeberry, bramble,* g*reater woodrush, ivy* and *ferns* (other than bracken), in addition to *dog rose,* were recorded relatively infrequently in the plots and their distribution across the site appears to be limited [Table 34]. Comparison between the distribution of preferentially browsed species at Ardvar and within the Loch a' Mhuilinn ring fenced area, where browsing levels are light, shows that *bramble, greater woodrush, ivy* and *honeysuckle* are more widely distributed at Loch a' Mhuilinn. It is unclear whether this is the result of these being "missed" in some of the plots at Ardvar due to being heavily browsed back (in which case browsing would be a high risk), or whether other factors such as soil fertility, drainage or root/ shoot competition with the surrounding field layer vegetation are implicated.
4. Areas of mature woodland should not be fragmented and isolated from each other and no further fragmentation should occur.	Whilst the woodland has the potential for a significant pulse of regeneration and expansion through further reduction in browsing pressure, the current area of established regeneration (1.2 l*arge seedlings*, 2.1 *small saplings* & 3.1 *large saplings* combined) which will reach maturity before the existing mature trees senesce and die is below what is necessary (Stone, 2005; Seymour & Hunter, 1999). Consequently, the long term continuity of the mature woodland is compromised, and current established regeneration is insufficient to ensure that the future mature woodland will reflect the current distribution and extent of the existing habitat and will not be fragmented and mutually isolated.

<table>
<tr><th colspan="2">Aim: To enhance the extent, structure & function, and distribution of the Upland Birchwood habitat and its typical species.</th></tr>
<tr><th>Specific objectives/ targets to achieve favourable condition :</th><th>Risks:</th></tr>
<tr><td>5. Herbivore browsing and grazing pressure should be at a level which allows the development of a full range of woodland life stages, and a representative woodland understorey and field layer.</td><td>Whilst other potentially limiting factors have a significant impact on seedling and sapling stocking density [Table 8], this is not sufficient to prevent regeneration of trees in affected areas. Deer will seek shelter in response to low temperatures and high wind speeds (Mitchell et al., 1977). The woodland areas provide greater shelter and browsing opportunity for deer during poor winter weather than the open hill where the winter temperatures are lower, wind speeds higher, and there is senescence of non-dwarf shrub vegetation. Levels of winter occupancy and impacts are therefore heavier in the winter, and although at present considered to be ‘medium’, are still too high to allow the development of significant areas of established regeneration.

Notwithstanding this, the woodland now appears to be at a “tipping point” with the potential for a significant pulse of regeneration and expansion.</td></tr>
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8. DISCUSSION AND CONCLUSIONS

8.1 The ecological background

The key ecological characteristics of ‘upland birchwoods’ are firstly that the dominant tree species, which is a light demanding ‘pioneer’ does not regenerate successfully under woodland canopy, secondly that the predominant strategy for perpetuation involves “pulses” of regeneration following relatively infrequent episodic disturbance events in addition to “trickle” regeneration which occurs at a smaller scale where there are large enough canopy gaps as the result of the death of individuals or groups of canopy trees, and thirdly, as a result of these characteristics, that these woods are intrinsically highly mobile. Given suitable conditions of low browsing and available “safe sites” for seed germination and seedling establishment they therefore tend to oscillate around a semi-permanent core or occasionally move across the landscape through time. Given a suitable browsing/ grazing regime an understorey of more shade tolerant shrubs can establish under light woodland canopy and in canopy gaps, where seed sources are locally present.

The “reverse - J” or “normal curve” is assumed by forest ecologists to represent an idealised structure of a [semi] natural forest (Hett & Loucks, 1976), which is uneven-aged [or multi-staged], and displays a constant recruitment rate and mortality that is either constant or decreasing with age. When used in relation to age classes this curve describes what is termed by demographers as a “stable age distribution” that characterises a rapidly increasing population. However, as trees are highly plastic in their rates of growth and development, primarily in response to local environmental conditions, a Life Stage structure is more likely to provide meaningful information on which to interpret dynamics and condition. At the landscape scale therefore a “reverse – J” Life Stage structure, where each of the recognised life stages or stand development phases is represented in an irregular mosaic with associated open ground habitats at a significant scale, is considered to be desirable.

8.2 The current woodland structure

The current survey has indicated that the upland birch woodland within and immediately adjacent to the SSSI is varied in both pattern and structure, and based on the plot data and general observations walking between the plots (effectively woodland belt transects) the following structural components were identified:

- Widespread and frequent 1.1 small seedlings at generally high stocking density (average 1081/ha) with low browsing impact of green shoots (4%) and moderate browsing of woody shoots (42%), recorded in 96% of the survey plots, indicating significant potential for a new pulse of woodland regeneration.
- Widespread and frequent 1.2 large seedlings at moderate stocking density (average 372/ha), recorded in 83% of the survey plots, with moderate browsing of green shoots (19%) and a relatively high percentage of woody shoots browsed in the 12 months prior to the 2016 survey as they become visible to deer (82%), again indicating the potential for extensive woodland regeneration once released from current browsing levels.
- Patchy distribution of 2.1 small saplings at generally low-moderate stocking density (average 98/ha), recorded in 39% of the survey plots, although occasionally at high stocking density at woodland edges, with low browsing of green shoots (4%) and moderate browsing of woody shoots in the 12 months prior to the survey 49%.
- Scattered and infrequent 3.1 large saplings primarily at woodland edges, recorded in less than 20% of the survey plots, generally at very low stocking density (average 27/ha), with very low browsing of green shoots (2%) and light to moderate browsing of

woody shoots (31%). Saplings sometimes growing on low crags protected from browsing.

- Localised scattered small stands of high-density thicket birch approximately 20-25 yrs old, indicating past reductions in browsing pressure.
- Scattered small stands of high density thicket birch approximately 40-45 yrs old, mostly on the Ardvar estate, indicating past localised reductions in browsing pressure coinciding with the removal of sheep from the estate (only 2% of survey plots overall when included with the younger thicket stands described above).
- Mature birch dominated woodland with broad crowned trees at varying stocking densities, no established understorey, no or limited established regeneration and a depleted field layer in some places (36% of survey plots).
- Over-mature birch dominated woodland with senescent and moribund trees indicating canopy beak up, again with no established understorey, no or limited established regeneration, and a depleted field layer in some places (10% of survey plots).

8.3 Conclusions from the current survey

The results of this survey indicate that there is currently sufficient “capital” in terms of advance regeneration to facilitate a significant improvement in the extent structure, composition, and distribution of upland birch woodland within the site, including the restoration of representative biodiversity through the restoration of a diverse field layer and localised understorey.

However, there are a number of factors in addition to browsing with the potential to prevent or suppress natural regeneration (38% of plots have one limiting factor and 10% have two), and these have a significant impact on overall stocking density, with approximately half as many seedlings in plots with at least one of these factors.

Nevertheless, 7% of all seedlings/saplings combined were browsed during the 2016 growing season (green shoots) and 51% were browsed in the 12 months prior to the survey (woody shoots). It is therefore considered that the current level of deer browsing impact, which is classed as “medium”, is the principle factor preventing small seedlings from recruiting as established regeneration on any significant scale, although localised recruitment is occurring in some areas at the edges of mature woodland.

The woodland therefore now appears to be at a “tipping point” with the potential for a significant pulse of regeneration and expansion which could be achieved through a relatively minor sustained reduction in browsing pressure. Such a sustained reduction would secure the extent and distribution of mature canopy woodland over the whole site over the long term, in addition to allowing the development of maximum potential woodland biodiversity through the restoration of a woodland shrub layer and a diverse field layer vegetation.

