SCOTTISH NATURAL HERITAGE

COMMISSIONED REPORT

Commissioned Report No. 026

Testing methods for monitoring beaver impacts on terrestrial vegetation in Knapdale

(ROAME No. F02AC327_01)

For further information on this report please contact:

Jenny Bryce
Scottish Natural Heritage
2 Anderson Place
EDINBURGH
EH6 5NP
Telephone: 0131–446 2400
E-mail: jenny.bryce@snh.gov.uk

Martin Gaywood
Scottish Natural Heritage
2 Anderson Place
EDINBURGH
EH6 5NP
Telephone: 0131–446 2444
E-mail: martin.gaywood@snh.gov.uk

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Summary

Testing methods for monitoring beaver impacts on terrestrial vegetation in Knapdale

Commissioned Report No. 026 (ROAME No. F02AC327_01)
Contractor: Forest Research

Background

The European beaver *Castor fiber* was once native to Scotland, possibly until the 16th century. Over-hunting is understood to be the primary cause of its extinction. The UK Government has an obligation, under Article 22 of the European Council Directive 92/43/EEC *on the Conservation of Natural Habitats and of Wild Flora and Fauna* (the 'Habitats Directive'), to consider the desirability of re-introducing certain species, including European beavers. In line with this obligation, and after eight years of background research and national consultation, SNH has proposed that a trial re-introduction of the European beaver should take place at Knapdale in mid-Argyll. This has still to be given final approval from the Minister but, in the meantime, baseline monitoring is being put in place so that the beavers can be re-introduced quickly if, and when, permission is given.

This study describes a field test of a method of monitoring the impacts of beavers on the terrestrial vegetation surrounding a loch where they will be re-introduced. The results are used to describe the current nature, and state, of the terrestrial vegetation at the site as well as to suggest improvements to the methods and approaches to undertaking the full-scale monitoring.

Main findings

Six different habitat types were identified within the study area. They appeared to be sufficiently different that each should be considered as a separate stratum in any future sampling. Deer browsing on saplings (less than 1.5m tall) was heavy in two habitat types and may be restricting tree regeneration despite other signs of deer presence being low. The method tested in this study proved to be viable in the field and to provide useful, and detailed, information. Three suggestions have been made for refinements. The main drawback of the method is the time that it takes and, in particular, the time needed to carry out estimates of plant species ground cover. The following suggestions for optimising the use of resources are made:

1 Concentrate resources in the habitat types on which the beavers are likely to have most effect whilst doing minimal 'tracking' in the other habitat types.
2 Sample ground vegetation in the area within 10m of the loch intensively and use non-permanent quadrats.
3 Monitor only one complete transect per habitat type.
4 Set up further transects in which only the trees are monitored.

Keywords: beavers, monitoring methods, browsing, grazing, vegetation.

For further information on this project contact:
Jenny Bryce and Martin Gaywood, Scottish Natural Heritage, 2 Anderson Place, Edinburgh EH6 5NP.
Tel: 0131–446 2400

For further information on the SNH Research & Technical Support Programme contact:
The Advisory Services Co-ordination Group, Scottish Natural Heritage, 2 Anderson Place, Edinburgh EH6 5NP.
Tel: 0131–446 2400 or **ascg@snh.gov.uk**

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Contents

List of figures

List of tables

1 INTRODUCTION

The European beaver *Castor fiber* was resident in Scotland until the 16th century, when it was persecuted to extinction by over-hunting. Since 1995, Scottish Natural Heritage (SNH) has been investigating the potential for restoring this species to the natural fauna. This investigation has compiled a suite of information with regard to the scientific plausibility and desirability (both local and national) of conducting such a re-introduction.

The work SNH has undertaken during the European beaver project is in line with obligations on the UK Government, under Article 22 of the European Council Directive 92/43/EEC *on the Conservation of Natural Habitats and of Wild Flora and Fauna* (the 'Habitats Directive'), to consider the desirability of re-introducing certain species (listed on Annex IV), including European beavers. No work is currently planned for the restoration of any other species listed in Annex IV of the Habitats Directive.

Following a national consultation, SNH proposed that a trial re-introduction of the European beaver should take place at Knapdale, mid-Argyll. The loch into which the beavers would be re-introduced falls within a candidate Special Area of Conservation designated for its oak woods. Final approval of this proposal is still awaited since the re-introduction of a mammal to the wild in Scotland is subject to a licence from the First Minister (under section 16 (4) of the Wildlife & Countryside Act 1981 (as amended)). In the meantime, necessary baseline survey and monitoring is being undertaken at Knapdale should permission be granted for the trial.

The aim of the trial is, if approved, to re-introduce up to four beaver families to Knapdale for a five year period in order to:

- study the ecology of the beaver in the Scottish environment;
- assess the effects of beaver activities on the environment, including land uses.

At the end of the trial the results of the studies will be assessed and a decision made as to whether to proceed with a full scale re-introduction.

The trial will involve the monitoring of both the beavers themselves and their impacts on their environment. This study reports on a trial of a method of monitoring the effects of beavers on the terrestrial vegetation.

2 MATERIALS AND METHODS

2.1 Site description

If the beaver trial re-introduction project is approved, the beavers will be introduced to a number of sites in Knapdale Forest in Mid Argyll. One of these sites will be Loch Linne, the site used for this study. Loch Linne is a narrow loch running from north east to south west and is connected to a smaller loch (Loch Fidhle) which lies parallel to Loch Linne on its south east side (Figure 1). The beavers would be introduced to an artificial lodge which is likely to be situated in an area of mature birch/alder with a heather/*Molinia caerulea* field layer (Area 12, see below). Beavers normally graze vegetation up to about 50m from the edge of water bodies, although most grazing activity is within 10m, and within the water bodies themselves. In summer they tend to graze on aquatic vegetation and in areas with nutritious ground layer vegetation. Towards autumn and winter they will take more woody species, often felling them to get access to the bark. Felled trees are usually 8cm or less in diameter, although larger trees may be taken.

Following a field assessment, the area around Loch Linne was divided into 17 different Areas representing different habitats and/or difficulty of access (Figure 1). The Areas were categorized as:

1 Clear-felled conifer that now has dense birch regeneration at sapling stage. Bracken field layer. A path goes through this area near the water's edge.

2 This area was previously a conifer plantation that was probably felled in the 1980s. There has been abundant birch and alder regeneration since then. There have also been a few Sitka spruce trees regenerating. Some oak trees, now of about 10 years old, had been tubed. These may have been planted or have regenerated naturally. Moss/*M. caerulea* ground layer. Very wet.

3 Mostly mature and regenerating birch with some alder with one small open area next to the loch.

4 Very steep slope from the water's edge to about 30–50m in. Largely covered with dense birch. Mixed grass/herb/bracken field layer. There is a mature Norway spruce plantation towards the north of this area.

5 Sitka spruce plantation about 15 years old. Heather/blaeberry field layer.

6 Scots pine plantation about 50 years old. Some birch. Heather/blaeberry field layer.

7 Mature birch with a *M.caerulea* field layer. Very wet.

8 Very steep slope from the water's edge to 30–50m or more.

9 Sitka spruce plantation about 15 years old. Heather/blaeberry field layer.

10 Mature birch and alder. Grass/herb field layer. Steep but not precipitous.

11 Mature birch. Heather/*M.caerulea*/bog myrtle field layer. Ploughing ditches still present. Very wet.

12 Mature birch/alder. Heather/*M. caerulea* field layer.

13 Very steep slope from the water's edge to about 30–100m or more. Mature birch with some oak. Heather/bracken field layer.

14 Mature birch and alder. Grass/herb field layer. Steep but not precipitous.

15 Open. Mature birch with some oak by the loch. *M.caerulea*/bracken field layer.

16 Mature oak/hazel wood. *M.caerulea*/bracken field layer in places, heather/blaeberry in others.

17 Very steep bank from the water's edge to about 30–50m.

Areas 4, 8, 13 and 17 were considered to be too steep to be able to do any monitoring. Ropes would be needed and any monitoring in these Areas would have serious health and safety implications. Areas 5 and 9 were excluded from consideration in this study for two reasons. Firstly, they were considered to be relatively unattractive to beavers since Sitka spruce and heather are not favoured species and, secondly, these areas are not adjacent to the loch and the beavers would have to cross the steep ground of Areas 4 and 8, respectively, to get to them. The remaining Areas fell into the habitat types listed in Table 1.

Table 1 Allocation of Areas to different habitat types

Habitat type	Area (see Figure 1)
1. Birch at sapling stage with dwarf shrub/herb field layer	1
2. Mature birch/alder with *M.caerulea*/Sphagnum field layer	2, 3, 7
3. Mature birch/alder with grass/herb field layer	10, 14
4. Mature birch/alder with heather/*M.caerulea*/bog myrtle field layer	11, 12
5. Mature oak/hazel with *M.caerulea*/heather/blaeberry field layer	16
6. Mature Scots pine plantation with heather/blaeberry field layer	6

2.2 Field methods

2.2.1 Location of transects

The impact of the beavers on terrestrial vegetation is expected to be greatest nearest to the loch edge and to fall off with distance from the loch edge to a maximum of about 50m. The method therefore involved sampling along 50m transects laid out perpendicular to the water's edge. One transect was located in each of Areas 1, 6, 11, 14 and 16. The artificial lodge is likely to be somewhere around the boundary between Areas 11 and 12 so it was considered important to have a transect in at least one of these Areas. The other areas were chosen so as to cover the main habitat types (Table 1). Only habitat type 2 was not sampled since it is fairly similar to habitat type 4. Area 14 has been included because it is an example of a relatively rich habitat on a steep slope. The relative richness of the habitat may attract beavers and the steepness (relative to the other habitat types) means that it may take longer to complete a transect. Area 14 is not adjacent to the shore so the transect was started at a random point on the edge of Area 14 and continued up the slope at approximately right angles to the shoreline. Access to all Areas except Area 1 was facilitated by the use of a boat. The grid references of the starting points of each transect (all at the water's edge except for Transect 3 in Area 14) is given in Table 2.

Table 2 Location of each transect

Transect number	Grid reference at start	Habitat Type[1]	Area Number[2]
1	NR795908	1	1
2	NR798913	5	16
3	NR800914	3	14
4	NR799911	4	11
5	NR797909	6	6

[1] See Section 2.1

[2] See Table 1

Large, metal pegs were used to mark the corners of each plot and a wooden stake was used to mark the start of each transect except for Transect 1 where the ground was too rocky. The wooden stake was offset from the corner of the transect by about 2m so that the nearest plots would not be affected by deer or beavers which might be attracted to the posts. The distance and orientation of the stake from the start of the transect was standardised as far as possible and recorded.

2.2.2 Vegetation sampling

Five 10 x 4m contiguous plots were established along the length of each transect. The following was carried out in the order listed below. Quadrats were assessed before plots so that the quadrats did not get trampled before they were assessed.

A 2 x 2m quadrat, located 4m from either end of the plot and 1m from each side of the plot, was marked out with a specially constructed collapsible quadrat. The quadrat had cross bars to divide it into 4 or 16 sub-quadrats. Inside the quadrat the following was recorded:

1 Percentage top cover (to the nearest 5%) of every field and ground layer species, and of bare ground, litter and tree basal area. The cover of bare ground and litter was estimated assuming that the field layer had been removed but that the ground layer i.e. bryophytes and lichens, was still in place. Total cover could come to more than 100%. Cover was estimated visually in each of the four 1 x 1m quarters of the quadrat and was aided by using a square quadrat of side 22.4cm as a guide to estimating 5% cover as well as diagrams of different patterns of a range of cover percentages. Percentage cover of species that were present, but that had a cover of less than 2.5%, were recorded as having 0% cover. All bryophyte and lichen species were considered together for the purposes of estimating percentage cover. In the first quadrat per transect, each of the 16 sub-quadrats was assessed, and recorded, separately.

2 All species of bryophyte and lichen present in each 1 x 1m quarter of the quadrat.

3 Plant species that were obviously grazed, in each quarter of the quadrat.

4 Height of the ground layer vegetation at the nine points where the 16 sub-quadrat cross bars intersected each other. Height was measured without straightening any vegetation that had fallen over and may have been of dead or live vegetation. The species of plant, and whether it was dead or alive, were also recorded. Where the nearest vegetation was also the closest to another intersection, the result for the intersection was recorded as 'no vegetation present'.

5 Presence or absence of leader browsing by deer (where this could be identified) on each tree or shrub sapling (less than, or equal to, 1.5m tall) and the species and height of the tree. The six saplings nearest to the centre of the quadrat were measured first, together with the distance from the fifth and sixth nearest sapling to the centre of the quadrat. If there were fewer than five saplings within 5m of the centre of the quadrat the sample was limited to the number of saplings found within this distance and the distance to the two furthest out saplings was measured. All other saplings within the 2 x 2m quadrat were also measured. [In future monitoring, the presence/absence of beaver damage will also be recorded]. Coppiced stems were treated in the same way as 'free standing' saplings, but records from all stems coming from the same root stock were bracketed together on the field sheet.

In each of the five 10 x 4m plots that made up each transect the following were measured:

1 Percentage canopy cover (estimated to nearest 5%).

2 Number of deer pellet groups (six or more pellets constitute a group. 'Stringers' or scattered pellets will not be included). [In future, number of beaver scats will also be counted.]

3 Diameter and length of all deadwood with a diameter greater than 3cm at its mid-point. Where a piece of deadwood fell across the boundary of the plot the mid-point applied only to the length of wood that was within the plot. For smaller pieces of deadwood, diameter was measured using callipers. DBH tape was used for larger pieces. Each piece was classed as standing or fallen. If a piece of fallen deadwood was partly buried, its length was measured to the point at which it entered the ground. Very decomposed deadwood i.e. if there was no resistance when prodded, was not included. [In future monitoring, dead wood will be classified as gnawed by beavers or not].

4 DBH (at 1.3m height on the upward side of the tree) and species of each tree or shrub taller than 1.5m. Each tree was recorded as being either 'established' or 'coppice'. Data for coppiced stems coming from the same root stock was bracketed together on recording sheets. Normally, DBH tape or callipers were used to measure individual tree diameters. However, where there was a high density of trees with a diameter less than, or equal to, 3cm and of one species, diameter class, growth form [and, in future, beaver damage status], they were not individually recorded. Instead, diameter was visually assessed, or measured, and the number of trees in each of six diameter classes (0.1–0.5, 0.51–1.0, 1.01–1.5, 1.51–2.0, 2.01–2.5, 2.51–3.0) was counted. [In future monitoring, presence/absence of damage by beavers to trees taller than 1.5m will also be recorded].

2.2.3 Timing of measurements

Measurements were carried out in late April, May and early June 2003 (Appendix 1). It was thought that this would allow for over-winter damage on trees to be assessed before too much new growth had started but, at the same time, it would be late enough in the year for most ground plants to be apparent and for the trees to be in leaf.

2.2.4 Time requirements

The time taken to complete each part of the method was recorded for each plot.

2.3 Data analysis and presentation of results

It is intended that data from the full-scale monitoring will be analysed at the level of the plot where the sample will be all plots at a given distance from the start of the transect within a given habitat type. The data will consist of measures of change within the plot. Since the variance in the level of change across plots will be unknown until monitoring has been repeated, it is not possible to determine how many transects will be needed to detect a given level of change until repeat monitoring has been carried out. In any case, in this pilot study only one transect was monitored in each habitat type. This pilot study was therefore designed to provide information on the staff, and other, resources needed to carry out the monitoring and on the variation in starting values between the five habitat types. The latter information will assist with decisions on sample stratification. It was anticipated that the findings of this study might result in the final method differing from the one tested here.

Methods used to analyse data were generally straightforward and self-evident from the results presented. The exception is the method used to calculate density of saplings of each species in each plot. Two methods were compared. The first was to measure all saplings within each 2 x 2m quadrat. The density of saplings within each quadrat was calculated. The second method was a 'nearest neighbour' approach where the five saplings nearest to the centre of the quadrat were measured along with the distance to each of the fifth and sixth furthest out sapling. The five saplings were then taken as occurring within an area with radius equal to the mean distance from the centre of the quadrat to the fifth and sixth furthest out saplings. The density of saplings was calculated on this basis. Both methods were used to calculate sapling density in each plot. The 'combined' results (Table 6) were obtained by using the nearest neighbour results when there were fewer than six trees within a quadrat and the quadrat results when there were six or more trees present within a quadrat. The rationale for this is given in section 4.4.