8.4 Desired future woodland condition

SNH has produced a statement of its “Vision for Ardvar” (SNH, 2016) which outlines the current condition of the woodland and presents a vision for its condition in 30 years’ time. This states that the SAC/SSSI will contain “*a flourishing woodland habitat, supporting the full range of woodland species characteristic of the site including not just trees but the flowering plants, mosses, liverworts, lichens and fungi; and the insects and other animals that make up the woodland ecosystem”.* It goes on to state that *“The mature ancient woodland will have a mixed canopy of trees and a thriving understorey of shade tolerant species”* … all of which will be regenerating, in addition to a “*fully developed diverse field layer vegetation”*. It also states that the current areas of regeneration will be expanding, and recognises the role of deer in maintaining woodland structure by providing sites suitable for seedling germination and subsequent growth, and maintaining open “glade” areas in the woodland.

The results of this survey have indicated that there is the potential to improve woodland structure and extent, and ultimately to achieve the SNH vision, through the appropriate co-operative management of the deer population to reduce browsing impact.

At both the catchment (compartment) and landscape scales, the long-term maintenance of the existing woodland canopy of mature and over-mature trees, and old growth forest where it occurs, together with their current distribution across the survey area, is important to prevent deterioration in overall biodiversity and condition [Stone, 2003]. Additionally, as there are some areas where isolation and fragmentation of mature woodland occur, better connectivity between woodland stands is also highly desirable.

Oliver & Larsen (1996) recognise four distinct phases of woodland stand development [*1.stand initiation*; *2.stem exclusion*'; *3.understorey re-initiation* and *4.mature/old-growth*]. The first and third of these represent respectively natural regeneration onto open ground around existing woodland stands, and natural regeneration in canopy gaps of sufficient size within woodland stands and under low canopy woodland. Both phases comprise the *seedling* and *sapling* life stages targeted in this survey, and woodland of the scale and extent of that at Ardvar should ideally display an irregular interconnected mosaic of the four phases together with associated open habitats. However, the proportion of each phase would vary depending on the age and longevity of the trees, and the disturbance history of the site.

Both Scots pine and birch are “light demanders” which do not regenerate successfully under woodland canopy, and birch has a similar strategy for perpetuation and expansion as Scots pine. Mason *et al*. (2004) use a simple fire frequency model for a Scots pine ecosystem (Seymour & Hunter, 1999), which suggests that, with a variation in the return period of disturbance events of between 50 -150 years, the ideal relative proportions of the four different stand development phases would lie within the following ranges; *12-33% stand initiation, 29-46% stem exclusion, 15-22% understorey re-initiation and 6-37% “mature/old growth.* Stone (2005) supports this and suggests that approximately 20-25% of the woodland area at any time should be young forest cover. Under the circumstances it seems reasonable to suggest that this guidance could also be applied to upland birch woodland in the Highlands.

As already mentioned above, the long-term continuity of the existing woodland canopy of mature and over-mature trees and the niches associated with them, and as a minimum, their current distribution across the site, is essential in order to prevent deterioration in condition and overall biodiversity [SNH, 2010; Stone, 2003 & 2005]. This requires regular recruitment of new seedlings to the population and the free movement of a sufficient number of these through each of the woodland life stages to ensure the long-term continuity of this resource. Therefore, at the scale of the total resource, as noted above, the ideal Life stage structure is a ‘reverse J’ curve (Hett & Loucks, 1976), where there is constant recruitment, and mortality is either constant or reducing with age.

The minimum area of woodland habitat in which all the dynamic states and processes persist is known as the *minimum dynamic area* and is likely to be in the region of 20 hectares for woodlands in Scotland (Peterken *et al*., 1995). This is therefore considered to be the minimum viable single “patch” of woodland in terms of providing true woodland interior conditions, the full complement of associated species and avoidance of isolation and fragmentation.

Based on these characteristics a complementary long-term vision for the structure, spatial pattern and extent of the Ardvar upland birchwood in 30 years’ time might be as follows:

- It will display an irregular interconnected mosaic of the four woodland stand development phases, together with associated open habitats.
- Approximately 25% of the overall woodland area will be old growth forest, or mature forest moving towards old growth with a gradually increasing dead wood component.
- Approximately 25% of the woodland area will comprise a mixture of *advance* and *established regeneration* up to and including large saplings ≥3m ≤5m tall and <7cm DBH.
- The minimum “patch size” of individual woodland stands will be approximately 20ha.
- In those areas with sufficient light, local seed sources and suitable soils there will be a developing woodland understorey comprising hazel, holly, willow and rowan, and stands of aspen will have expanded from their current *refugia*. The field layer vegetation will display its optimum structure and diversity.
- Whilst the structure of the woodland within each of the main catchments, and at the woodland stand (patch) scale will be variable, at the landscape scale there will be a ‘reverse J’ life stage curve.

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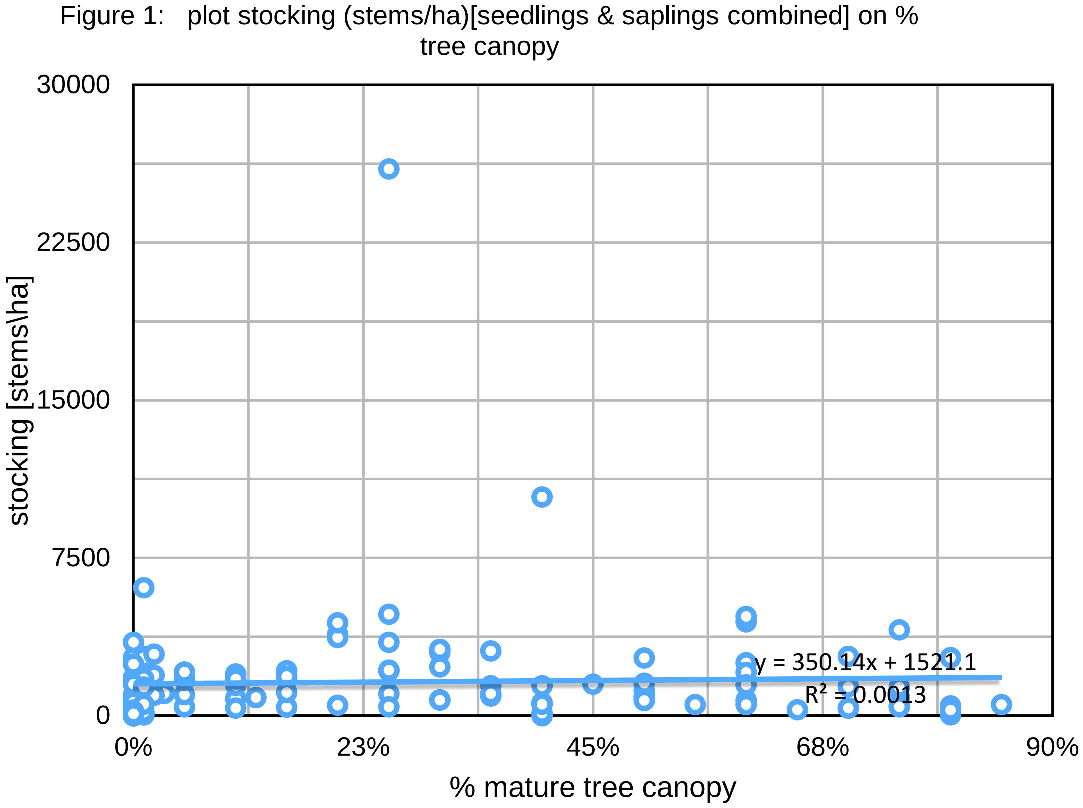
ANNEX 1: THE RAW SURVEY DATA

This annex can be downloaded from the SNH website as a separate file.