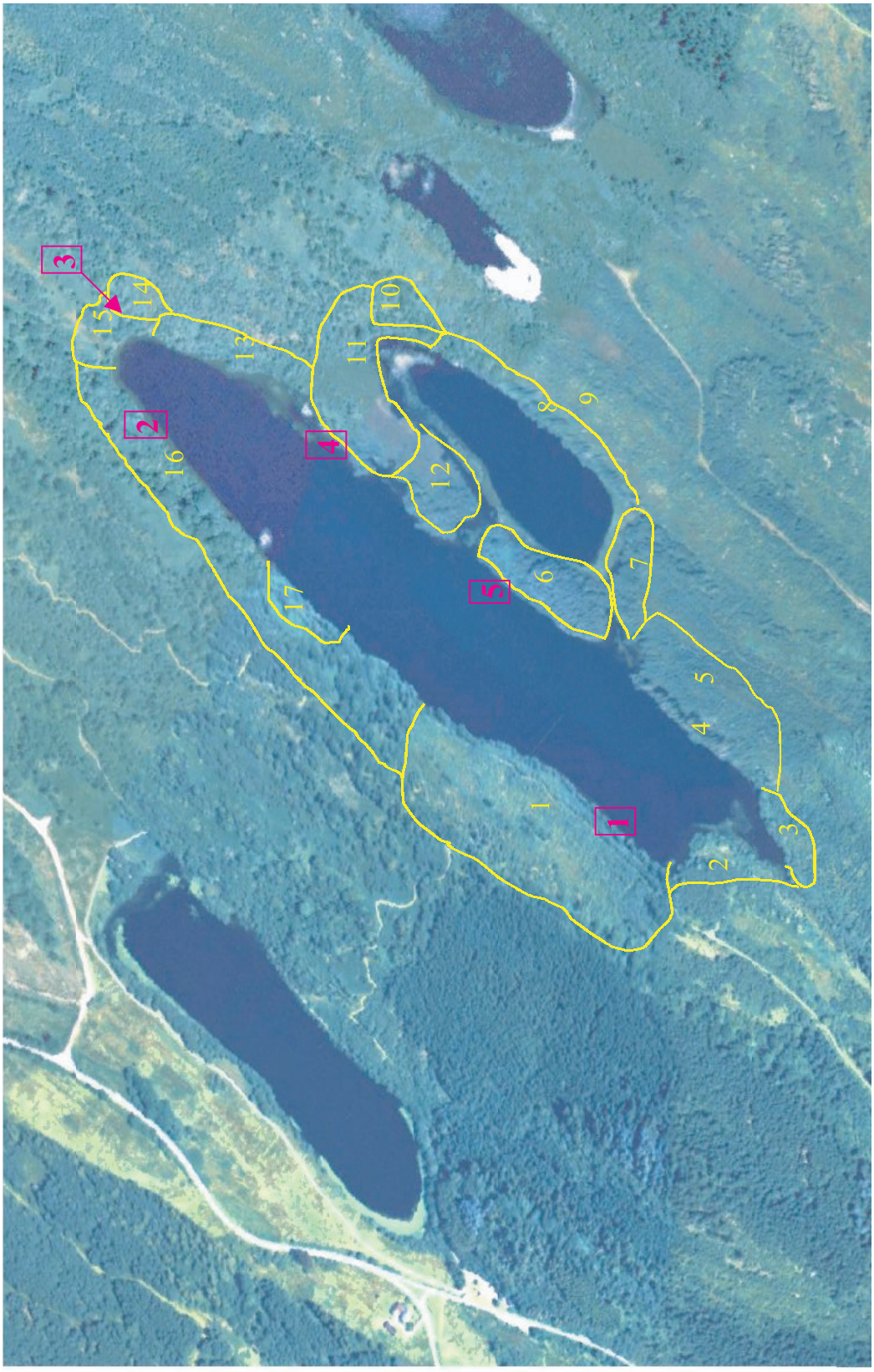


Figure 1 Map of the different Areas around Loch Linne (see Section 2.1 for a description of each Area). Numbers in red indicate the approximate location of the start of each transect.

3 RESULTS

3.1 Ground cover

Appendix 2 gives details of estimates of percentage cover for all ground cover types, angiosperms, ferns and fungi, as well as bryophytes and lichens combined, in each quarter quadrat. The mean percentage cover of each ground cover type or plant species is also given in Appendix 2 as is the mean percentage cover for the quadrats in which estimates were made in 16 as well as 4 sub-quadrats. For those cover types with a mean cover of ≥ 5%, the mean cover of the 4 sub-quadrats is illustrated in Figures 2–6.

Appendix 3 lists the species of moss, liverwort and lichen present in each quarter of each quadrat, together with the total frequency in the whole quadrat. Table 3 gives the total number of species, of each of a number of plant types, found in each quadrat.

Table 3 Total number of species, of each of a number of plant types, found in each quadrat.

Transect	Plot	Mosses	Lichens	Liverworts	Herbs	Grasses/ sedges/ rushes	Ferns	Fungi	Trees	Shrubs	Dwarf shrubs	Total
1	1	14	0	1	10	8	1	0	1	1	0	36
	2	9	0	1	2	1	2	0	1	1	2	19
	3	10	4	1	0	2	4		2	0	2	25
	4	11	2	1	0	1	3	2	2	1	2	25
	5	8	2	1	0	0	2	2	2	0	2	19
2	1	11	0	1	0	2	2	0	0	0	1	17
	2	14	3	1	0	2	2	0	1	0	2	25
	3	10	0	2	2	3	2	0	1	0	1	21
	4	8	2	1	3	2	2	1	2	0	1	22
	5	10	1	1	5	5	1	0	3	0	1	27
3	1	8	1	3	12	7	1	0	2	0	0	34
	2	12	0	0	5	5	1	0	2	0	0	25
	3	17	1	2	10	3	3	0	3	0	1	40
	4	16	6	1	5	3	3	0	3	0	0	37
	5	15	1	3	7	5	4	0	1	0	0	36
4	1	7	0	3	1	1	0	0	0	0	2	14
	2	9	2	1	1	1	0	1	1	0	2	18
	3	7	4	4	0	2	0	0	1	0	2	20
	4	6	1	1	0	1	2	0	1	0	3	15
	5	7	1	2	0	1	0	0	0	0	2	13
5	1	11	1	3	0	1	1	0	0	0	2	19
	2	12	1	2	1	1	0	0	2	0	2	21
	3	8	3	2	0	0	0	0	0	0	1	14
	4	5	3	2	0	0	0	0	3	0	2	15
	5	9	3	2	0	1	0	0	5	0	2	22

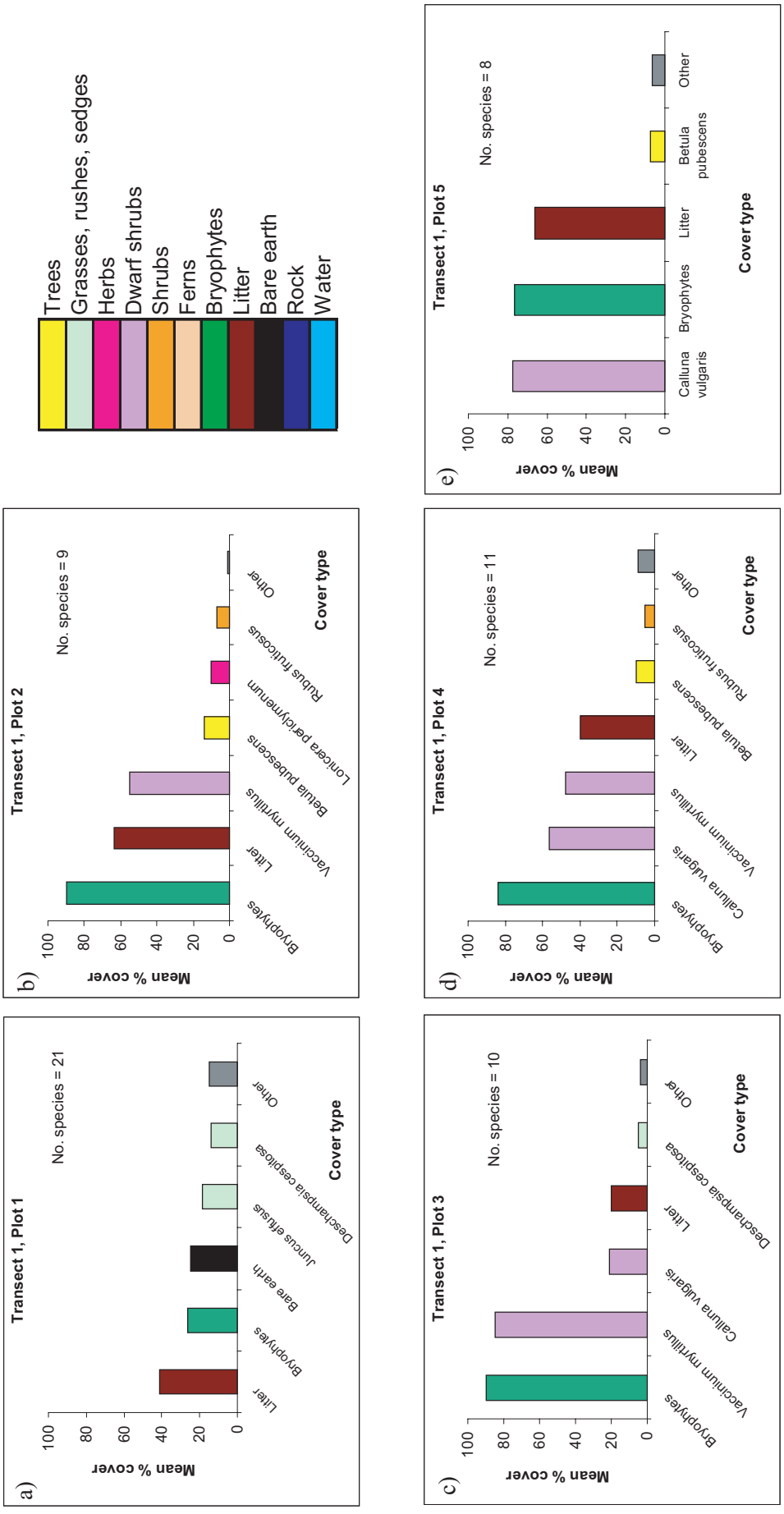


Figure 2 Mean percentage cover of all ground cover types and plant species with a cover of ≥5%, calculated from estimates made in each of four quarters of the 2 x 2m quadrats located on transect 1. a) – e) show results for plots 1–5 respectively. Colouring of histogram bars is based on groupings of plant species (see legend). The number of plant species found in each plot, excluding mosses, lichens and liverworts, is also given.

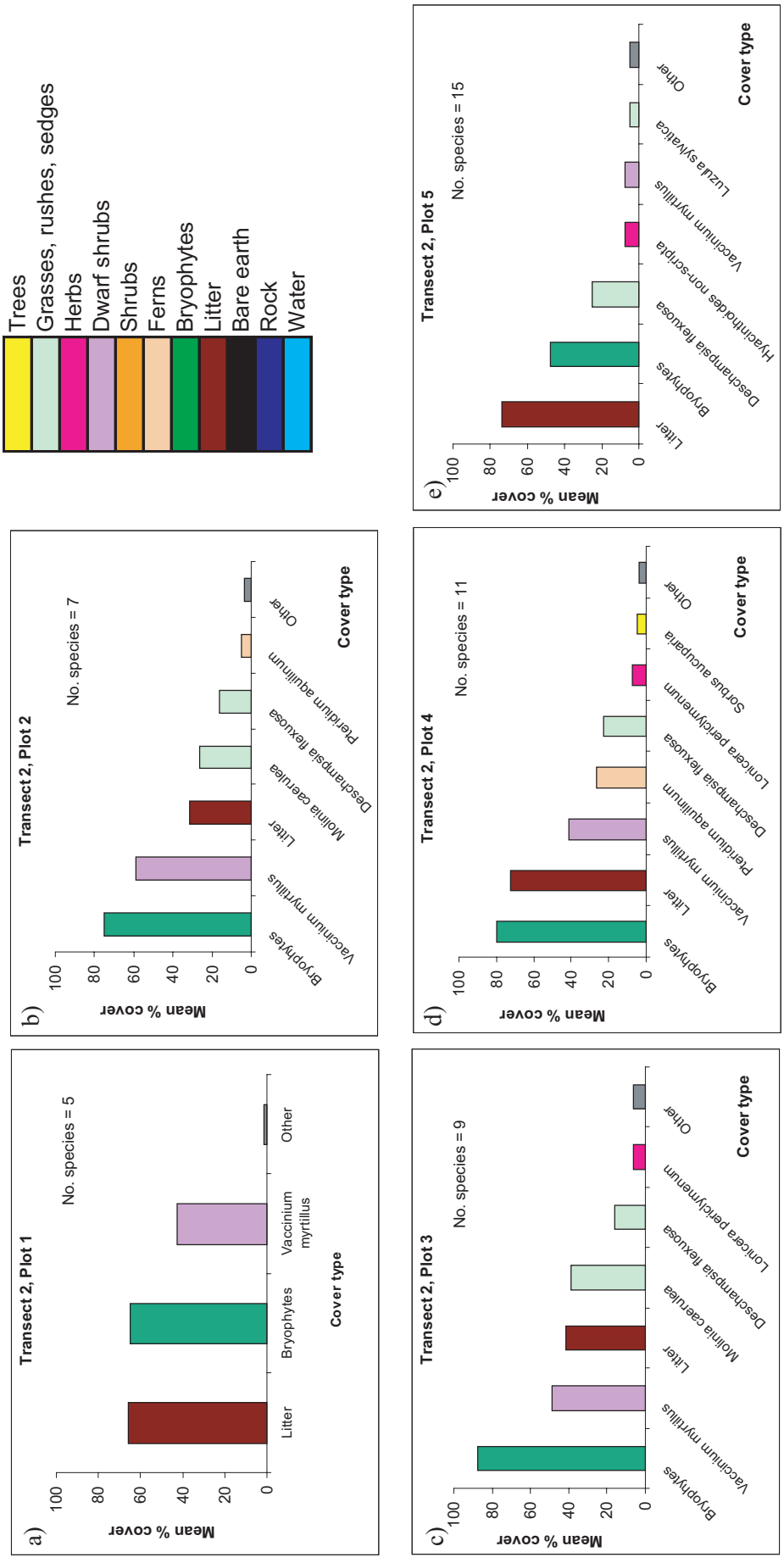


Figure 3 Mean percentage cover of all ground cover types and plant species with a cover of ≥5%, calculated from estimates made in each of four quarters of the 2 x 2m quadrats located on transect 2. a) – e) show results for plots 1–5 respectively. Colouring of histogram bars is based on groupings of plant species (see legend). The number of plant species found in each plot, excluding mosses, lichens and liverworts, is also given.

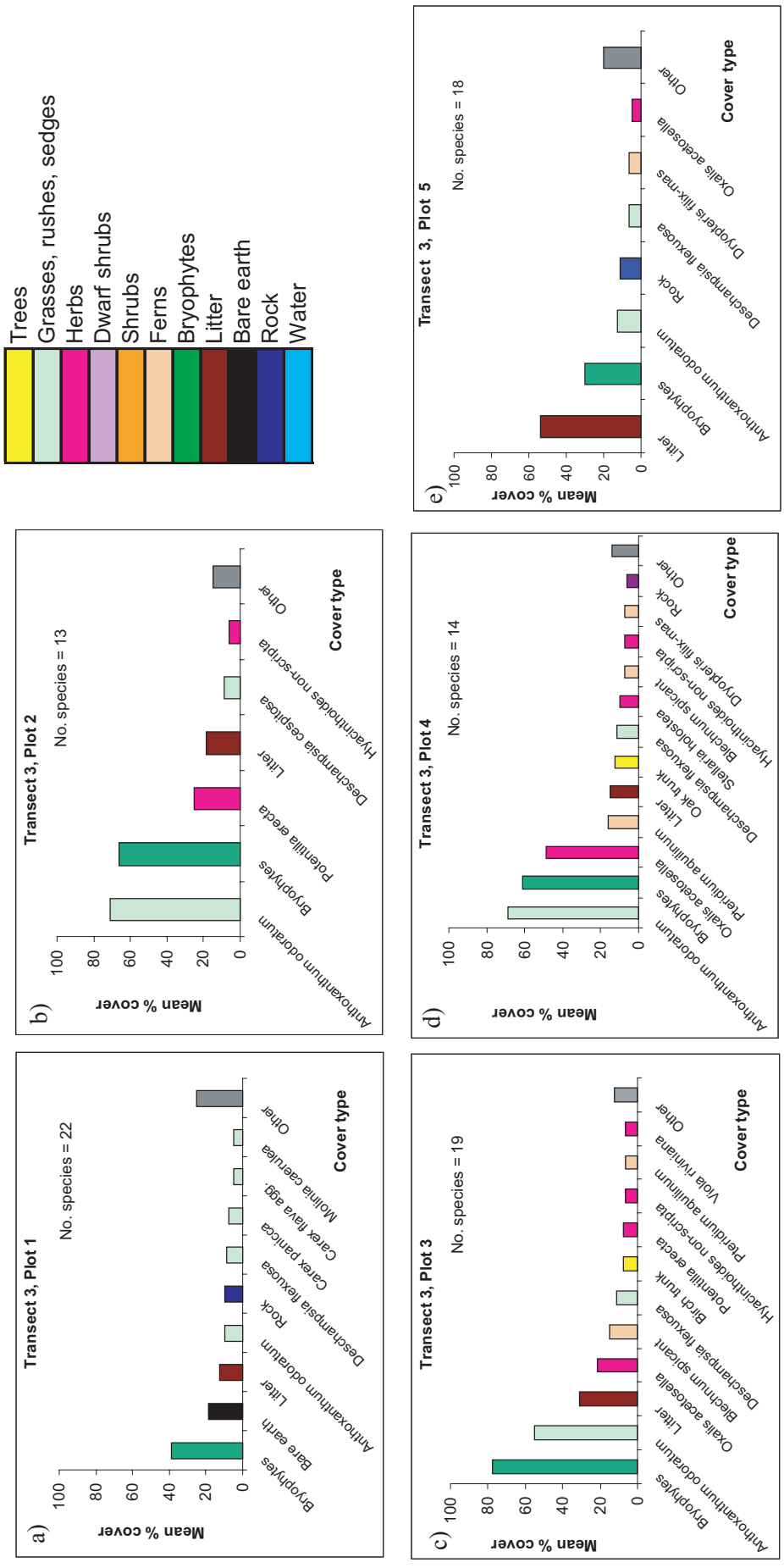


Figure 4 Mean percentage cover of all ground cover types and plant species with a cover of ≥5%, calculated from estimates made in each of four quarters of the 2 x 2m quadrats located on transect 3. a) – e) show results for plots 1–5 respectively. Colouring of histogram bars is based on groupings of plant species (see legend). The number of plant species found in each plot, excluding mosses, lichens and liverworts, is also given.

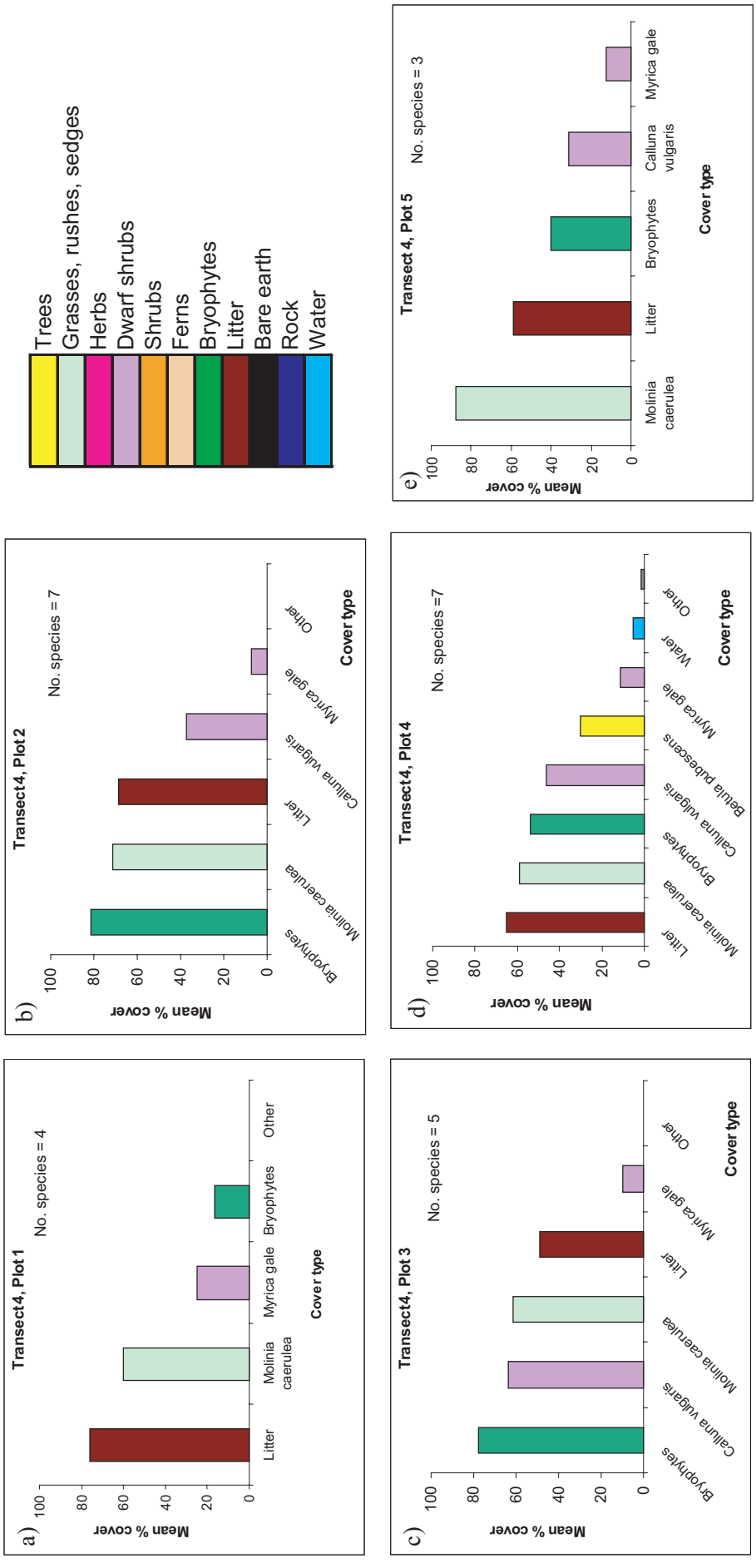


Figure 5 Mean percentage cover of all ground cover types and plant species with a cover of ≥5%, calculated from estimates made in each of four quarters of the 2 x 2m quadrats located on transect 4. a) – e) show results for plots 1–5 respectively. Colouring of histogram bars is based on groupings of plant species (see legend). The number of plant species found in each plot, excluding mosses, lichens and liverworts, is also given.

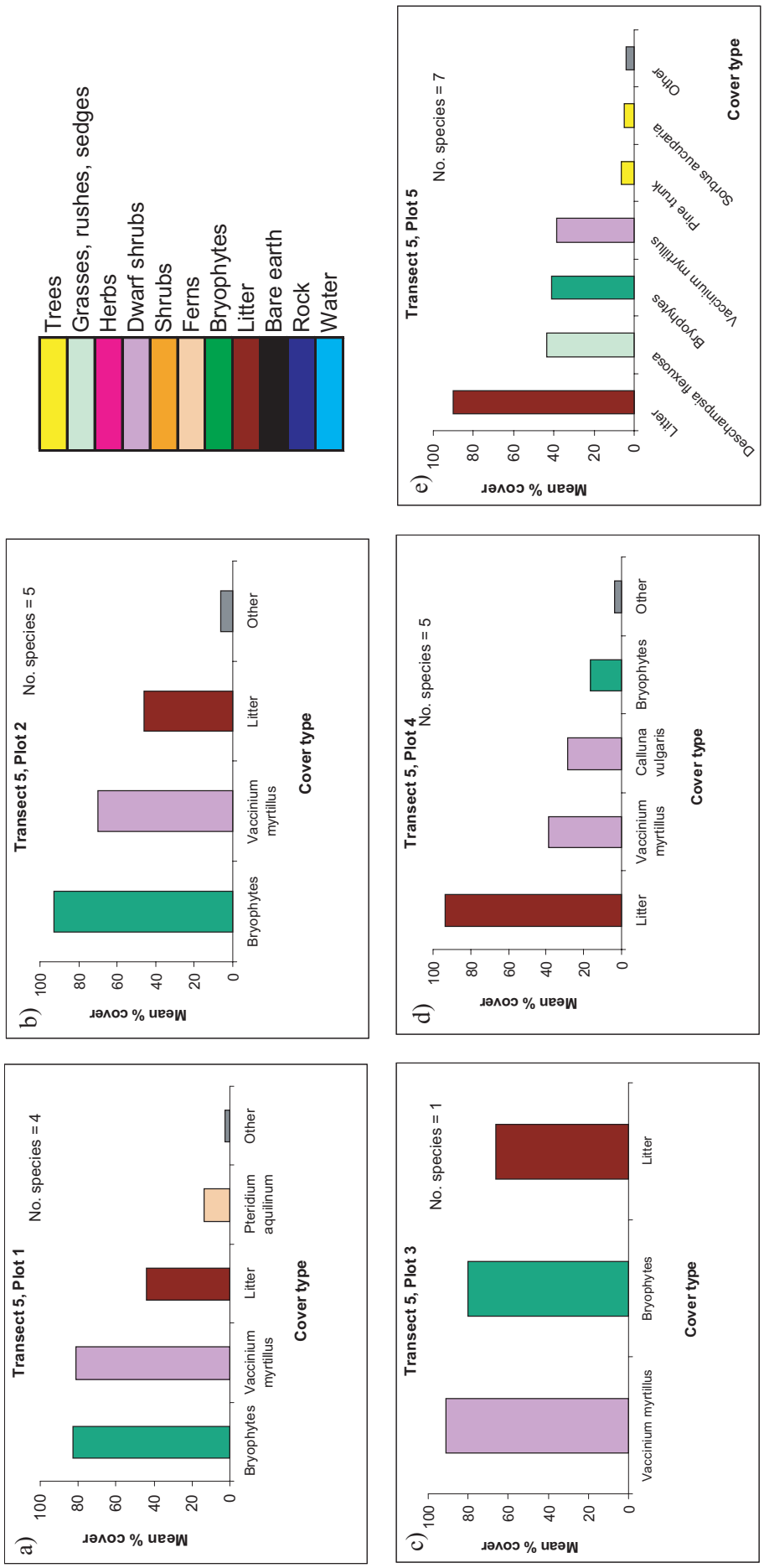


Figure 6 Mean percentage cover of all ground cover types and plant species with a cover of ≥5%, calculated from estimates made in each of four quarters of the 2 x 2m quadrats located on transect 5. a) – e) show results for plots 1–5 respectively. Colouring of histogram bars is based on groupings of plant species (see legend). The number of plant species found in each plot, excluding mosses, lichens and liverworts, is also given.

3.2 Grazing by deer on ground vegetation

Table 4 and Table 5 show the plant species that were recorded as having been grazed by deer, both at the quadrat level and in total for all quadrats.

Table 4 Ground layer plant species grazed by deer in the 2 x 2m quadrat within each plot.

Transect no.	Plot no.	Species	No. grazed[1]	Total occurrences[2]
1	2	*Vaccinium myrtillus*	4	4
2	1	*Molinia caerulea*	1	3
2	1	*Vaccinium myrtillus*	4	4
2	2	*Molinia caerulea*	4	4
2	2	*Sorbus aucuparia*	1	2
2	2	*Vaccinium myrtillus*	4	4
2	3	*Molinia caerulea*	4	4
2	3	*Sorbus aucuparia*	4	4
2	4	*Pteridium aquilinum*	1	4
2	4	*Sorbus aucuparia*	3	4
2	4	*Vaccinium myrtillus*	4	4
2	5	*Hyacinthoides non-scripta*	1	4
2	5	*Sorbus aucuparia*	2	4
2	5	*Vaccinium myrtillus*	4	4
3	1	*Anthoxanthum odoratum*	2	4
3	1	*Carex flava*	3	4
3	1	*Molinia caerulea*	3	3
3	2	*Anthoxanthum odoratum*	1	4
3	2	*Deschampsia caespitosa*	1	2
3	2	*Luzula sylvatica*	1	1
3	3	*Luzula sylvatica*	1	3
3	4	*Anthoxanthum odoratum*	2	4
3	4	*Luzula sylvatica*	1	2
3	5	*Anemone nemorosa*	1	1
3	5	*Anthoxanthum odoratum*	2	4
3	5	*Hyacinthoides non-scripta*	3	3
3	5	*Luzula sylvatica*	1	3
4	1	*Molinia caerulea*	4	4
4	2	*Molinia caerulea*	3	4
4	2	*Myrica gale*	2	4
4	3	*Molinia caerulea*	3	4
4	3	*Myrica gale*	3	3
4	4	*Molinia caerulea*	3	4
4	4	*Myrica gale*	3	3
4	5	*Bryophytes*	3	4
4	5	*Molinia caerulea*	4	4
4	5	*Myrica gale*	1	4

[1] Number of quarter sub-quadrats in which the species occurred and was grazed by deer.

[2] Number of quarter sub-quadrats in which the species occurred.

Table 5 Total number of quarter sub-quadrats, for Transects 1–4, in which each grazed ground layer species both occurred and was grazed by deer.

	No. sub-quadrats	
	Grazed	**Total**
Anemone nemorosa	1	2
Anthoxanthum odoratum	7	22
Bryophytes	3	79
Carex flava agg.	3	7
Deschampsia cespitosa	1	8
Hyacinthoides non-scripta	4	19
Luzula sylvatica	4	16
Molinia caerulea	29	37
Myrica gale	9	18
Pteridium aquilinum	1	36
Sorbus aucuparia	10	23
Vaccinium myrtillus	24	38

3.3 Ground vegetation height

Within the 25 quadrats, there were only two intersections where there was no vegetation nearer to the intersection in question than to another intersection i.e. there were only two missing values out of a total of 225. The mean height of each species found in each quadrat, together with means for each species, each quadrat, and in total, are given in Appendix 4. Live and dead vegetation of the same species has been treated separately.

3.4 Saplings

Two methods were used to determine the density of saplings in the plots. The results from both the 2 x 2m quadrats, and from the nearest neighbour method, (section 2.2.2) are presented in Table 6.

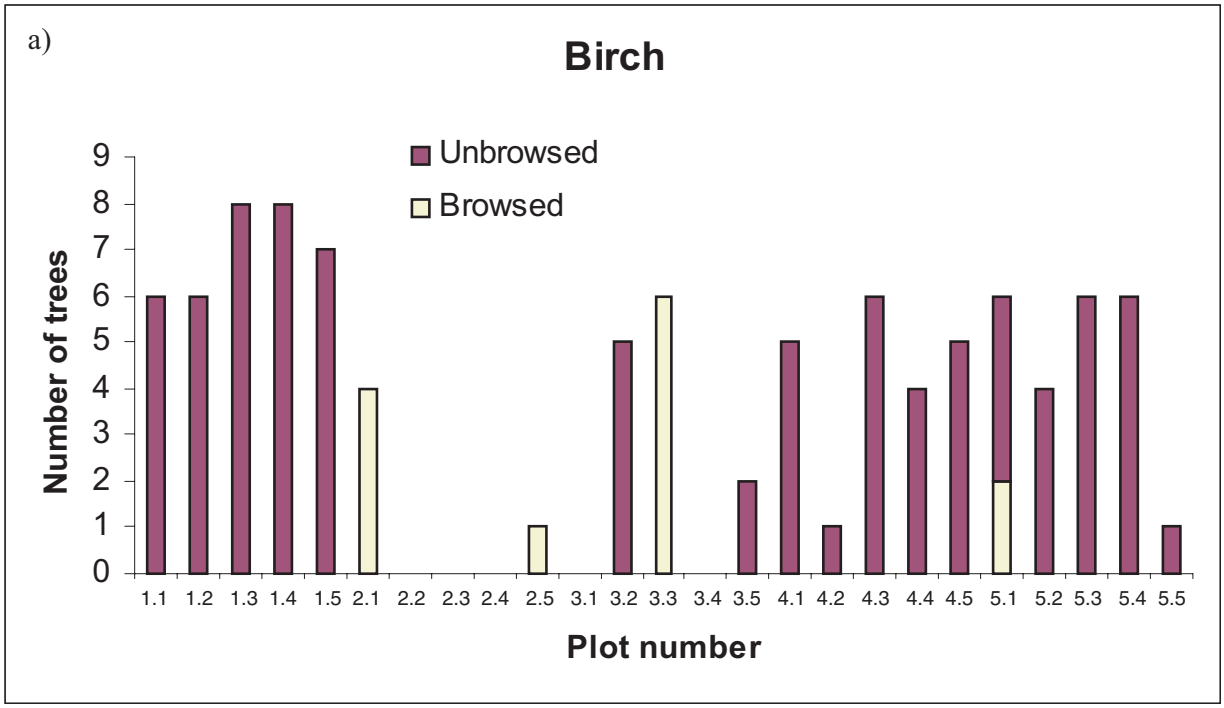
Only six species of sapling (less than 1.5m tall) were recorded. Of these, only birch and rowan were recorded in significant numbers. The number of unbrowsed, and browsed, birch and rowan recorded in each plot is shown in Figure 7. Transects 1, 4 and 5 had high densities of birch trees whereas Transect 2 and two plots on Transect 5 had a high density of rowan trees. Both species occurred in moderate densities on Transect 3 (Figure 7). Only two each of alder, hazel and oak saplings were recorded, all of which were unbrowsed. The alders were both found in Transect 3, plot 1, the hazels in Transect 3, plot 5 and the oaks in Transect 2, plot 4 and Transect 3, plot 2. Seven unbrowsed Sitka spruce were recorded, five on Transect 4 and one each on Transects 1 and 2.

The number of browsed and unbrowsed birch and rowan saplings in a range of height classes is shown in Figure 8 for all plots. No rowan saplings were found that were between 90 and 150cm tall and most were less than 30cm tall. The birch trees were more evenly distributed in terms of height. Browsing appeared not to be related to the height of the birch trees, but seemed to be highest on rowans of between 11 and 30cm tall.

Table 6 Density of saplings in plots calculated using data from 2 x 2m quadrats and from nearest neighbour method.