ANNEX 2: RELATIONSHIPS BETWEEN PAIRED VARIABLES – SCATTER DIAGRAMS AND CORRELATION COEFFICIENTS



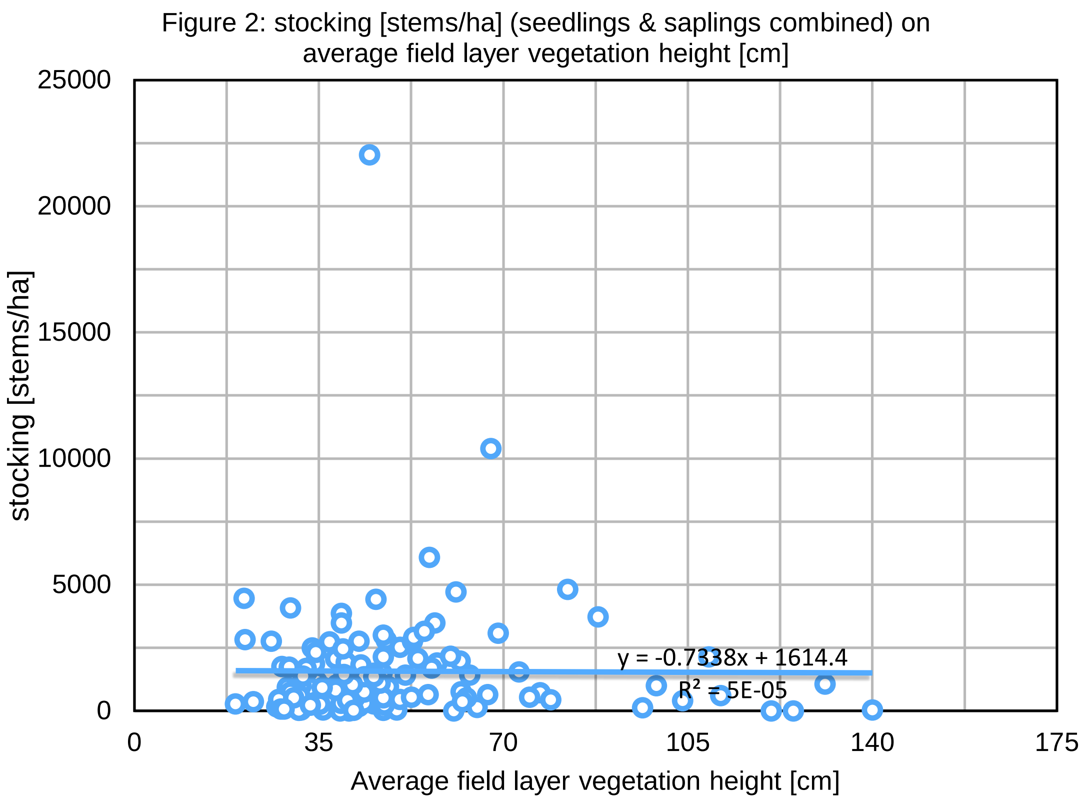


Figure 3: % of seedlings/saplings browsed in 12 months prior to 2016 survey on average vegetation height [cm]

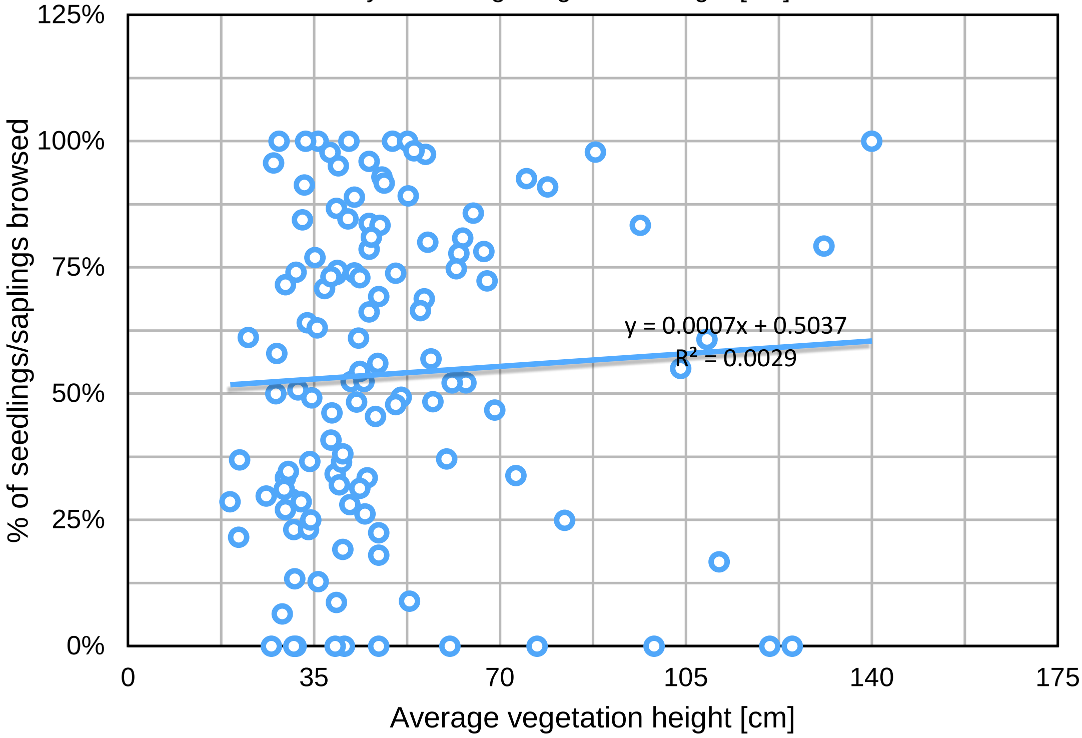


Figure 4: % browsing of seedling/saplings combined (stems/ha) during 2016 growing season on average vegetation height (cm)

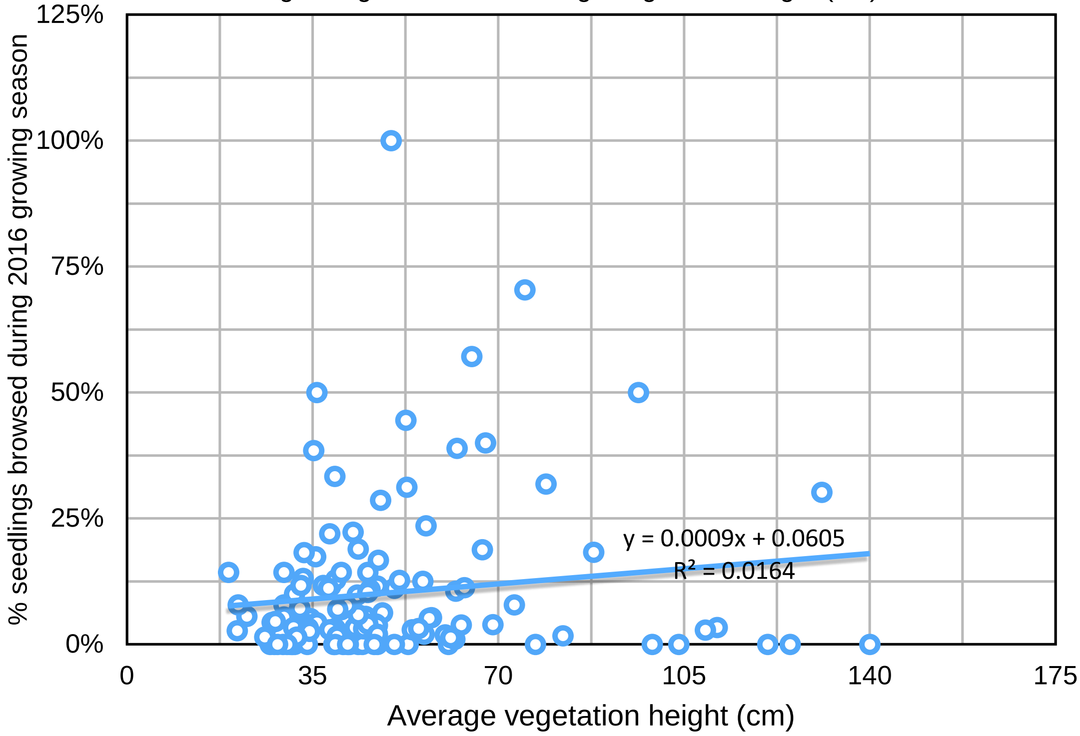


Figure 5: % browsing of seedlings/saplings combined in the 12 months prior to the survey on stocking density of seedlings/saplings (stems/ha)

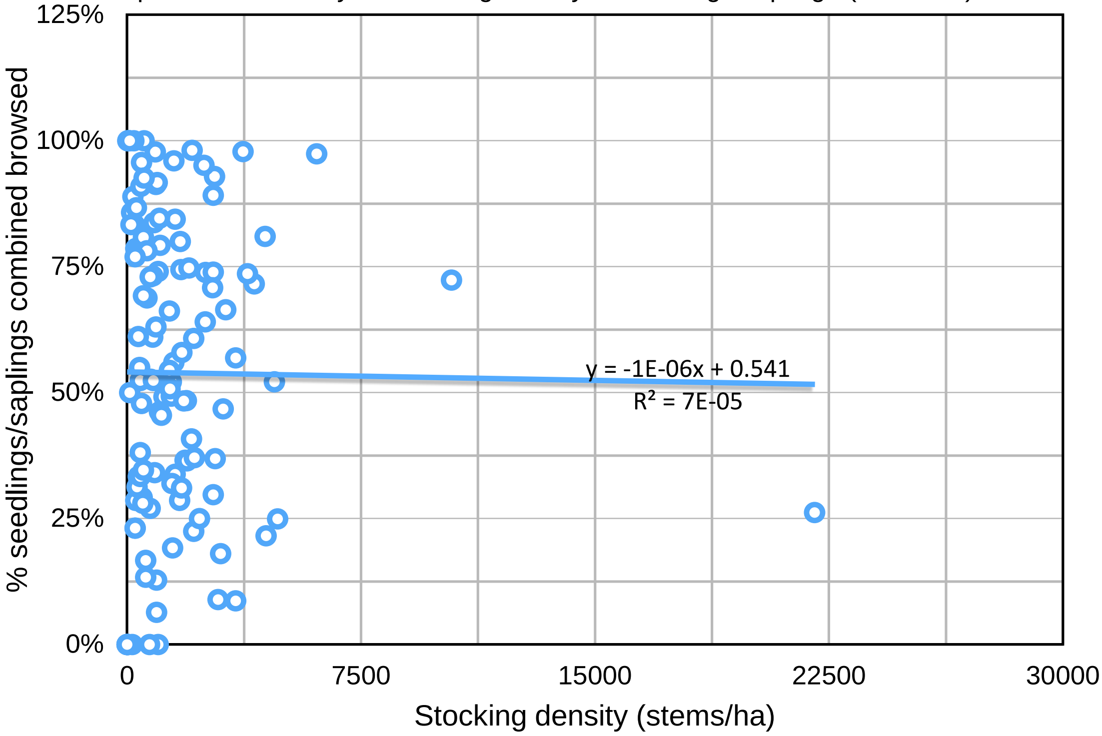


Figure 6: % browsing of seedlings/saplings combined in the 2016 growing season on stocking density of seedlings/saplings (stems/ha)

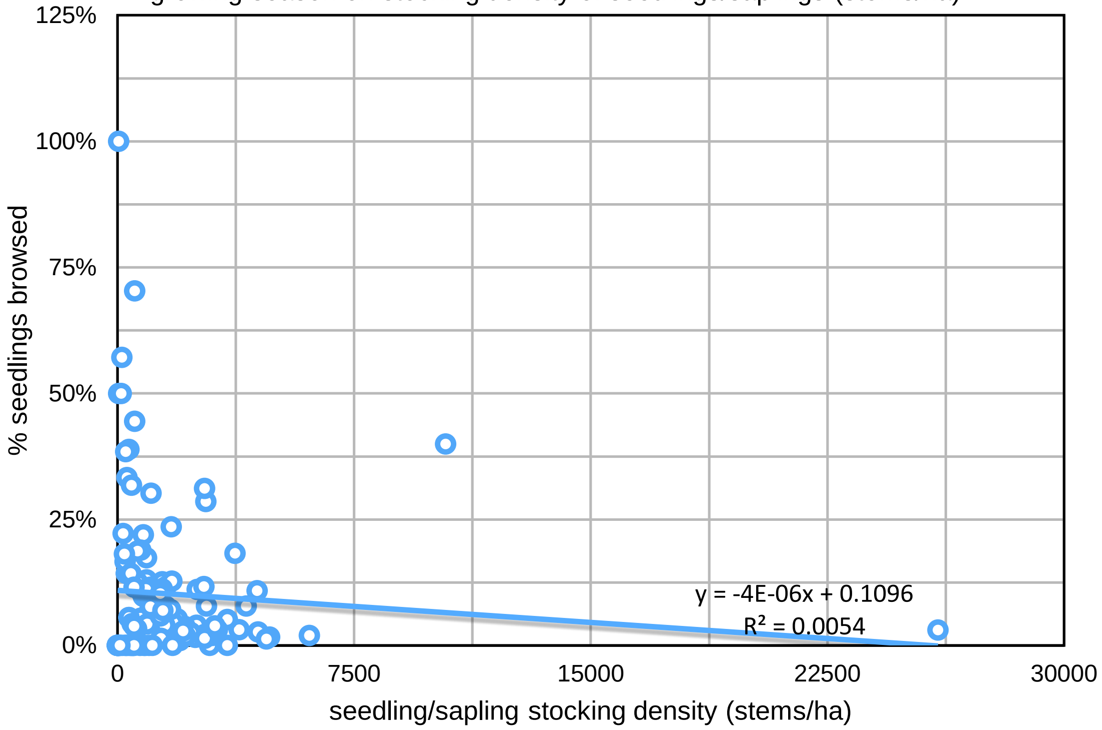


Figure 7.1: stocking of established rowan [life stages 1.2, 2.1 & 3.1 combined] on % tree canopy