				Density (/m2)		
Transect no.	**Plot no.**	**≥ 6 trees in quadrat?**	**No. of trees in quadrat**	**2 x 2 m quadrat**	**Nearest neighbour**	**Combination**
1	1	No	1	0.25	0.30	0.30
1	2	No	5	1.25	0.90	0.90
1	3	Yes	11	2.75	1.39	2.75
1	4	Yes	9	2.25	7.69	2.25
1	5	Yes	8	2.00	2.72	2.00
2	1	No	0	0.00	0.09	0.09
2	2	No	4	1.00	1.11	1.11
2	3	Yes	17	4.25	3.44	4.25
2	4	Yes	16	4.00	2.28	4.00
2	5	Yes	9	2.25	4.81	2.25
3	1	No	2	0.50	0.23	0.23
3	2	Yes	6	1.50	2.01	1.50
3	3	Yes	7	1.75	3.03	1.50
3	4	Yes	9	2.25	1.03	2.25
3	5	No	1	0.25	0.25	0.25
4	1	No	0	0.00	0.07	0.07
4	2	No	1	0.25	0.15	0.15
4	3	No	2	0.50	0.16	0.16
4	4	No	0	0.00	0.25	0.25
4	5	No	0	0.00	0.11	0.11
5	1	No	0	0.00	0.18	0.18
5	2	No	4	1.00	0.29	0.29
5	3	No	0	0.00	0.18	0.18
5	4	Yes	20	5.00	5.26	5.00
5	5	Yes	20	5.00	4.07	5.00

Figure 7 **Number of unbrowsed and browsed saplings found in each plot of a) birch and b) rowan.**



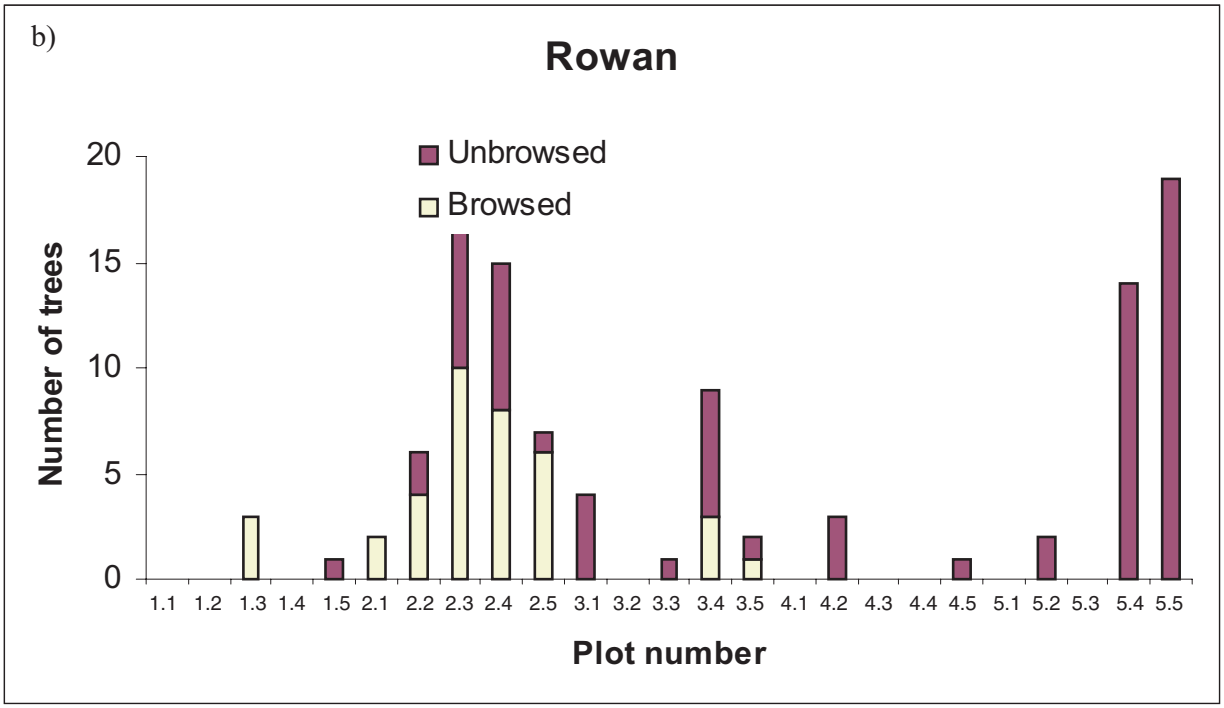
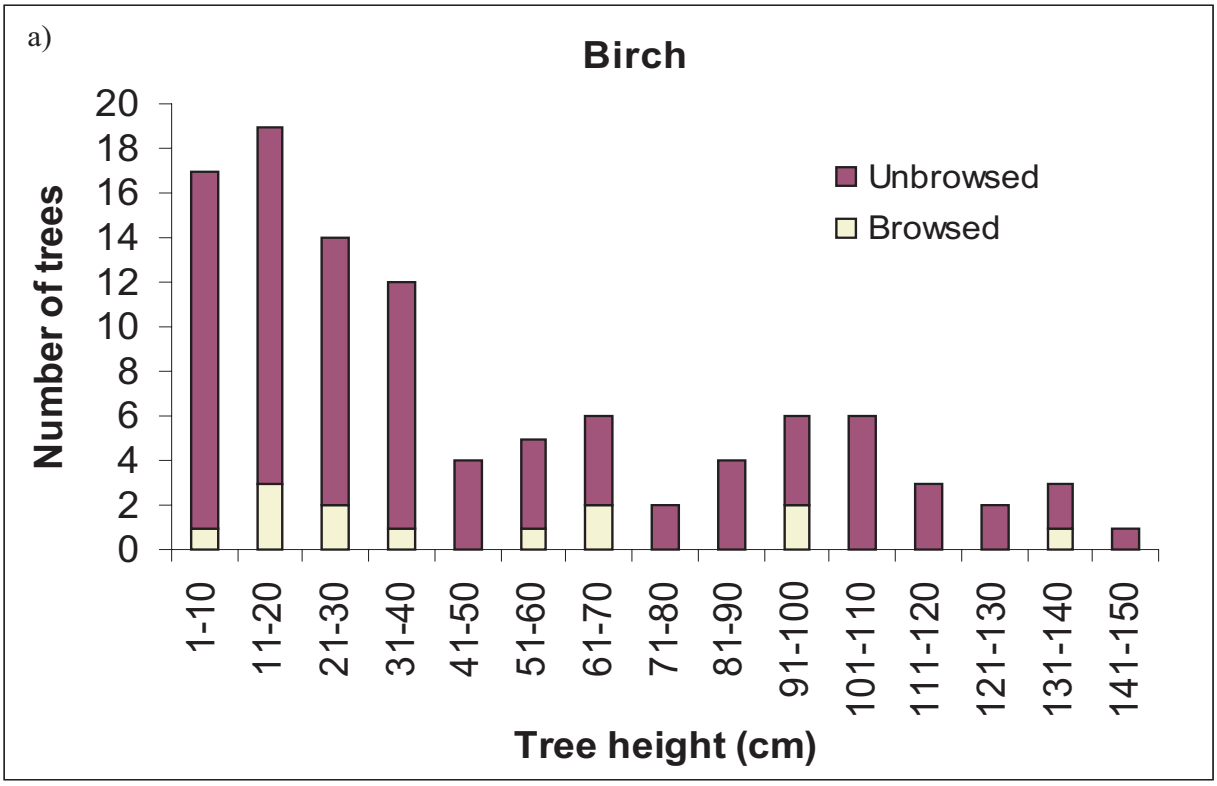


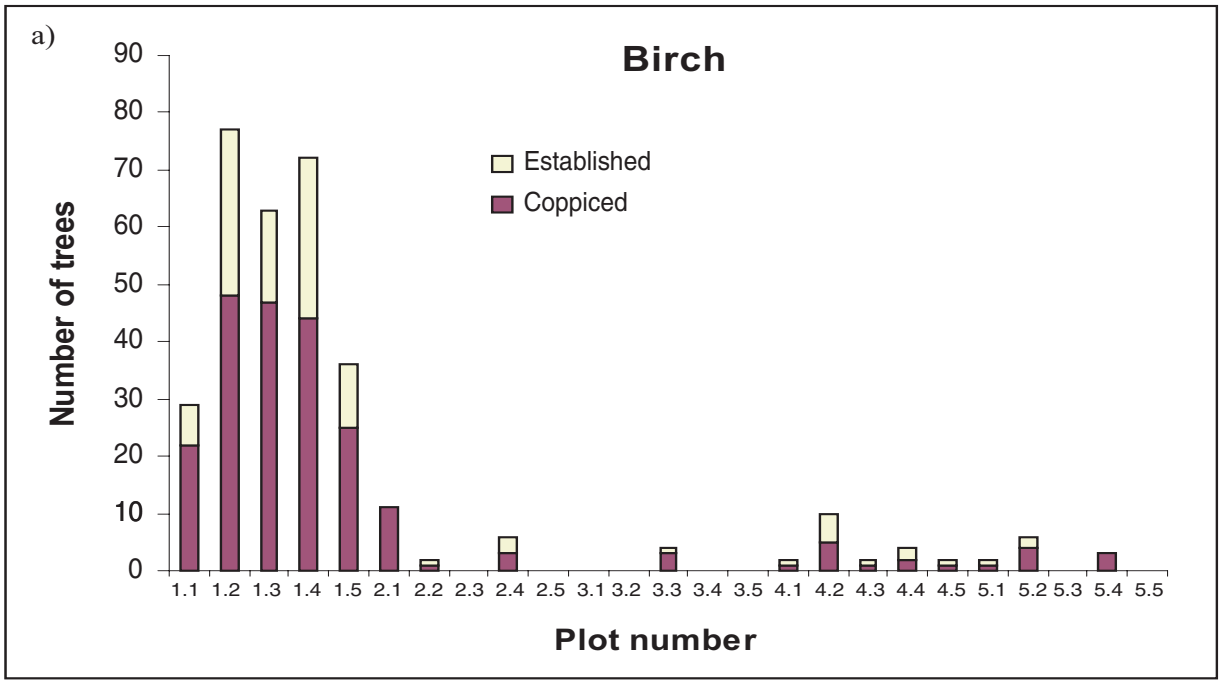
Figure 8 **Numbers of browsed and unbrowsed a) birch and b) rowan saplings in different size categories in all plots.**

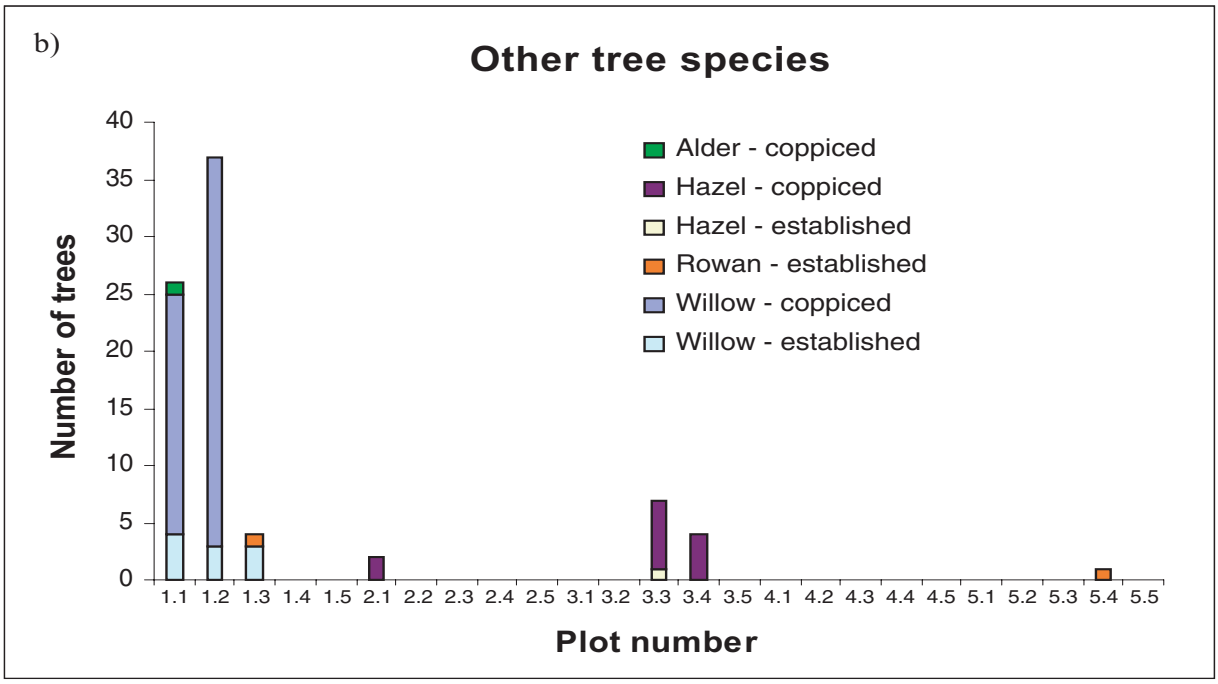


3.5 Tall trees with a diameter of 3cm or less

Appendix 5 lists the number of trees taller than 1.5m and with a diameter of 3cm or less of each tree species recorded in each plot. The trees have also been classified as coppiced or established and divided into 0.5cm diameter classes. This information is summarized in Figure 7 excluding information on diameter class. The trees were approximately equally distributed between the 0.5cm diameter classes.

Figure 9 Number of trees in each plot taller than 1.5m and with a diameter of 3cm or less of a) birch and b) other tree species. Willow = goat willow, alder = common alder.

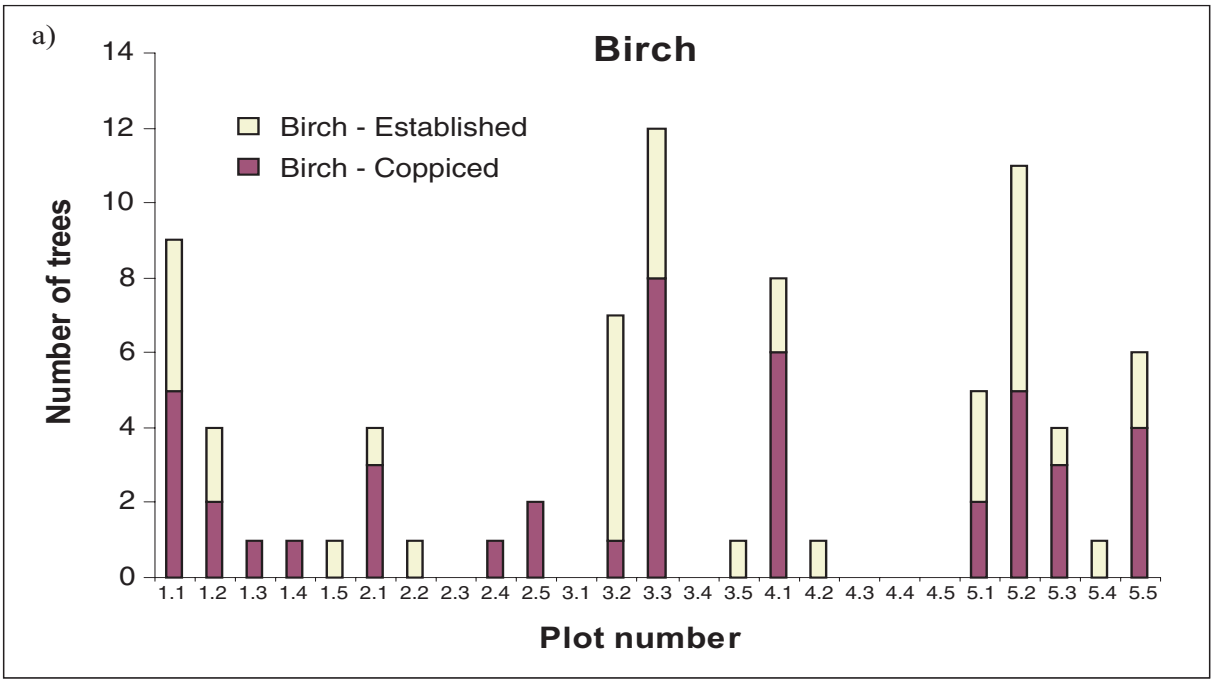


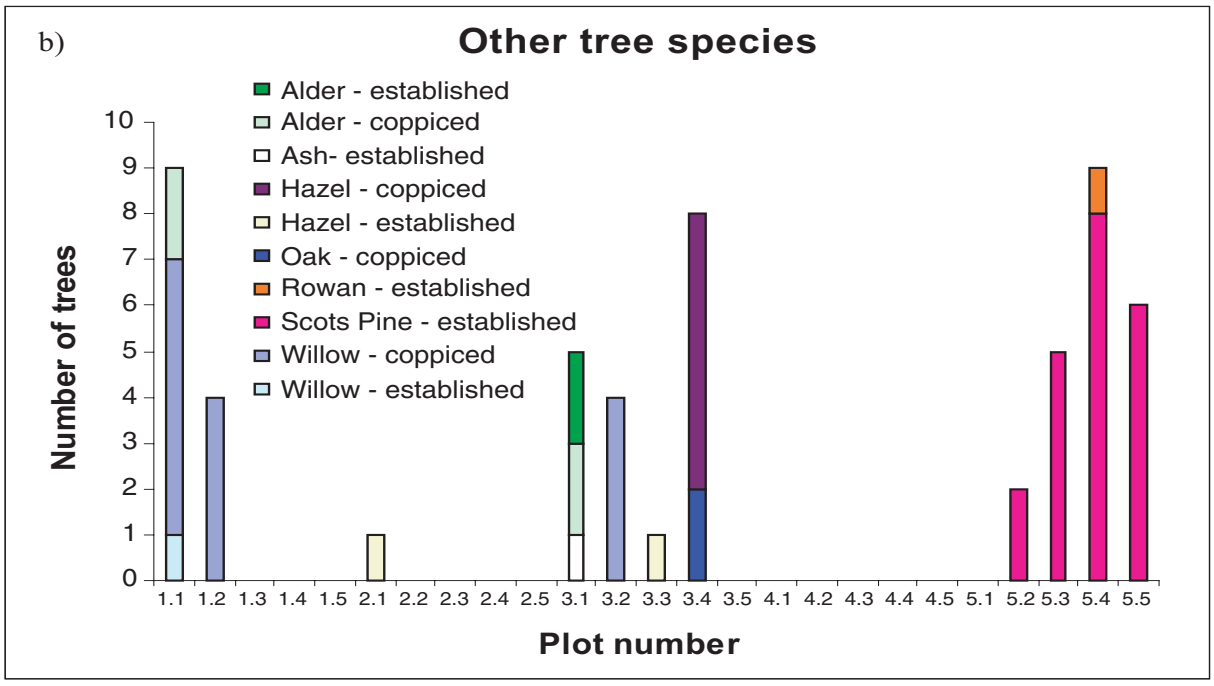


3.6 Tall trees with a diameter of more than 3cm

Figure 10 shows the number of trees taller than 1.5m, and with a diameter greater than 3cm, present on each plot.