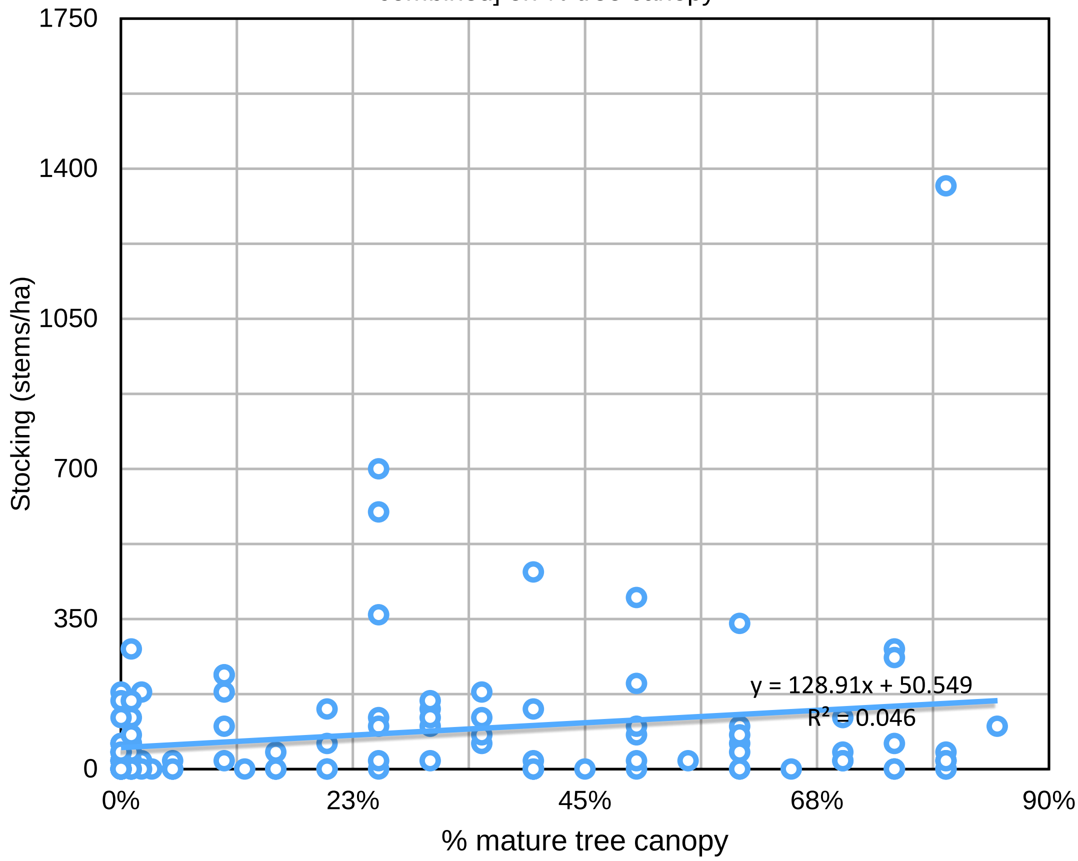
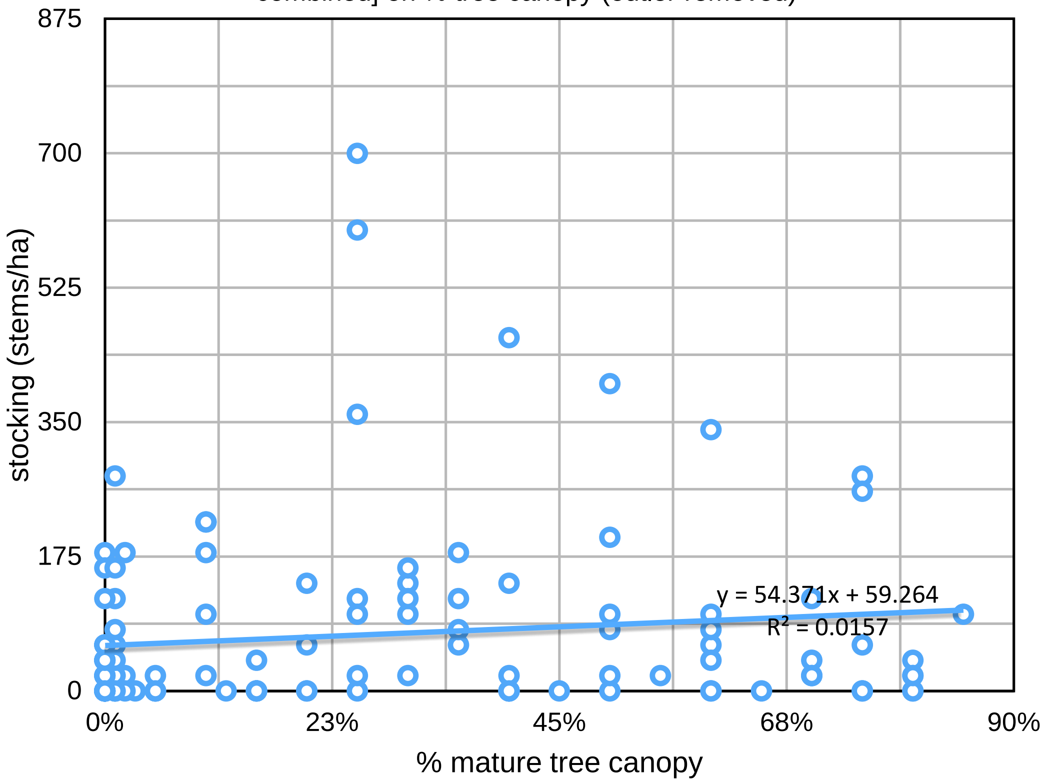
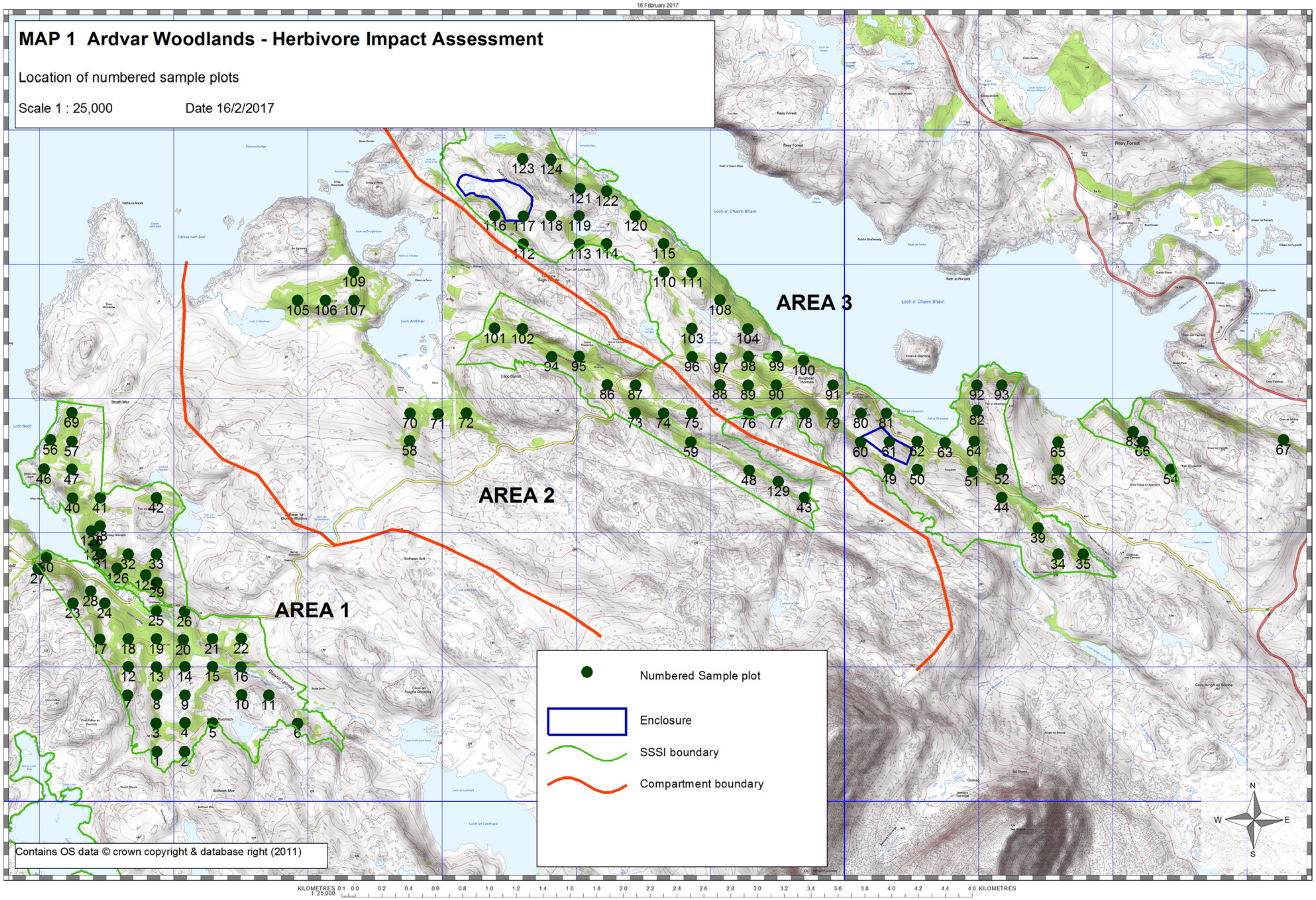
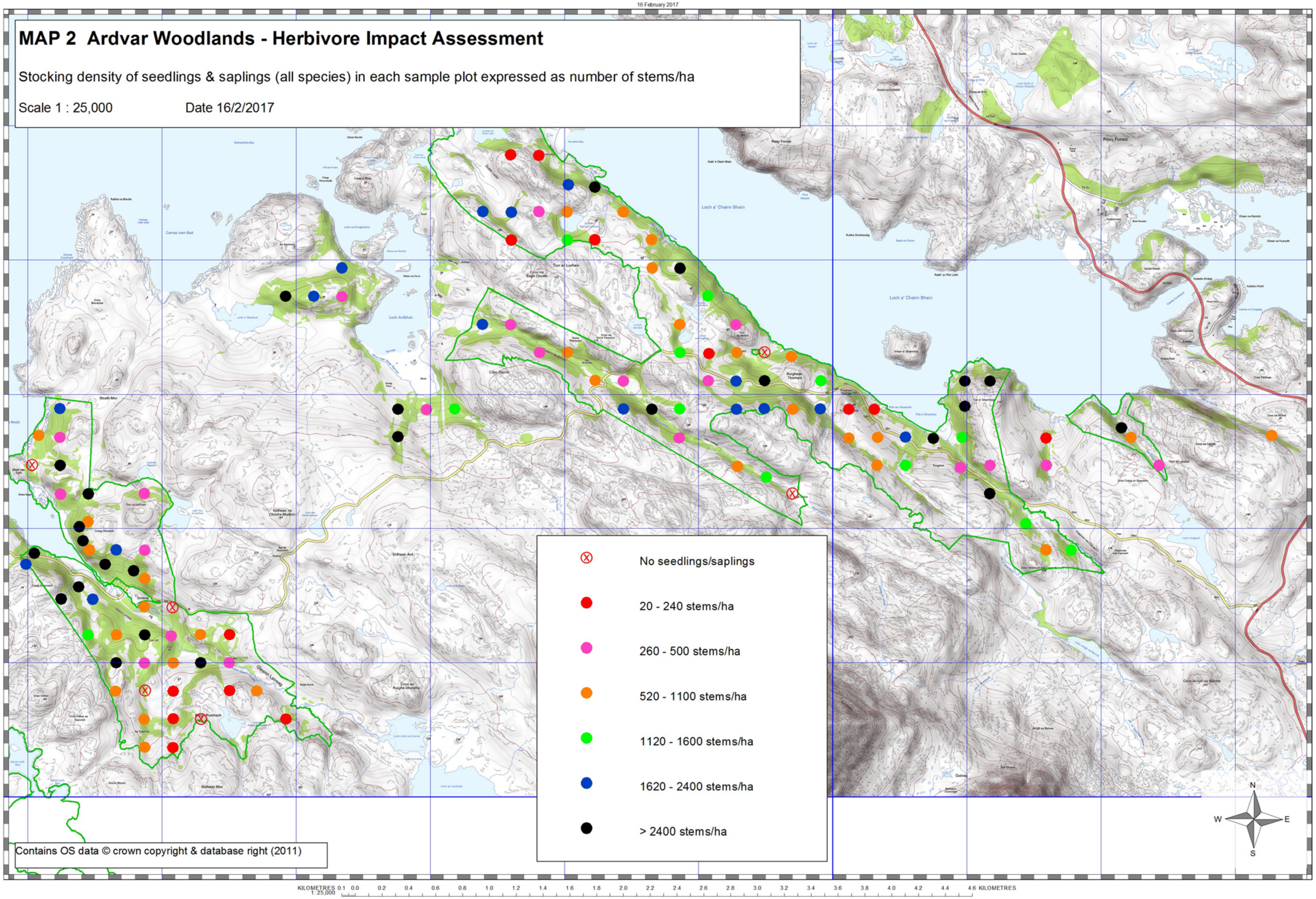