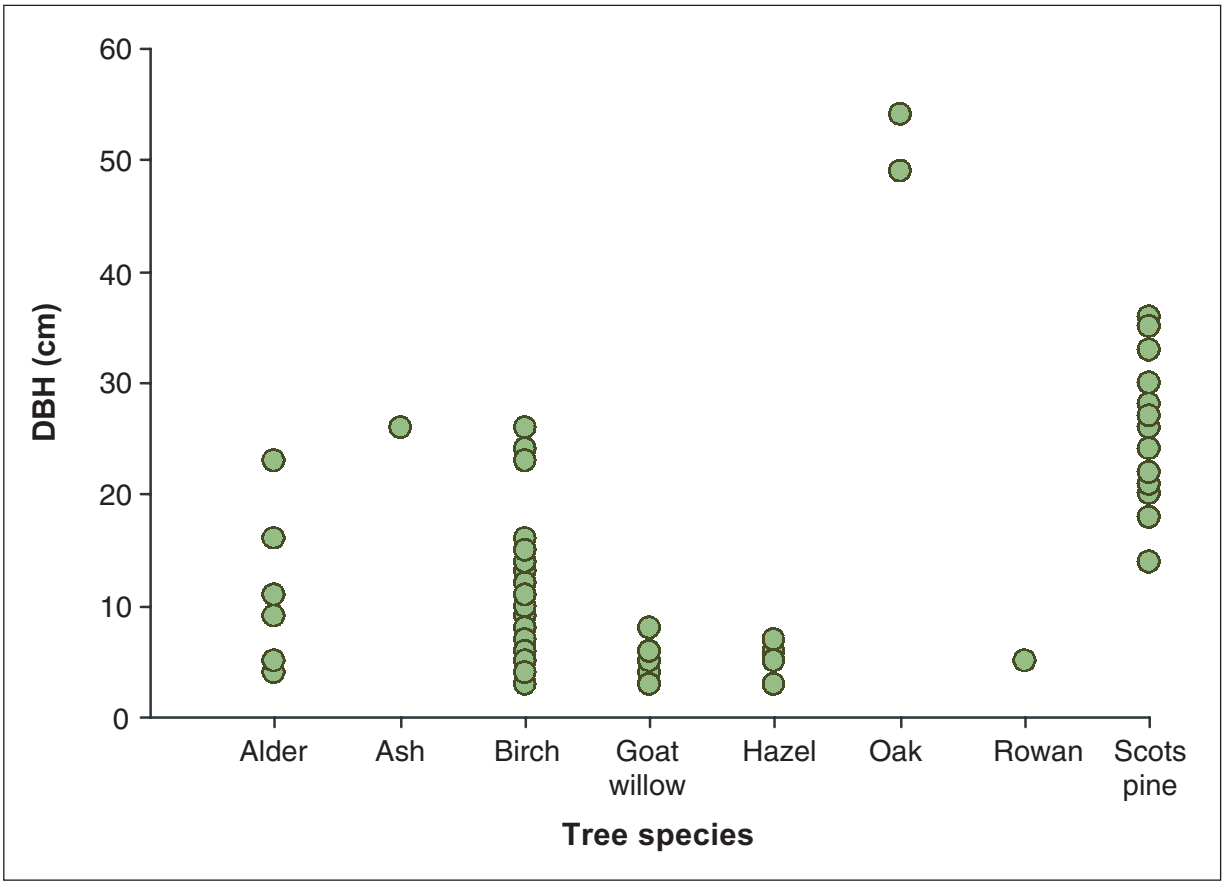
Figure 10 Number of trees in each plot taller than 1.5m and with a diameter of 3cm or more of a) birch and b) other tree species. Willow = goat willow, alder = common alder.





The diameters of all tall trees with a diameter greater than 3 cm is shown in Figure 11.

Figure 11 DBH of all trees recorded which were taller than 1.5 m and had a diameter greater than 3 cm.



3.7 Deer pellet groups

There were no deer pellet groups found in any of the plots.

3.8 Tree canopy cover

Tree canopy cover in each plot is given in Table 7. The plots on Transects 1, 2, 3 and 5 all have canopy covers between 45 and 100 % apart from plots 4 and 5 on Transect 2 which have covers of 25 and 5% respectively and plot 5 on Transect 3 with a cover of 30%. Conversely, only plot 1 on Transect 4 has a canopy cover greater than zero (25%). Thus Transect 4 appears to be in very much more open conditions than the other transects.

3.9 Dead wood

The number of pieces of fallen and standing dead wood, and the total volume in each plot, is given in Table 8.

3.10 Timings

The time taken to complete each component of the monitoring, as well as set-up times and total times, is given for each plot in Table 9.

Table 7 Tree canopy cover within each plot.

Transect no.	Plot no.	Cover (%)
1	1	45
1	2	80
1	3	85
1	4	95
1	5	50
2	1	90
2	2	90
2	3	65
2	4	25
2	5	5
3	1	100
3	2	80
3	3	70
3	4	100
3	5	30
4	1	25
4	2	0
4	3	0
4	4	0
4	5	0
5	1	95
5	2	100
5	3	85
5	4	85
5	5	100

Table 8 Number of pieces of fallen and standing dead wood, and the total volume of each.

Transect no.	Plot no.	No. fallen	Volume fallen per plot (m^3)	No. standing	Volume standing per plot (m^3)	Mean fallen volume[1]	Mean standing volume[1]
1	1	5	1.15	0	0.00		
	2	1	0.30	0	0.00		
	3	7	3.22	0	0.00		
	4	2	0.19	0	0.00		
	5	1	0.18	2	0.09	1.01	0.02
2	1	3	0.35	1	0.79		
	2	4	0.75	0	0.00		
	3	3	0.88	0	0.00		
	4	2	0.21	2	0.23		
	5	0	0.00	0	0.00	0.44	0.21
3	1	0	0.00	0	0.00		
	2	0	0.00	0	0.00		
	3	0	0.00	0	0.00		
	4	9	1.99	0	0.00		
	5	9	0.99	0	0.00	0.60	0.00
4	1	0	0.00	0	0.00		
	2	0	0.00	0	0.00		
	3	0	0.00	0	0.00		
	4	0	0.00	0	0.00		
	5	0	0.00	0	0.00	0.00	0.00
5	1	0	0.00	3	0.76		
	2	0	0.00	2	1.35		
	3	0	0.00	0	0.00		
	4	2	1.56	1	1.41		
	5	0	0.00	0	0.00	0.31	0.70

[1] Mean volume per plot for all plots on the transect (m^3).

Table 9 Time needed to complete the different components of the field measurements. All times are in minutes except where stated.

Transect no.	Plot no.	Plot set-up time	Quadrat set-up time	A1	A1a	A2	A3	B1	B2	B3	B4	Total time	Total time (hours)	Transect total (hours)	Transect total (days)
1	1	18	10	90	30	10	15	2	1	5	90	271	4.52		
1	2	18	10	60		10	10	2	2	5	30	147	2.45		
1	3	18	10	40		10	15	2	1	5	30	131	2.18		
1	4	18	10	60		10	15	2	1	5	30	151	2.52		
1	5	18	10	60		10	20	5	1	15	30	169	2.82	14.48	2.41
2	1	6	5	60	30	10	20	2	1	5	10	149	2.48		
2	2	6	5	75		10	10	2	1	5	2	116	1.93		
2	3	6	5	60		10	10	2	1	5	1	100	1.67		
2	4	6	5	70		10	15	1	1	5	5	118	1.97		
2	5	6	5	90		5	5	2	1	1	2	117	1.95	10.00	1.67
3	1	14	15	90	80	10	10	2	2	2	10	235	3.92		
3	2	14	15	40		10	10	2	2	2	10	105	1.75		
3	3	14	15	75		10	10	2	1	1	15	143	2.38		
3	4	14	15	70		10	10	2	1	15	15	152	2.53		
3	5	14	15	75		10	15	2	1	10	2	144	2.40	12.98	2.16
4	1	12	10	50	25	10	8	2	1	1	8	127	2.12		
4	2	12	10	45		10	8	1	1	1	5	93	1.55		
4	3	12	10	40		5	5	1	1	1	2	77	1.28		
4	4	12	10	40		10	10	1	1	1	2	87	1.45		
4	5	12	10	30		10	10	1	1	1	2	77	1.28	7.68	1.28
5	1	12	10	65	60	5	10	2	2	5	5	176	2.93		
5	2	12	10	45		5	10	2	2	5	15	106	1.77		
5	3	12	10	35		5	10	2	2	2	10	88	1.47		
5	4	12	10	35		5	20	2	2	5	10	101	1.68		
5	5	12	10	35		10	15	2	1	3	10	98	1.63	9.48	1.58

A1 = Ground cover plants (4 sub-quadrats), A1a = Ground cover plants (16 sub-quadrats), A2 = Vegetation height, A3 = Saplings.

B1 = Canopy cover, B2 = deer pellet groups, B3 = Dead wood, B4 = Tall trees.

4 DISCUSSION

4.1 Ground cover

Transect 1 changes in its composition with distance from the loch. In the quadrat in plot 1, next to the loch, a quarter of the quadrat was bare earth (Figure 2). *Juncus effusus* and *Deschampsia caespitosa* were the only two flowering plant species with a cover of greater than 5%. However, there was a large number of higher plant species with a cover of <5% and the overall species richness was high (Table 3). This indicates a quadrat that was relatively wet, shaded and nutrient rich. The quadrats sited in plots 2–5 had a much higher cover of dwarf shrubs (*Calluna vulgaris* and *Vaccinium myrtillus*), no bare earth, a higher cover of bryophytes and about half as many higher plant species. This indicates that these quadrats were drier, less shaded and more acidic.

Again with Transect 2 the quadrat in the plot next to the loch side appears to differ from the others (Figure 3). The first quadrat is very species poor (Table 3) with only 5 flowering plant species present, has a high cover of litter, bryophytes and *V. myrtillus*. The other quadrats on the transect are similar but with other grass, rush and herb species present. The number of flowering plant species present increases with increasing distance from the loch, from 5–15 (Figure 3). Overall, this habitat type appears to be relatively dry, to have a high canopy cover (resulting in a high litter cover), to be acidic and species poor next to the loch but to gradually become less acidic and more species rich with distance from the loch.

Transect 3 is the most species rich of the five transects (Figure 4, Table 3). The quadrats along this transect had, in general, a low cover of litter (though it is higher in the quadrat in plot 5) and a high cover of grasses, herbs and ferns. It also has a high number of bryophyte, lichen and liverwort species compared with the other transects. There were no dwarf shrubs present. This indicates a fertile site with a ground vegetation which could be very attractive to beavers. However Area 14 is on a slope and is not adjacent to the loch edge so will be less accessible to beavers than other parts of the site.

Transects 4 and 5 (Figure 5, Figure 6, Table 3) both have a low species richness of most plant types with almost no herb, fern, grass, sedge or rush species present. The number of moss species is also relatively low although the number of lichen and liverwort species does not seem to differ from that found on the other transects. The cover of dwarf shrub species is high in all quadrats on both these transects but on Transect 4 the dwarf shrub species that dominate are *C. vulgaris* and *Myrica gale* whereas on Transect 5 *V. myrtillus* dominates. The quadrats on Transect 4 also have a high cover of *M. caerulea* which is not the case on Transect 5. These factors indicate that both transects are acidic and that Transect 4 is probably wetter (indicated by the presence of *M. caerulea* and *M. gale*) than Transect 5. These two transects are in adjacent Areas (Figure 1) and it is possible that the vegetation communities started off similar but the planted Scots pines have dried out the ground.

Using 16, rather than 4, sub-quadrats to estimate cover gave very similar result, however there was a tendency for the results for 4 sub-quadrats to be slightly higher than those for 16 sub-quadrats (Appendix 2). The same species were recorded using both methods except for Transect 1, quadrat 1 where two species were not recorded using the 16 sub-quadrat method. Without knowing why the cover estimates are slightly higher when 4 sub-quadrats are used, it is impossible to know which method gives the most accurate result. However, the overall similarity of the results suggests that there is little to be gained from using 16 sub-quadrats, rather than 4 sub-quadrats, as long as the same method is used each time.

4.2 Grazing by deer on ground vegetation

No grazing by deer was recorded in any of the quadrats on Transect 5 (Table 4). Transect 5 is on an island so this is perhaps to be expected, however the distance to the mainland is small on the south east side of the island and deer might be expected to cross to the island if they were short of food. The complete lack of grazing suggests that the deer were not short of food. Very little grazing was recorded in the quadrats on Transect 1 perhaps because of the dense birch regeneration preventing easy access (Table 4). Grazing occurred on some species in the quadrats on Transects 2–4 but, in may cases, was not recorded on all occurrences of the same species within sub-quadrats of the same quadrat (Table 4). This indicates that deer grazing, although present, was not heavy or uniform. This is supported by the summarized data for all sub-quadrats on Transects 1–4 (Table 5) which show that only 12 species were grazed and, of those, only *M. caerule*a and *V. myrtillus* were grazed in more than half of the sub-quadrats in which they occurred (78% and 63% respectively).

4.3 Ground vegetation height

The method of measuring vegetation height at the intersections of the 16 sub-quadrats worked well in that there was no vegetation present at only two intersections. Most of the differences in vegetation height would appear to be due to differences in plant species composition between quadrats (Appendix 4). Since there was very little grazing by deer at the site (Section 3.1) this is to be expected. This means that analysis of any future monitoring data will have to be done at the level of species within quadrats, however, the sample size for any individual species within a quadrat was often low. It might therefore be preferable to sample only the dominant one or two species within any habitat type and ensure that there is an adequate sample size of each.

4.4 Saplings

There were no saplings present in 6 of the 25 quadrats and there were fewer than 6 saplings present in 14 quadrats, including all those on Transect 4. In these cases the density of saplings obtained from the nearest neighbour method is likely to give more accurate results. Where the number of trees within the quadrat is large, the quadrat method involves the measurement of a larger number of trees, over a bigger area, than does the nearest neighbour method and is therefore likely to be the more accurate method. A combination of the two approaches, where the nearest neighbour method is used only when there are five, or fewer, trees in the quadrat, may be the best approach.

The only transect where birch, rowan, alder, hazel and oak trees were all recorded, albeit in low numbers (Section 2.4) was Transect 3. This corresponds with the results for the ground vegetation where this transect was also found to be the most species rich (Section 4.1). There was an indication that rowan was less common where birch was more common (Figure 7). The heaviest browsing by deer appeared to be on Transect 2, followed by Transect 3, with very little browsing on Transects 1 and 5 and none on Transect 4. This pattern is probably due to Transect 2 being the most open and accessible to deer, followed by Transect 3. Transect 1 has dense birch regeneration, Transect 4 has a dense, and tall, *C. vulgaris* understorey (Appendix 4) and Transect 5 is on an island (Figure 1). On Transect 2, 76% of the 46 saplings recorded had been browsed by deer. This is likely to be sufficient to limit, if not completely suppress, regeneration. This is despite the ground vegetation not being heavily grazed, suggesting that the saplings are either browsed largely in winter or are preferentially browsed in spring.

Although birch saplings were more numerous in the height classes up to 40cm, there were trees present in every 10cm height class up to 150cm (Figure 8). By contrast, the number of young rowans declined with tree height and became very low above 30cm and zero by 90cm. The high deer browsing rates on the smaller rowans may account for the lack of taller trees of this species, most of which occurred on Transect 2, as postulated above.

4.5 Tall trees with a diameter of 3cm or less

Figure 9 shows that birch was the most prolific tree species of this size recorded. Most were coppiced i.e. were part of a group of stems coming from the same root stock and most were recorded in the plots on Transect 1. A few trees were recorded on all other transects and in all plots on Transect 4. The regeneration on Transect 4 may be facilitated by the low canopy cover and the lack of browsing (Figure 7a). On Transect 1 the birch regenerated following clear felling of a conifer crop.

Goat willow is the only other tree species to be recorded in high numbers and these were all in the three plots nearest to the loch on Transect 1. A few hazel trees were also recorded on Transect 3. No rowans were recorded on Transect 2 which supports the hypothesis that the rowans on this transect are being suppressed by deer browsing (Section 4.4).

4.6 Tall trees with a diameter of more than 3cm

Birch was the most numerous species, occurring on all transects and with roughly equal numbers of coppiced and established trees (Figure 10a). On Transect 1 willow and alder were recorded only in the two plots closest to the loch (Figure 10b). This corresponds with the results for tall trees with a diameter of 3 cm or less (Figure 9b, section 4.5). The highest number of species was recorded on Transect 3 where alder, ash, hazel, oak and goat willow all occurred. This, together with the presence of saplings of a range of species (Section 4.4), suggests that this area of woodland has a rich tree, as well as ground layer flora (Section 4.1) with a varied size structure of trees (Section 4.1 and 4.4). However, the lack of tall trees with a diameter of 3 cm or less, together with the relatively high browsing rates (Figure 7) suggests that deer browsing may be restricting regeneration of species other than birch. Only one tree, other than birch, was recorded on Transect 2 again suggesting that some birch is regenerating, but supporting the conclusion that no rowan survives to become established (sections 4.4 and 4.5). On Transect 4 all but one of the trees recorded was birch, again suggesting that birch is regenerating well on this transect (Section 4.5). On Transect 5 numerous Scots pines, and one rowan, were recorded. The Scots pines had diameters ranging from 15–35 cm (Figure 11) suggesting that they were all either trees that were part of the original planting or that they regenerated early on. Similarly, the large diameters of the two oak trees indicates that these were adult trees on Transect 2. The one ash tree also had a diameter large enough to indicate that it was well established (Figure 11). The birch trees encompassed a wide range of diameters indicating that this species has been able to regenerate consistently over the years.

4.7 Deer pellet groups

The lack of deer pellet groups supports the conclusion than deer grazing pressure is generally low. It also indicates that low numbers of deer may be responsible for the high browsing rates on the young trees in the plots on Transect 2 (Area 16) and Transect 3 (Area 1).

4.8 Canopy cover

All the transects generally had a high tree canopy cover except for Transect 4, which was in much more open conditions. This may account for the high cover of tall *C. vulgaris* in this area (Appendix 4).

4.9 Dead wood

No dead wood at all was recorded on Transect 4 (Table 9) as might be expected from the low canopy cover on this transect (Table 7). Most fallen dead wood was recorded in the plots on Transect 1. This, again, is to be expected since it is likely that at least some of the dead wood originated when the previous conifer plantation was felled. Significant amounts of standing wood was only recorded on Transect 2 and Transect 5. The standing dead wood on Transect 5 may include planted trees that have died through self-thinning.