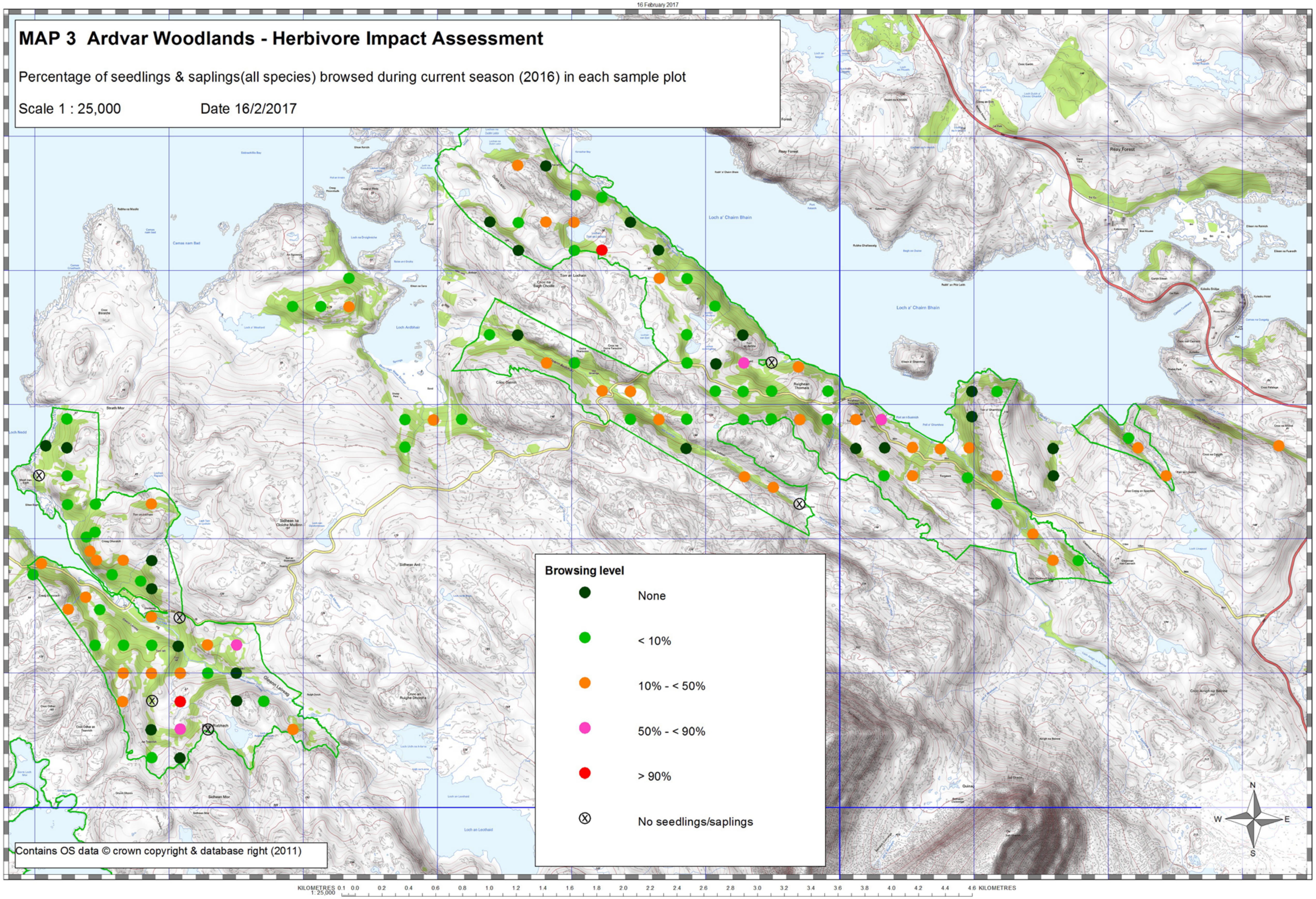
Figure 7.2: stocking of established rowan [life stages 1.2, 2.1 & 3.1 combined] on % tree canopy (outler removed)

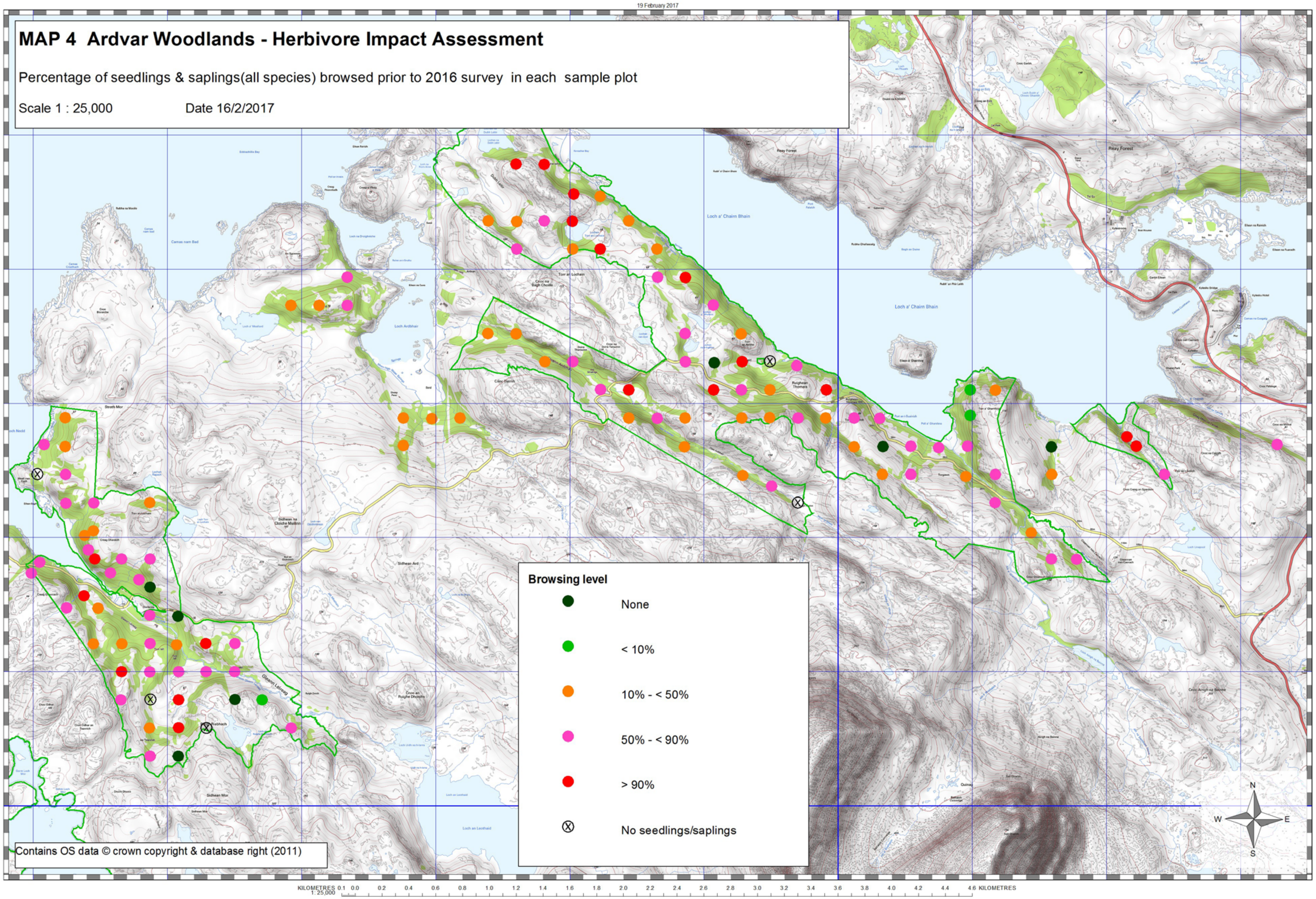


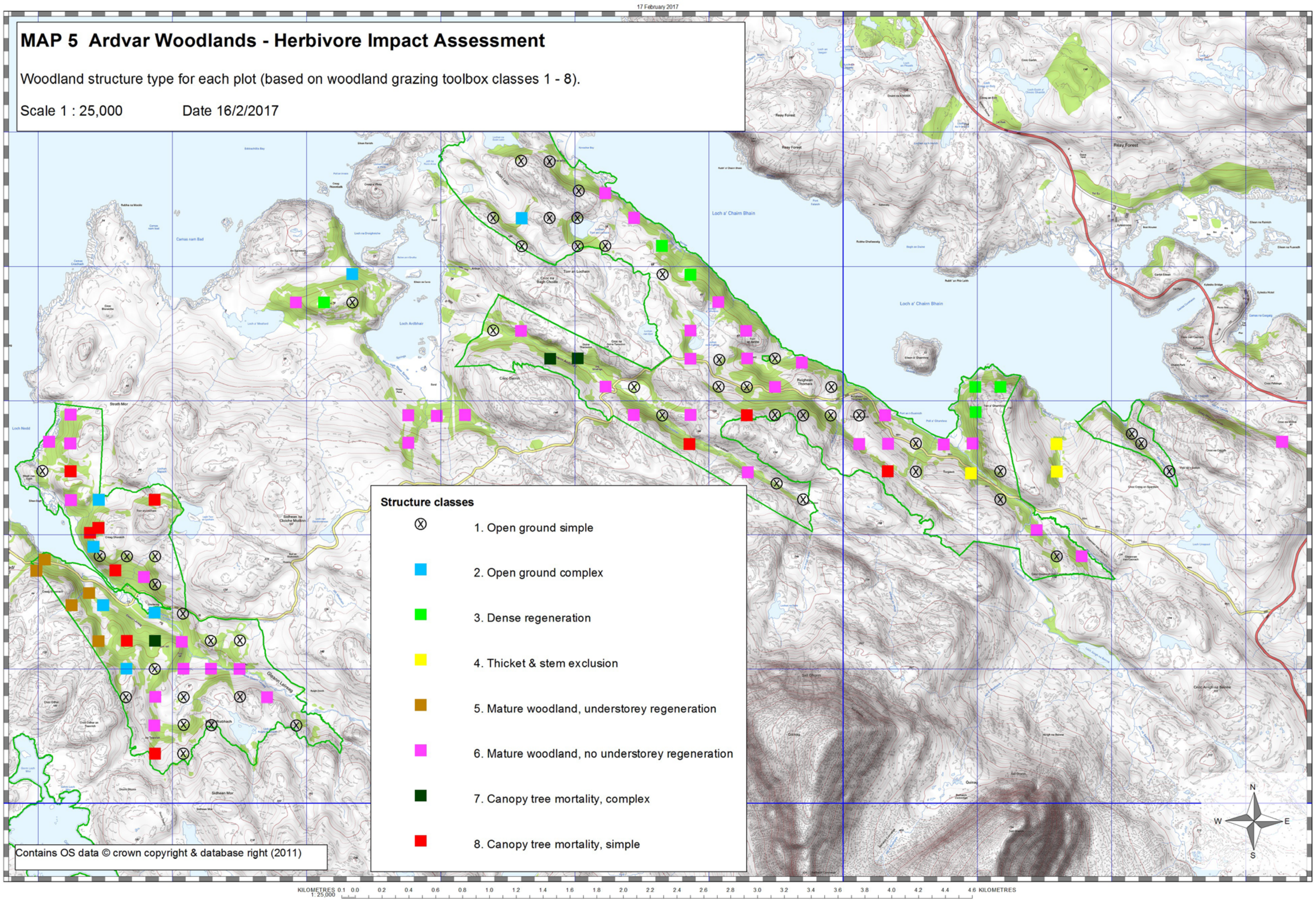
ANNEX 3: MAPS

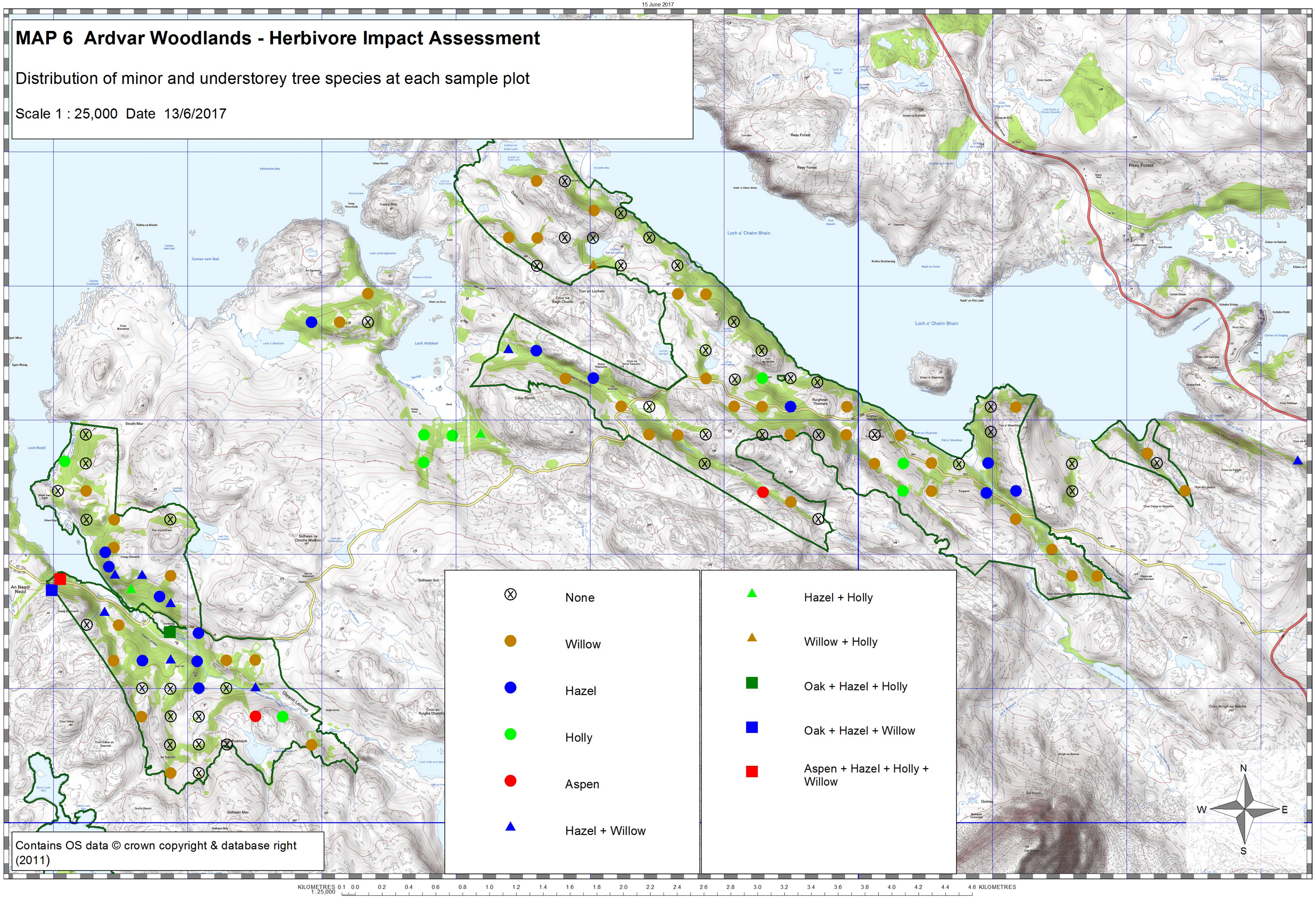

MAP 1 Ardvar Woodlands - Herbivore Impact Assessment
Location of numbered sample plots
Scale 1 : 25,000
Date 16/2/2017
AREA 1
AREA 2
AREA 3
Numbered Sample plot
Enclosure
SSSI boundary
Compartment boundary
Contains OS data © crown copyright & database right (2011)
16 February 2017
N
S
E
W
KILOMETRES
1:25,000


16 February 2017
MAP 2 Ardvar Woodlands - Herbivore Impact Assessment
Stocking density of seedlings & saplings (all species) in each sample plot expressed as number of stems/ha
Scale 1 : 25,000
Date 16/2/2017
No seedlings/saplings
20 - 240 stems/ha
260 - 500 stems/ha
520 - 1100 stems/ha
1120 - 1600 stems/ha
1620 - 2400 stems/ha
> 2400 stems/ha
Contains OS data © crown copyright & database right (2011)
N
W
E
S
KILOMETRES 0.1 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 KILOMETRES
1 : 25,000


MAP 3 Ardvar Woodlands - Herbivore Impact Assessment
Percentage of seedlings & saplings(all species) browsed during current season (2016) in each sample plot
Scale 1 : 25,000
Date 16/2/2017
Browsing level
None
< 10%
10% - < 50%
50% - < 90%
> 90%
No seedlings/saplings
Contains OS data © crown copyright & database right (2011)
N
W
E
S


19 February 2017
MAP 4 Ardvar Woodlands - Herbivore Impact Assessment
Percentage of seedlings & saplings(all species) browsed prior to 2016 survey in each sample plot