4.10 Timings

The collection of data on the field and ground vegetation took longer than any other component of the field measurements and, in many cases, took longer than all the other components combined (Table 9). It appeared to take less time to carry out the field and ground cover measurements in the 16 sub-quadrats than in the 4 sub-quadrats, however the 4 sub-quadrats were measured first hence all the plant identification had been carried out before the 16 sub-quadrats were assessed. Also, the bryophytes and lichens were not identified to species in the 16 sub-quadrats. There does seem to be a relationship between number of species and the time taken to assess the quadrat with quadrats on Transects 4 and 5, with relatively low species richness, taking less time than those on Transects 1, 2 and 3.

The time taken to identify bryophytes to species and to record their presence was not measured separately, but was judged to have taken a large proportion of the time allocated to assessing the field and ground layer vegetation in the 4 sub-quadrats. A direct comparison of the time taken to assess percentage cover within 4 or 16 sub-quadrats cannot be made, however, it is probably reasonable to assume that it will take as long to estimate percentage cover in a quarter of a quadrat as in a sixteenth. The percentage cover estimates alone would therefore take 4 times as long for 16, as compared to 4, sub-quadrats.

The measurements of vegetation height and of saplings generally took less than 15 minutes each and the assessment of canopy cover and deer pellet groups each took a couple of minutes at most (Table 9). The assessment of dead wood varied depending on the quantities present, but never took longer than 15 minutes. The measurement of tall trees also took no more than 15 minutes except in the plots on Transect 1 where there was a dense growth of young birch trees and the times needed were considerably longer.

Overall, Transects 1 and 3 took the longest because of the dense birch re-growth on Transect 1 and the high number of species present on Transect 3. The time taken to complete a transect ranged from 1.28–2.41 days, not including travelling time. Setting up time would be reduced at future visits but would not be insignificant. However, species identification should be quicker on repeat visits so the assessment of ground cover and presence of bryophytes and lichens should take less time.

4.11 General discussion

This study showed high variation between transects in most of the variables measured. This indicates that we were correct to assume that habitat type would be a major cause of variation and that, therefore, sampling will have to be stratified by habitat type. In this study we had time to record data from only five transects so we could only sample five habitat types. However, assuming that our classification of the different Areas into habitat types is reasonable (Table 1) then this leaves only habitat type 2 (Mature birch/alder with *M. caerulea*/Sphagnum field layer) unsampled. Although this is similar to habitat type 4, it is likely to be wetter and, in fact, parts of Areas 2 and 7 were flooded on the day we carried out our habitat assessment. This habitat type is therefore likely to be favoured by beavers for canal building and therefore also for feeding. Future monitoring should therefore include habitat type 2 as one of the sampling strata. Other areas not sampled were very steep; presumably too steep for beavers to negotiate however, if the beavers are introduced, it would be advisable to check these Areas for beaver presence to be sure that they are not being used.

Assuming our transects were representative of the Areas and habitat types in which they were situated (Table 1 and Table 2), it seems likely that the beavers will prefer habitat type 3 (Areas 10 and 14) for ground layer feeding given the species richness of the ground flora and high cover of herbs and grasses (Transect 3; Figure 4). However both these Areas are set back from the loch and are on a slope (though not a precipitous one) and this may deter the beavers. Habitat type 5 (Area 26) was also fairly species rich further away from the loch (Transect 2; Figure 3) so may also be preferred for ground layer feeding, especially since it is open and not too steep. For winter felling of young trees the beavers are likely to prefer Habitat type 1 (Area 1) because of the high density of young birch and willow (Transect 1; Figure 7). Bark stripping is most likely to occur in Habitat types 1 and 5 where there is the highest density, and greatest species diversity, of broadleaved trees with a diameter greater than 3cm (Transects 1 and 3; Figure 10). Habitat type 6 (Area 6) also has a high density of birch of the same size and may also be used for this purpose.

It cannot be assumed that the beavers will, in practice, show these preferences, however, with limited resources for monitoring, it might make sense to concentrate monitoring of ground layer plants in Habitat types 3 and 5, of tall trees with a diameter less than 3cm in Habitat type 1 and of larger trees in Habitat types 1, 5 and 6. Given that a potentially significant deer browsing effect was detected on saplings in Habitat types 3 and 5 (Areas 14 and 16; Transects 3 and 2; Figure 7) it is important that saplings are monitored in these Habitat types but they should also be monitored in the other Habitat types to provide information on the potential future stock of young trees able to provide food for beavers.

Despite the apparent low presence of deer on the site (Section 4.7), deer may be a potential problem in Habitat types 3 and 5 where they may be suppressing regeneration of young trees. This would limit the stock of trees available to beavers in the future but this may not be a problem given the high density of birch and willow in Habitat type 1 which, if continually coppiced by beavers, might provide a continuing source of food, assuming deer browsing does not increase in this Habitat type as the trees are thinned. In Habitat 5 a lack of tree regeneration may be a problem for other reasons since this oak wood must be maintained in favourable condition to meet the requirements of the candidate Special Area of Conservation.

The method used here worked well and produced some good descriptive data. Three suggestions have been made to improve the method. The first is to divide the 2 x 2m quadrats into 4, and not 16, for the estimation of percentage cover since there seemed to be no advantage to be gained from using 16 sub-quadrats and

it is likely to take significantly longer. The second is to measure the heights of only the two dominant plant species, or species of most interest, in each Habitat type so that a reasonable sample could be obtained from each. Nine measures of height of each within each quadrat would probably be sufficient. A method would have to be devised for 'picking' the nine sampling points for each plant species. The third suggestion is that a combination of 'quadrat' and 'nearest neighbour' sampling is used for saplings, as was done in this study. By ensuring a minimum sample size in almost all cases, this is likely to give a more accurate result than using either one of these approaches on its own.

The disadvantage of the methods described here is the time that would be needed to collect enough data to be able to detect significant changes. A minimum of five transects per Habitat type would be needed. Since each transect took between 1.3 and 2.4 days to complete, excluding preparation and travelling time, carrying out adequate monitoring would almost certainly be prohibitively expensive. Some suggestions have been made above for Habitat types which might be targeted for particular parts of the monitoring whilst other Habitat types might receive only minimal 'tracking' monitoring. Similarly, since beavers are expected to have most impact close to the loch, it might be sensible to have intensive monitoring in the first 10m from the loch shore but only monitor one transect per Habitat type to its full length. This might apply particularly to the estimates of field and ground layer cover since this is especially time consuming. Species identification will speed up as the experience of the surveyors increases, but this is still likely to remain the most time-consuming part of the method. Another potential approach would be to record data in high numbers of randomly positioned, non-permanent quadrats in the first 10m from the loch. Not having to measure out and mark the location of the quadrats would save some time but a larger sample size would be needed. It might also be worth considering recording only presence absence of each species in nested quadrats. Recording presence/absence is likely to be less subject to observer error, and to be faster, than is the estimation of percentage cover but again, a large sample size, of perhaps 100 or more, is likely to be needed. A reduction in observer error could be particularly important where different people carry out the monitoring in different years. We did not have the resources in this study to investigate observer error, but if percentage cover is used in the final method then it would be worth considering setting up training for observers and devising a means of testing consistency between observers and years.

5 CONCLUSIONS

Six different Habitat types were identified within the study area. They appeared to be sufficiently different that each should be considered as a separate stratum in any future sampling.

Deer browsing on saplings (less than 1.5m tall) was heavy in two Habitat types and may be restricting tree regeneration despite other signs of deer presence being low. Deer impacts on saplings need to be monitored throughout the site but, in particular, in these two Habitat types.

The method tested in this study for monitoring the impact of beavers on terrestrial vegetation proved to be viable in the field and to provide useful, and detailed, information. Based on the field tests, three suggestions have been made for refinements:

1 Use 4 sub-quadrats, rather than 16, for assessing ground cover.

2 Only measure the height of the two dominant plant species, or those of most interest, in each Habitat type.

3 Use of a combined 'quadrat' and 'nearest neighbour' method for monitoring saplings.

The main drawback of the method is the time that it takes and, in particular, the time needed to carry out estimates of plant species ground cover. The following suggestions are made for targeting resources in a manner that might provide the most useful information:

1 Concentrate resources in the Habitat types on which the beavers are likely to have most effect whilst doing minimal 'tracking' in the other Habitat types.

2 Sample field and ground vegetation in the area within 10m of the loch intensively, use non-permanent quadrats and possibly record only presence/absence of each species.

3 Monitor only one complete transect per Habitat type.

4 Set up further transects in which only the trees are monitored.

APPENDIX 1 – Dates of field assessments and identity of observers

		Ground cover		Plant height and saplings		Canopy cover/dung		Deadwood		Tall trees <3cm dbh		Tall trees >3cm dbh	
Transect	**Plot**	**Obs.[1]**	**Date**	**Obs.[1]**	**Date**	**Obs.[1]**	**Date**	**Obs.[1]**	**Date**	**Obs.[1]**	**Date**	**Obs.[1]**	**Date**
1	1	PS/JW	1/5/2003	PS	1/5/2003	PS/JW	1/5/2003	PS/JW	1/5/2003	PS/JW	1/5/2003	PS/JW	1/5/2003
	2	PS/JW	27/5/2003	PS/JW	27/5/2003	PS/JW	9/5/2003	PS/JW	9/5/2003	PS/JW	9/5/2003	PS/JW	9/5/2003
	3	PS/JW	27/5/2003	PS/JW	27/5/2003	PS/JW	9/5/2003	PS/JW	9/5/2003	PS/JW	9/5/2003	PS/JW	9/5/2003
	4	PS	28/5/2003	PS/JW	28/5/2003	PS/JW	9/5/2003	PS/JW	9/5/2003	PS/JW	9/5/2003	PS/JW	9/5/2003
	5	PS/JW	28/5/2003	PS/JW	8/5/2003	PS/JW	8/5/2003	PS/JW	9/5/2003	PS	8/5/2003	PS	8/5/2003
2	1	PS/JW	23/4/2003	PS/JW	23/4/2003	PS/JW	29/4/2003	PS/JW	29/4/2003	PS/JW	29/4/2003	PS/JW	29/4/2003
	2	PS	26/5/2003	PS	26/5/2003	PS/JW	29/4/2003	PS/JW	29/4/2003	PS/JW	29/4/2003	PS/JW	29/4/2003
	3	PS	28/5/2003	PS	28/5/2003	PS/JW	29/4/2003	PS/JW	29/4/2003	JW	2/6/2003	-	-
	4	PS	28/5/2003	PS	28/5/2003	PS/JW	29/4/2003	PS/JW	29/4/2003	PS	15/5/2003	PS/JW	29/4/2003
	5	PS/JW	29/4/2003	PS/JW	29/4/2003	PS/JW	29/4/2003	-	-	-	-	PS/JW	29/4/2003
3	1	PS	14/5/2003	PS	14/5/2003	JW	2/6/2003	-	-	-	-	JW	2/6/2003
	2	PS	2/6/2003	JW	2/6/2003	JW	2/6/2003	-	-	-	-	JW	2/6/2003
	3	PS/JW	2/6/2003	JW	2/6/2003	JW	2/6/2003	-	-	JW	2/6/2003	JW	2/6/2003
	4	PS/JW	2/6/2003	PS/JW	2/6/2003	PS	15/5/2003	PS	15/5/2003	PS	15/5/2003	PS	15/5/2003
	5	PS	15/5/2003	PS	15/5/2003	PS	15/5/2003	PS	15/5/2003	-	-	PS	15/5/2003
4	1	PS	20/5/2003	PS	20/5/2003	JW	4/6/2003	-	-	JW	4/6/2003	JW	4/6/2003
	2	PS	5/6/2003	JW	4/6/2003	JW	4/6/2003	-	-	JW	4/6/2003	JW	4/6/2003
	3	PS	5/6/2003	JW	4/6/2003	JW	4/6/2003	-	-	JW	4/6/2003	-	-
	4	PS	5/6/2003	JW	4/6/2003	JW	4/6/2003	-	-	JW	4/6/2003	-	-
	5	PS	5/6/2003	JW	4/6/2003	JW	4/6/2003	-	-	JW	4/6/2003	-	-
5	1	PS	3/6/2003	JW	3/6/2003	JW	3/6/2003	JW	3/6/2003	JW	3/6/2003	JW	3/6/2003
	2	PS	3/6/2003	JW	3/6/2003	JW	3/6/2003	JW	3/6/2003	JW	3/6/2003	JW	3/6/2003
	3	PS	3/6/2003	PS	3/6/2003	JW	3/6/2003	-	-	-	-	JW	3/6/2003
	4	PS	3/6/2003	JW	3/6/2003	JW	3/6/2003	JW	3/6/2003	JW	3/6/2003	JW	3/6/2003
	5	PS	3/6/2003	JW	3/6/2003	JW	3/6/2003	-	-	-	-	JW	3/6/2003

[1] Observer. PS = Pauline Simson, JW = James Wilson. [2] Carried out on both 15th and 18th May 2003.

APPENDIX 2 – Percentage cover of ground and field layer plant species in each plot

Transect	Plot	Species	Quarter				Mean of 4	Mean of 16
			1	2	3	4		
1	1	Litter	60	25	25	55	41	44
		Bryophytes	35	20	20	30	26	18
		Bare earth	0	45	50	5	25	28
		Juncus effusus	20	5	25	25	19	13
		Deschampsia cespitosa	0	20	25	10	14	12
		Deschampsia flexuosa	0	10	0	0	3	0
		Molinia caerulea	0	10	0	0	3	3
		Potentilla erecta	0	5	5	0	3	1
		Agrostis canina montana	0	5	0	0	1	1
		Anthoxanthum odoratum	0	0	5	0	1	1
		Galium saxatile	0	5	0	0	1	0
		Pteridium aquilinum	0	0	5	0	1	0
		Ranunculus repens	0	0	0	5	1	2
		Succisa pratensis	0	5	0	0	1	0
		Betula pubescens	0	0	0	0	0	0
		Carex binervis	0	0	0	0	0	0
		Epilobium sp.	0	0	0	0	0	0
		Fragaria vesca	0	0	0	0	0	0
		Lonicera periclymenum	0	0	0	0	0	-
		Luzula sylvatica	0	0	0	0	0	0
		Oxalis acetosella	0	0	0	0	0	-
		Rubus fruticosus	0	0	0	0	0	0
		Rubus idaeus	0	0	0	0	0	0
		Rumex sp.	0	0	0	0	0	0
	2	Bryophytes	80	90	95	95	90	
		Litter	40	90	50	75	64	
		Vaccinium myrtillus	30	65	75	50	55	
		Betula pubescens	5	0	50	0	14	
		Lonicera periclymenum	5	5	0	30	10	
		Rubus fruticosus	0	0	25	0	6	
		Dryopteris filix-mas	0	5	0	0	1	
		Calluna vulgaris	0	0	0	0	0	
		Deschampsia flexuosa	0	0	0	0	0	
		Dryopteris affinis	0	0	0	0	0	
		Epilobium sp.	0	0	0	0	0	
	3	Bryophytes	95	95	80	90	90	
		Vaccinium myrtillus	95	95	50	100	85	

Appendix 2 *(continued)*

Transect	Plot	Species	Quarter				Mean of 4	Mean of 16
			1	2	3	4		
		Calluna vulgaris	5	20	10	50	21	
		Litter	15	10	35	20	20	
		Deschampsia cespitosa	0	0	20	0	5	
		Betula pubescens	5	0	5	5	4	
		Athyrium filix-femina	0	0	0	0	0	
		Deschampsia flexuosa	0	0	0	0	0	
		Dryopteris filix-mas	0	0	0	0	0	
		Dryopteris sp.	0	0	0	0	0	
		Pteridium aquilinum	0	0	0	0	0	
		Sorbus aucuparia	0	0	0	0	0	
1	4	Bryophytes	75	80	90	90	84	
		Calluna vulgaris	60	80	30	55	56	
		Vaccinium myrtillus	40	40	70	40	48	
		Litter	40	40	40	40	40	
		Betula pubescens	10	10	10	10	10	
		Rubus fruticosus	5	0	5	10	5	
		Dryopteris sp.	0	0	5	5	3	
		Rock	0	0	10	0	3	
		Deschampsia flexuosa	0	0	5	0	1	
		Picea sitchensis	0	0	5	0	1	
		Pteridium aquilinum	0	0	5	0	1	
		Blechnum spicant	0	0	0	0	0	
		Small brown fungus	0	0	0	0	0	
		Small white fungi	0	0	0	0	0	
	5	*Calluna vulgaris*	80	70	95	65	78	
		Bryophytes	70	80	80	75	76	
		Litter	90	55	80	40	66	
		Betula pubescens	10	0	5	15	8	
		Vaccinium myrtillus	5	0	0	5	3	
		Blechnum spicant	0	5	0	0	1	
		Dryopteris sp.	0	5	0	0	1	
		Sorbus aucuparia	0	0	5	0	1	
		Small brown fungus	0	0	0	0	0	
		Small grey fungus	0	0	0	0	0	
2	1	Litter	80	50	70	64	66	68
		Bryophytes	45	95	75	45	65	49
		Vaccinium myrtillus	20	55	50	45	43	38
		Blechnum spicant	0	5	0	0	1	0