Scale 1 : 25,000
Date 16/2/2017
Browsing level
None
< 10%
10% - < 50%
50% - < 90%
> 90%
No seedlings/saplings
Contains OS data © crown copyright & database right (2011)
N
E
S
W
KILOMETRES 0.1 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 KILOMETRES
1: 25,000


17 February 2017
MAP 5 Ardvar Woodlands - Herbivore Impact Assessment
Woodland structure type for each plot (based on woodland grazing toolbox classes 1 - 8).
Scale 1 : 25,000
Date 16/2/2017
Structure classes
1. Open ground simple
2. Open ground complex
3. Dense regeneration
4. Thicket & stem exclusion
5. Mature woodland, understorey regeneration
6. Mature woodland, no understorey regeneration
7. Canopy tree mortality, complex
8. Canopy tree mortality, simple
Contains OS data © crown copyright & database right (2011)
N
W
E
S
KILOMETRES 0.1 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 KILOMETRES
1: 25,000


15 June 2017
MAP 6 Ardvar Woodlands - Herbivore Impact Assessment
Distribution of minor and understorey tree species at each sample plot
Scale 1 : 25,000 Date 13/6/2017
None
Willow
Hazel
Holly
Aspen
Hazel + Willow
Hazel + Holly
Willow + Holly
Oak + Hazel + Holly
Oak + Hazel + Willow
Aspen + Hazel + Holly + Willow
Contains OS data © crown copyright & database right (2011)
N
S
E
W
KILOMETRES 0.1 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 KILOMETRES
1:25,000
Loch a' Chairn Bhain
Reay Forest
An Nead/Nedd

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