Appendix 2 *(continued)*

Transect	Plot	Species	Quarter				Mean of 4	Mean of 16
			1	2	3	4		
		Deschampsia flexuosa	0	0	0	0	0	0
		Molinia caerulea	0	0	0	0	0	0
		Pteridium aquilinum	0	0	0	0	0	0
	2	Bryophytes	60	65	85	90	75	
		Vaccinium myrtillus	40	50	70	75	59	
		Litter	35	55	20	15	31	
		Molinia caerulea	20	30	25	30	26	
		Deschampsia flexuosa	20	25	10	10	16	
		Pteridium aquilinum	5	0	5	10	5	
		Bare earth	15	0	0	0	4	
		Blechnum spicant	0	0	0	0	0	
		Calluna vulgaris	0	0	0	0	0	
		Sorbus aucuparia	0	0	0	0	0	
	3	Bryophytes	90	90	90	80	88	
		Vaccinium myrtillus	35	60	70	30	49	
		Litter	40	35	40	50	41	
		Molinia caerulea	50	15	25	65	39	
		Deschampsia flexuosa	20	20	15	10	16	
		Lonicera periclymenum	5	10	5	5	6	
		Pteridium aquilinum	0	5	5	5	4	
		Blechnum spicant	0	0	5	0	1	
		Sorbus aucuparia	5	0	0	0	1	
		Luzula sp.	0	0	0	0	0	
		Oxalis acetosella	0	0	0	0	0	
2	4	Bryophytes	90	90	70	70	80	
		Litter	80	70	80	60	73	
		Vaccinium myrtillus	50	50	45	20	41	
		Pteridium aquilinum	5	5	50	45	26	
		Deschampsia flexuosa	45	30	0	15	23	
		Lonicera periclymenum	5	5	10	10	8	
		Sorbus aucuparia	5	10	0	5	5	
		Oxalis acetosella	10	0	0	0	3	
		Luzula sp.	0	0	5	0	1	
		Blechnum spicant	0	0	0	0	0	
		Hyacinthoides non-scripta	0	0	0	0	0	
		Quercus sp.	0	0	0	0	0	
		Small brown fungus	0	0	0	0	0	
	5	Litter	60	80	60	95	74	

Appendix 2 *(continued)*

Transect	Plot	Species	Quarter				Mean of 4	Mean of 16
			1	2	3	4		
		Bryophytes	55	55	45	35	48	
		Deschampsia flexuosa	30	20	20	30	25	
		Hyacinthoides non-scripta	15	5	5	5	8	
		Vaccinium myrtillus	15	5	5	5	8	
		Luzula sylvatica	5	5	5	5	5	
		Potentilla erecta	10	5	0	0	4	
		Sorbus aucuparia	0	5	0	0	1	
		Agrostis canina montana	0	0	0	0	0	
		Anemone nemorosa	0	0	0	0	0	
		Anthoxanthum odoratum	0	0	0	0	0	
		Betula pubescens	0	0	0	0	0	
		Galium saxatile	0	0	0	0	0	
		Molinia caerulea	0	0	0	0	0	
		Oxalis acetosella	0	0	0	0	0	
		Picea sitchensis	0	0	0	0	0	
		Pteridium aquilinum	0	0	0	0	0	
3	1	Bryophytes	55	45	45	10	39	38
		Bare earth	15	20	20	20	19	10
		Litter	15	15	15	5	13	8
		Anthoxanthum odoratum	15	10	10	5	10	8
		Rock	5	5	20	10	10	8
		Deschampsia flexuosa	10	10	5	10	9	4
		Carex panicea	5	15	5	5	8	3
		Carex flava agg.	10	0	5	5	5	0
		Molinia caerulea	0	10	5	5	5	2
		Ajuga reptans	5	0	0	10	4	1
		Lysimachia nemorum	0	5	0	10	4	1
		Ranunculus flammula	5	5	0	5	4	3
		Primula vulgaris	0	0	10	0	3	0
		Alder root	0	0	0	5	1	0
		Cirsium palustre	0	0	5	0	1	0
		Crepis paludosa	0	0	0	5	1	0
		Dryopteris sp.	0	0	5	0	1	0
		Juncus effusus	5	0	0	0	1	0
		Luzula sylvatica	5	0	0	0	1	0
		Potentilla erecta	0	5	0	0	1	0
		Succisa pratensis	0	5	0	0	1	0
		Viola palustris	0	5	0	0	1	1

Appendix 2 *(continued)*

Transect	Plot	Species	Quarter				Mean of 4	Mean of 16
			1	2	3	4		
		Galium saxatile	0	0	0	0	0	0
		Oxalis acetosella	0	0	0	0	0	0
		Ranunculus repens	0	0	0	0	0	0
		Sorbus aucuparia	0	0	0	0	0	0
3	2	*Anthoxanthum odoratum*	90	80	60	55	71	
		Bryophytes	90	90	85	0	66	
		Potentilla erecta	10	40	35	15	25	
		Litter	10	20	25	20	19	
		Deschampsia cespitosa	0	0	30	5	9	
		Hyacinthoides non-scripta	5	0	10	10	6	
		Birch trunk	0	0	0	15	4	
		Pteridium aquilinum	0	0	5	10	4	
		Luzula sylvatica	10	0	0	0	3	
		Stellaria holostea	0	0	5	5	3	
		Carex flava agg.	0	5	0	0	1	
		Juncus effusus	0	5	0	0	1	
		Betula pubescens	0	0	0	0	0	
		Oxalis acetosella	0	0	0	0	0	
		Quercus spp.	0	0	0	0	0	
		Viola palustris	0	0	0	0	0	
	3	Bryophytes	70	70	80	90	78	
		Anthoxanthum odoratum	40	65	80	35	55	
		Litter	30	65	20	10	31	
		Oxalis acetosella	30	25	30	0	21	
		Blechnum spicant	15	15	25	5	15	
		Deschampsia flexuosa	10	5	10	20	11	
		Birch trunk	0	0	0	30	8	
		Potentilla erecta	10	5	5	10	8	
		Hyacinthoides non-scripta	10	5	0	10	6	
		Pteridium aquilinum	5	10	10	0	6	
		Viola riviniana	5	10	5	5	6	
		Dryopteris filix-mas	5	0	5	5	4	
		Betula pubescens	5	0	0	5	3	
		Luzula sylvatica	0	5	0	5	3	
		Galium saxatile	0	0	0	5	1	
		Succisa pratensis	0	5	0	0	1	
		Vaccinium myrtillus	0	0	0	5	1	
		Conopodium majus	0	0	0	0	0	

Appendix 2 *(continued)*

Transect	Plot	Species	Quarter				Mean of 4	Mean of 16
			1	2	3	4		
		Lysimachia nemorum	0	0	0	0	0	
		Sorbus aucuparia	0	0	0	0	0	
		Stellaria holostea	0	0	0	0	0	
		Teucrium scorodonia	0	0	0	0	0	
	4	*Anthoxanthum odoratum*	85	65	65	60	69	
		Bryophytes	90	40	35	80	61	
		Oxalis acetosella	70	45	40	40	49	
		Pteridium aquilinum	10	50	5	0	16	
		Litter	5	25	25	5	15	
		Oak trunk	0	0	0	50	13	
		Deschampsia flexuosa	10	0	20	15	11	
		Stellaria holostea	5	10	15	10	10	
		Blechnum spicant	0	0	10	20	8	
		Dryopteris filix-mas	0	5	25	0	8	
		Hyacinthoides non-scripta	10	10	0	10	8	
		Rock	0	0	5	20	6	
		Quercus spp.	0	0	15	0	4	
		Luzula sylvatica	0	5	5	0	3	
		Potentilla erecta	5	5	0	0	3	
		Sorbus aucuparia	5	0	0	5	3	
		Succisa pratensis	0	0	0	5	1	
		Teucrium scorodonia	0	0	0	5	1	
3	5	Litter	55	10	90	60	54	
		Bryophytes	25	35	30	30	30	
		Anthoxanthum odoratum	20	20	0	10	13	
		Rock	15	25	0	5	11	
		Deschampsia flexuosa	5	10	0	10	6	
		Dryopteris filix-mas	0	5	20	0	6	
		Oxalis acetosella	10	0	5	5	5	
		Dryopteris affinis	5	0	0	5	3	
		Hyacinthoides non-scripta	10	0	0	0	3	
		Luzula sylvatica	5	0	5	0	3	
		Molinia caerulea	0	0	0	10	3	
		Potentilla erecta	0	5	0	5	3	
		Pteridium aquilinum	5	0	5	0	3	
		Succisa pratensis	0	10	0	0	3	
		Corylus avellana	0	5	0	0	1	
		Teucrium scorodonia	0	5	0	0	1	

Appendix 2 *(continued)*

Transect	Plot	Species	Quarter				Mean of 4	Mean of 16
			1	2	3	4		
		Anemone nemorosa	0	0	0	0	0	
		Blechnum spicant	0	0	0	0	0	
		Geranium robertianum	0	0	0	0	0	
		Holcus mollis	0	0	0	0	0	
		Viola riviniana	0	0	0	0	0	
4	1	Litter	70	70	80	85	76	77
		Molinia caerulea	40	60	60	80	60	58
		Myrica gale	15	45	20	20	25	20
		Bryophytes	40	5	15	5	16	13
		Potentilla erecta	0	0	0	0	0	0
		Vaccinium myrtillus	0	0	0	0	0	0
	2	Bryophytes	80	70	80	95	81	
		Molinia caerulea	60	55	90	80	71	
		Litter	60	70	75	70	69	
		Calluna vulgaris	50	50	40	10	38	
		Myrica gale	5	20	0	5	8	
		Potentilla erecta	0	0	0	0	0	
		Sorbus aucuparia	0	0	0	0	0	
		Very small yellow fungus - *Mycena acicula*?	0	0	0	0	0	
	3	Bryophytes	95	65	80	70	78	
		Calluna vulgaris	75	20	80	80	64	
		Molinia caerulea	10	90	75	70	61	
		Litter	20	85	60	30	49	
		Myrica gale	10	30	0	0	10	
		Betula pubescens	0	0	0	0	0	
		Eriophorum angustifolium	0	0	0	0	0	
	4	Litter	85	55	65	55	65	
		Molinia caerulea	50	50	80	55	59	
		Bryophytes	50	55	50	60	54	
		Calluna vulgaris	25	75	55	30	46	
		Betula pubescens	50	5	10	55	30	
		Myrica gale	10	25	10	0	11	
		Water	10	0	0	10	5	
		Dryopteris sp.	0	0	0	5	1	
		Cystopteris fragilis	0	0	0	0	0	
		Vaccinium myrtillus	0	0	0	0	0	
	5	*Molinia caerulea*	80	95	95	80	88	
		Litter	50	45	80	60	59	

Appendix 2 *(continued)*

Transect	Plot	Species	Quarter				Mean of 4	Mean of 16
			1	2	3	4		
		Bryophytes	60	15	20	65	40	
		Calluna vulgaris	25	20	5	75	31	
		Myrica gale	15	25	5	5	13	
5	1	Bryophytes	95	70	70	95	83	85
		Vaccinium myrtillus	80	90	95	60	81	79
		Litter	20	60	70	25	44	43
		Pteridium aquilinum	10	20	5	20	14	14
		Calluna vulgaris	0	5	0	0	1	1
		Deschampsia flexuosa	5	0	0	0	1	1
	2	Bryophytes	95	95	95	85	93	
		Vaccinium myrtillus	80	55	50	95	70	
		Litter	50	50	25	60	46	
		Birch trunk	0	10	0	0	3	
		Lonicera periclymenum	0	0	5	5	3	
		Betula pubescens	0	5	0	0	1	
		Calluna vulgaris	0	0	0	0	0	
		Deschampsia flexuosa	0	0	0	0	0	
	3	*Vaccinium myrtillus*	95	95	100	75	91	
		Bryophytes	65	90	75	90	80	
		Litter	80	50	85	50	66	
	4	Litter	90	95	100	90	94	
		Vaccinium myrtillus	0	60	80	15	39	
		Calluna vulgaris	90	15	0	10	29	
		Bryophytes	0	20	15	30	16	
		Pine trunk	0	0	0	10	3	
		Betula pubescens	0	0	0	5	1	
		Sorbus aucuparia	0	0	0	0	0	
	5	Litter	85	100	95	80	90	
		Deschampsia flexuosa	50	5	50	70	44	
		Bryophytes	35	40	50	40	41	
		Vaccinium myrtillus	40	55	0	60	39	
		Pine trunk	10	0	0	15	6	
		Sorbus aucuparia	5	5	5	5	5	
		Betula pubescens	0	0	5	0	1	
		Birch trunk	0	0	5	0	1	
		Calluna vulgaris	5	0	0	0	1	
		Picea sitchensis	0	0	0	0	0	
		Quercus spp.	0	0	0	0	0	

APPENDIX 3 – Presence of each species of moss, liverwort and lichen in each quarter of each quadrat and total fequency per quadrat

Transect no.	Plot no.	Species	Quarter				Frequency
			1	2	3	4	
1	1	*Atrichum undulatum*	1			1	2
		Calliergon cuspidatum			1		1
		Dicranum majus		1			1
		Eurynchium praelongum	1		1	1	3
		Hylocomium splendens		1		1	2
		Hypnum jutlandicum	1				1
		Liverwort	1	1	1	1	4
		Plagiothecium undulatum		1			1
		Pleuriozium schreberi		1			1
		Polytrichum commune		1	1		2
		Rhytidiadelphus loreus	1	1	1	1	4
		Rhytidiadelphus squarrosus	1	1	1	1	4
		Rhytidiadelphus triquetrus				1	1
		Sphagnum palustre		1			1
		Thuidium tamariscinum	1	1	1	1	4
	2	*Atrichum undulatum*	1				1
		Dicranum majus	1	1	1	1	4
		Dicranum scoparium				1	1
		Eurynchium praelongum	1	1	1	1	4
		Hypnum jutlandicum	1	1	1	1	4
		Isothecium myosuroides			1		1
		Mnium hornum	1				1
		Plagiothecium undulatum	1	1	1	1	4
		Scapania sp.	1	1		1	3
		Thuidium tamariscinum	1	1	1	1	4
	3	*Cladonia coniocraea*	1			1	2
		Cladonia polydactyla			1		1
		Cladonia uncialis	1				1
		Dicranum majus		1		1	2
		Dicranum scoparium	1	1	1	1	4
		Eurynchium praelongum	1	1		1	3
		Hylocomium splendens		1			1
		Hypnum jutlandicum	1	1	1	1	4
		Mnium hornum	1				1
		Peltigera canina	1				1
		Pleuriozium schreberi	1	1	1		3

Appendix 3 *(continued)*

Transect no.	Plot no.	Species	Quarter				Frequency
			1	2	3	4	
		Polytrichum formosum	1			1	2
		Rhytidiadelphus loreus	1	1	1	1	4
		Scapania sp.			1		1
		Thuidium tamariscinum	1	1	1	1	4
1	4	*Cladonia coniocraea*		1	1		2
		Cladonia portentosa				1	1
		Dicranum majus	1	1	1		3
		Dicranum scoparium	1	1	1	1	4
		Eurynchium praelongum	1	1	1	1	4
		Hypnum jutlandicum	1	1	1	1	4
		Liverwort	1			1	2
		Mnium hornum		1		1	2
		Polytrichum formosum	1	1	1	1	4
		Rhytidiadelphus loreus	1	1	1	1	4
		Rhytidiadelphus triquetrus				1	1
		Scleropodium purum		1			1
		Sphagnum palustre				1	1
		Thuidium tamariscinum				1	1
	5	*Cladonia coniocraea*		1	1		2
		Cladonia uncialis				1	1
		Dicranum majus	1	1	1	1	4
		Dicranum scoparium		1			1
		Eurynchium praelongum	1	1	1	1	4
		Hypnum jutlandicum	1	1	1	1	4
		Liverwort	1	1	1	1	4
		Polytrichum formosum	1	1		1	3
		Rhytidiadelphus loreus	1			1	2
		Rhytidiadelphus squarrosus			1	1	2
2	1	*Atrichum undulatum*	1			1	2
		Dicranum majus	1	1	1	1	4
		Eurynchium praelongum	1	1	1	1	4
		Hylocomium splendens	1	1	1	1	4
		Hypnum jutlandicum			1	1	2
		Leucobryum glaucum				1	1
		Lophocolea heterophylla				1	1
		Mnium hornum	1		1	1	3
		Plagiothecium undulatum	1		1	1	3
		Pleuriozium schreberi		1	1		2

Appendix 3 *(continued)*

Transect no.	Plot no.	Species	Quarter				Frequency
			1	2	3	4	
		Scleropodium purum		1	1		2
		Thuidium tamariscinum	1	1	1	1	4
2	2	*Cladonia coniocraea*	1	1	1	1	4
		Cladonia portentosa	1		1		2
		Dicranum majus	1	1	1		3
		Dicranum scoparium	1	1			2
		Eurynchium praelongum		1		1	2
		Frullania tamarisci				1	1
		Hylocomium splendens	1	1	1	1	4
		Hypnum cupressiforme		1			1
		Hypnum jutlandicum	1			1	2
		Hypogymnia physodes	1		1	1	3
		Mnium hornum	1				1
		Plagiothecium undulatum	1			1	2
		Pleuriozium schreberi	1	1		1	3
		Polytrichum formosum			1		1
		Rhytidiadelphus loreus			1	1	2
		Scleropodium purum				1	1
		Tetraphis pellucida		1		1	2
		Thuidium tamariscinum	1	1	1	1	4
	3	*Dicranum majus*			1		1
		Dicranum scoparium			1		1
		Eurynchium praelongum		1	1	1	3
		Hylocomium splendens	1	1	1	1	4
		Hypnum jutlandicum			1	1	2
		Liverwort	1		1	1	3
		Lophocolea heterophylla	1			1	2
		Plagiothecium undulatum	1			1	2
		Pleuriozium schreberi	1			1	2
		Polytrichum formosum		1			1
		Rhytidiadelphus loreus	1				1
		Thuidium tamariscinum	1	1	1	1	4
	4	*Cladonia portentosa*			1		1
		Dicranum majus		1	1		2
		Dicranum scoparium	1				1
		Eurynchium praelongum	1	1	1	1	4
		Hylocomium splendens	1	1		1	3
		Hypnum jutlandicum	1	1	1	1	4

Appendix 3 *(continued)*

Transect no.	Plot no.	Species	Quarter				Frequency
			1	2	3	4	
		Hypogymnia physodes	1				1
		Liverwort	1				1
		Plagiothecium undulatum	1				1
		Pleuriozium schreberi	1				1
		Rhytidiadelphus loreus		1	1		2
		Rhytidiadelphus triquetrus	1			1	2
		Scleropodium purum	1	1	1	1	4
		Thuidium tamariscinum	1	1	1	1	4
	5	*Cladonia coniocraea*		1			1
		Dicranum majus	1	1	1	1	4
		Dicranum scoparium	1				1
		Eurynchium praelongum		1	1	1	3
		Hylocomium splendens	1	1			2
		Hypnum jutlandicum	1	1	1		3
		Liverwort			1		1
		Plagiothecium undulatum		1			1
		Pleuriozium schreberi	1	1			2
		Rhytidiadelphus loreus	1		1	1	3
		Rhytidiadelphus squarrosus	1	1	1	1	4
		Thuidium tamariscinum	1	1	1	1	4
3	1	*Atrichum undulatum*	1	1			2
		Cladonia portentosa			1		1
		Dicranum scoparium			1		1
		Hylocomium splendens			1		1
		Liverwort	1	1	1	1	4
		Mnium hornum		1	1		2
		Pellia sp.	1	1	1	1	4
		Plagiothecium undulatum		1	1	1	3
		Polytrichum formosum			1	1	2
		Scapania sp.	1	1			2
		Sphagnum palustre	1	1			2
		Thuidium tamariscinum	1	1	1	1	4
	2	*Atrichum undulatum*		1			1
		Eurynchium praelongum	1		1	1	3
		Hypnum cupressiforme				1	1
		Hypnum jutlandicum			1		1
		Plagiomnium undulatum		1			1
		Plagiothecium undulatum	1	1		1	3

Appendix 3 *(continued)*

Transect no.	Plot no.	Species	Quarter				Frequency
			1	2	3	4	
		Rhizomnium punctatum			1		1
		Rhytidiadelphus loreus	1			1	2
		Rhytidiadelphus squarrosus	1	1	1		3
		Scleropodium purum	1	1	1	1	4
		Sphagnum	1				1
		Thuidium tamariscinum	1	1	1	1	4
3	3	*Dicranum majus*	1	1	1	1	4
		Dicranum scoparium	1				1
		Eurynchium praelongum			1		1
		Hylocomium splendens		1		1	2
		Hypnum cupressiforme	1				1
		Hypnum jutlandicum			1	1	2
		Hypnum mammillatum				1	1
		Isothecium myosuroides	1			1	2
		Liverwort			1	1	2
		Plagiothecium undulatum			1		1
		Pleuriozium schreberi				1	1
		Polytrichum formosum		1		1	2
		Rhizomnium punctatum	1	1			2
		Rhytidiadelphus loreus	1	1	1		3
		Rhytidiadelphus squarrosus	1		1		2
		Rhytidiadelphus triquetrus				1	1
		Scapania sp.				1	1
		Scleropodium purum	1	1	1	1	4
		Thuidium tamariscinum	1	1	1	1	4
		Usnea subfloridana				1	1
	4	*Atrichum undulatum*		1	1		2
		Cetraria chlorophylla				1	1
		Dicranum majus	1		1		2
		Dicranum scoparium		1	1	1	3
		Hylocomium splendens	1		1	1	3
		Hypnum cupressiforme	1		1		2
		Hypogymnia physodes				1	1
		Isothecium myosuroides	1	1	1	1	4
		Liverwort	1	1			2
		Lobaria pulmonaria				1	1
		Mnium hornum				1	1
		Parmelia caperata				1	1

Appendix 3 *(continued)*

Transect no.	Plot no.	Species	Quarter				Frequency
			1	2	3	4	
		Peltigera canina			1		1
		Plagiomnium undulatum	1	1	1	1	4
		Plagiothecium undulatum		1			1
		Pleuriozium schreberi	1			1	2
		Rhizomnium punctatum			1		1
		Rhytidiadelphus loreus			1		1
		Rhytidiadelphus squarrosus			1		1
		Rhytidiadelphus triquetrus	1	1			2
		Scleropodium purum	1				1
		Thuidium tamariscinum	1		1	1	3
		Usnea subfloridana			1		1
3	5	*Atrichum undulatum*		1	1	1	3
		Cladonia portentosa	1				1
		Dicranum majus				1	1
		Dicranum scoparium	1				1
		Eurynchium praelongum	1	1	1		3
		Hylocomium splendens	1	1	1	1	4
		Hypnum jutlandicum	1	1	1		3
		Isothecium myosuroides	1			1	2
		Liverwort	1				1
		Mnium hornum		1	1	1	3
		Pellia sp.	1			1	2
		Peltigera canina		1	1		2
		Plagiothecium undulatum		1		1	2
		Polytrichum formosum				1	1
		Rhizomnium punctatum		1	1	1	3
		Rhytidiadelphus loreus	1	1	1	1	4
		Rhytidiadelphus squarrosus		1			1
		Scleropodium purum	1	1	1		3
		Thuidium tamariscinum	1	1	1	1	4
4	1	*Dicranum scoparium*	1				1
		Eurynchium praelongum	1	1	1	1	4
		Green slime mould	1				1
		Hylocomium splendens				1	1
		Hypnum jutlandicum		1		1	2
		Lepidozia reptans			1		1
		Liverwort	1	1			2
		Plagiothecium undulatum	1	1	1		3

Appendix 3 *(continued)*

Transect no.	Plot no.	Species	Quarter				Frequency
			1	2	3	4	
		Pleuriozium schreberi			1	1	2
		Scapania sp.		1	1	1	3
		Scleropodium purum	1	1			2
	2	*Dicranum scoparium*		1			1
		Eurynchium praelongum	1	1	1	1	4
		Hylocomium splendens			1	1	2
		Hypnum jutlandicum	1	1	1	1	4
		Hypogymnia physodes	1	1			2
		Icmadophila ericetorum		1			1
		Pleuriozium schreberi	1	1		1	3
		Rhytidiadelphus loreus				1	1
		Scapania sp.		1	1	1	3
		Scleropodium purum		1			1
		Sphagnum capillifolium	1		1	1	3
		Sphagnum sp.			1		1
4	3	*Cladonia portentosa*				1	1
		Cladonia pyxidata				1	1
		Dicranum scoparium	1	1	1		3
		Eurynchium praelongum	1	1	1	1	4
		Hypnum jutlandicum	1	1		1	3
		Hypogymnia physodes	1	1	1	1	4
		Icmadophila ericetorum				1	1
		Lepidozia reptans				1	1
		Liverwort				1	1
		Lophocolea heterophylla		1		1	2
		Pleuriozium schreberi	1	1	1	1	4
		Polytrichum formosum			1		1
		Scapania sp.				1	1
		Sphagnum capillifolium		1	1		2
		Sphagnum sp.		1	1	1	3
	4	*Atrichum undulatum*				1	1
		Eurynchium praelongum	1	1	1	1	4
		Hypnum jutlandicum	1			1	2
		Hypogymnia physodes		1	1	1	3
		Plagiothecium undulatum	1			1	2
		Pleuriozium schreberi	1	1	1	1	4
		Scapania sp.	1				1
		Sphagnum sp.	1			1	2
	5	*Dicranum scoparium*		1			1

Appendix 3 *(continued)*

Transect no.	Plot no.	Species	Quarter				Frequency
			1	2	3	4	
		Eurynchium praelongum	1	1	1	1	4
		Hypnum jutlandicum	1			1	2
		Hypogymnia physodes	1		1	1	3
		Liverwort			1		1
		Plagiothecium undulatum		1			1
		Pleuriozium schreberi	1	1	1	1	4
		Scapania sp.			1	1	2
		Sphagnum capillifolium	1	1		1	3
		Sphagnum sp.	1	1	1	1	4
5	1	*Cladonia portentosa*		1	1		2
		Dicranum majus	1		1	1	3
		Dicranum scoparium		1	1	1	3
		Eurynchium praelongum	1	1	1	1	4
		Hylocomium splendens		1	1	1	3
		Hypnum jutlandicum		1			1
		Lepidozia reptans		1			1
		Liverwort	1	1			2
		Plagiothecium undulatum		1	1		2
		Pleuriozium schreberi	1	1	1		3
		Polytrichum formosum		1			1
		Rhytidiadelphus squarrosus	1		1		2
		Scapania sp.	1				1
		Scleropodium purum	1				1
		Sphagnum sp.	1				1
		Thuidium tamariscinum	1		1	1	3
5	2	*Cladonia portentosa*				1	1
		Dicranum majus	1	1	1		3
		Dicranum scoparium	1		1		2
		Eurynchium praelongum	1	1		1	3
		Hylocomium splendens	1		1	1	3
		Hypnum jutlandicum			1	1	2
		Hypnum mammillatum		1			1
		Plagiothecium undulatum	1	1	1	1	4
		Pleuriozium schreberi			1		1
		Polytrichum formosum	1				1
		Rhytidiadelphus squarrosus		1			1
		Scapania sp.		1			1
		Scleropodium purum	1		1	1	3
		Thuidium tamariscinum	1	1	1	1	4

Appendix 3 *(continued)*

Transect no.	Plot no.	Species	Quarter				Frequency
			1	2	3	4	
		Usnea subfloridana		1			1
	3	*Cladonia coniocraea*			1		1
		Cladonia portentosa			1		1
		Dicranum majus			1		1
		Dicranum scoparium			1	1	2
		Eurynchium praelongum	1	1	1	1	4
		Hypnum jutlandicum	1	1			2
		Hypogymnia physodes			1		1
		Lepidozia reptans			1	1	2
		Plagiothecium undulatum	1	1	1	1	4
		Pleuriozium schreberi	1				1
		Scapania sp.	1		1	1	3
		Scleropodium purum				1	1
		Sphagnum sp.	1	1		1	3
		Thuidium tamariscinum	1	1	1		3
	4	*Dicranum scoparium*			1	1	2
		Eurynchium praelongum		1	1	1	3
		Hypnum jutlandicum	1	1		1	3
		Hypogymnia physodes	1			1	2
		Lepidozia reptans				1	1
		Physcia adscendens				1	1
		Plagiothecium undulatum		1			1
		Scapania sp.		1			1
		Scleropodium purum	1	1	1	1	4
		Usnea subfloridana	1			1	2
	5	*Cladonia coniocraea*	1	1	1	1	4
		Dicranum majus	1	1	1	1	4
		Dicranum scoparium	1	1	1		3
		Eurynchium praelongum	1	1	1	1	4
		Hypnum cupressiforme				1	1
		Hypnum jutlandicum	1	1	1	1	4
		Hypogymnia physodes			1	1	2
		Lepidozia reptans		1			1
		Liverwort		1			1
		Plagiothecium undulatum	1	1	1		3
		Scleropodium purum	1		1	1	3
		Sphagnum sp.		1			1
		Thuidium tamariscinum	1	1		1	3
		Usnea subfloridana	1			1	2

APPENDIX 4 – Mean height (cm) of each species of ground vegetation in each quadrat

Transect number		1						2						3						4						5						Species Mean
Quadrat number		**1**	**2**	**3**	**4**	**5**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Mean**	
Anthoxanthum odoratum	Live														37	27	32		33													33
Blechnum spicant	Live									23			23			21			21													22
Bryophytes	Live							6					6																			6
Calluna vulgaris	Dead					15	15														56			56							36
	Live			25	64	58	54														73	75	66	73	71				19	25	21	60
Carex panicea	Live													7					7													7
Deschampsia flexuosa	Live								4		16	14	11	3					3											6	6	7
Dicranum scoparium	Live								2				2																			2
Dryopteris affinis	Live		99				99											18	18													59
Dryopteris filix-mas	Live															67	34		51													51
Hyacinthoides non-scripta	Live														39	26	23	1	27													27
Juncus effusus	Dead	18					18																									18
	Live	64					64																									64
Lonicera periclymenum	Live		67				67			39			39																			60
Luzula sylvatica	Live														21		35		28													28
Molinia caerulea	Dead	17					17													6				6								12
	Live	16					16			26			26	16				20	17	19	20	46	32	32	25							24
Myrica gale	Live																			24	43	42	76	55	52							52
Oxalis acetosella	Live																	8	8													8
Pellia sp.	Live													0					0													0
Potentilla erecta	Live											5	5																			5
Pteridium aquilinum	Dead	9					9	14			6	20	16					16	16													15
	Live								63	74	75		70		48		89	55	62							53					53	65
Ranunculus flammula	Live													10					10													10
Rhytidiadelphus squarrosus	Live	3					3																									3

Appendix 4 *(continued)*

Transect number		**1**						**2**						**3**						**4**						**5**						**Species Mean**
Quadrat number		**1**	**2**	**3**	**4**	**5**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Mean**	
Rubus fruticosus	Live		52				52																									52
Sorbus aucuparia	Live										9		9																			9
Stellaria holostea	Live															36			36													36
Teucrium scorodonia	Live																13		13													13
Thuidium tamariscinum	Live		5				5				5		5					1	1													4
Vaccinium myrtillus	Dead																			16					16							16
	Live		55	33	37		38	24	18	12	20	9	19			14			14							37	40	70	29	27	43	35
Quadrat mean		17	52	31	46	53	40	21	26	33	26	16	24	7	37	30	36	21	26	18	52	68	64	55	52	41	40	70	26	22	39	36

APPENDIX 5 – Numbers of coppiced and established trees taller than 1.5m and with a diameter of less than 3cm

Transect no.	Plot no.	Tree species	Diameter class (cm)	Coppiced	Established	Grand Total
1	1	Birch	0.1–0.5	13	2	15
			0.51–1.0	2		2
			1.01–1.5	4	3	7
			1.51–2.0		2	2
			2.52–3.0	3		3
		Birch Total		22	7	29
		Common Alder	2.01–2.5	1		1
		Common Alder Total		1		1
		Goat Willow	0.1–0.5	2	1	3
			0.51–1.0		1	1
			1.01–1.5	11	2	13
			1.51–2.0	4		4
			2.01–2.5	3		3
			2.52–3.0	1		1
		Goat Willow Total		21	4	25
	1 Total			44	11	55
	2	Birch	0.1–0.5	5	2	7
			0.51–1.0	16	12	28
			1.01–1.5	15	6	21
			1.51–2.0	5	4	9
			2.01–2.5	6	3	9
			2.52–3.0	1	2	3
		Birch Total		48	29	77
		Goat Willow	0.51–1.0	1	1	2
			1.01–1.5	13	2	15
			1.51–2.0	13		13
			2.01–2.5	5		5
			2.52–3.0	2		2
		Goat Willow Total		34	3	37
	2 Total			82	32	114
	3	Birch	0.1–0.5	6	2	8
			0.51–1.0	23	5	28
			1.01–1.5	6	5	11
			1.51–2.0	7	1	8
			2.01–2.5	4	3	7
			2.52–3.0	1		1
		Birch Total		47	16	63
		Goat Willow	1.01–1.5		2	2
			1.51–2.0		1	1
		Goat Willow Total			3	3

Appendix 5 *(continued)*

Transect no.	Plot no.	Tree species	Diameter class (cm)	Coppiced	Established	Grand Total
		Rowan	1.51–2.0		1	1
		Rowan Total			1	1
	3 Total			47	20	67
	4	Birch	0.1–0.5	8	3	11
			0.51–1.0	20	12	32
			1.01–1.5	10	8	18
			1.51–2.0	5	2	7
			2.01–2.5	1	3	4
		Birch Total		44	28	72
	4 Total			44	28	72
	5	Birch	0.1–0.5	12	5	17
			0.51–1.0	10	4	14
			1.01–1.5	3	1	4
			1.51–2.0		1	1
		Birch Total		25	11	36
	5 Total			25	11	36
1 Total				242	102	344
2	1	Birch	0.1–0.5	1		1
			0.51–1.0	5		5
			1.01–1.5	3		3
			1.51–2.0	1		1
			2.01–2.5	1		1
		Birch Total		11		11
		Hazel	1.01–1.5	1		1
			2.01–2.5	1		1
		Hazel Total		2		2
	1 Total			13		13
	2	Birch	2.01–2.5	1		1
		Birch Total		1		1
	2 Total			1		1
	4	Birch	0.1–0.5	1		1
			0.51–1.0	1		1
			1.51–2.0	1		1
		Birch Total		3		3
	4 Total			3		3
2 Total				17		17
3	3	Birch	1.01–1.5	2		2
			2.01–2.5		1	1
			2.52–3.0	1		1
		Birch Total		3	1	4
		Hazel	1.51–2.0		1	1
			2.01–2.5	6		6
		Hazel Total		6	1	7

Appendix 5 *(continued)*

Transect no.	Plot no.	Tree species	Diameter class (cm)	Coppiced	Established	Grand Total
	3 Total			9	2	11
	4	Hazel	0.1–0.5	1		1
			0.51–1.0	2		2
			1.01–1.5	1		1
		Hazel Total		4		4
	4 Total			4		4
3 Total				13	2	15
4	1	Birch	2.01–2.5		1	1
		Birch Total			1	1
	1 Total				1	1
	2	Birch	0.51–1.0		1	1
			1.51–2.0		1	1
			2.01–2.5		3	3
		Birch Total			5	5
	2 Total				5	5
	3	Birch	2.01–2.5		1	1
		Birch Total			1	1
	3 Total				1	1
	4	Birch	0.51–1.0		1	1
			2.01–2.5		1	1
		Birch Total			2	2
	4 Total				2	2
	5	Birch	2.01–2.5		1	1
		Birch Total			1	1
	5 Total				1	1
4 Total					10	10
5	1	Birch	1.51–2.0		1	1
		Birch Total			1	1
	1 Total				1	1
	2	Birch	0.51–1.0	4		4
			2.01–2.5		1	1
			2.52–3.0		1	1
		Birch Total		4	2	6
	2 Total			4	2	6
	4	Birch	1.51–2.0	3		3
		Birch Total		3		3
		Rowan	0.1–0.5		1	1
		Rowan Total			1	1
	4 Total			3	1	4
5 Total				7	4	11
Grand Total				279	118	397