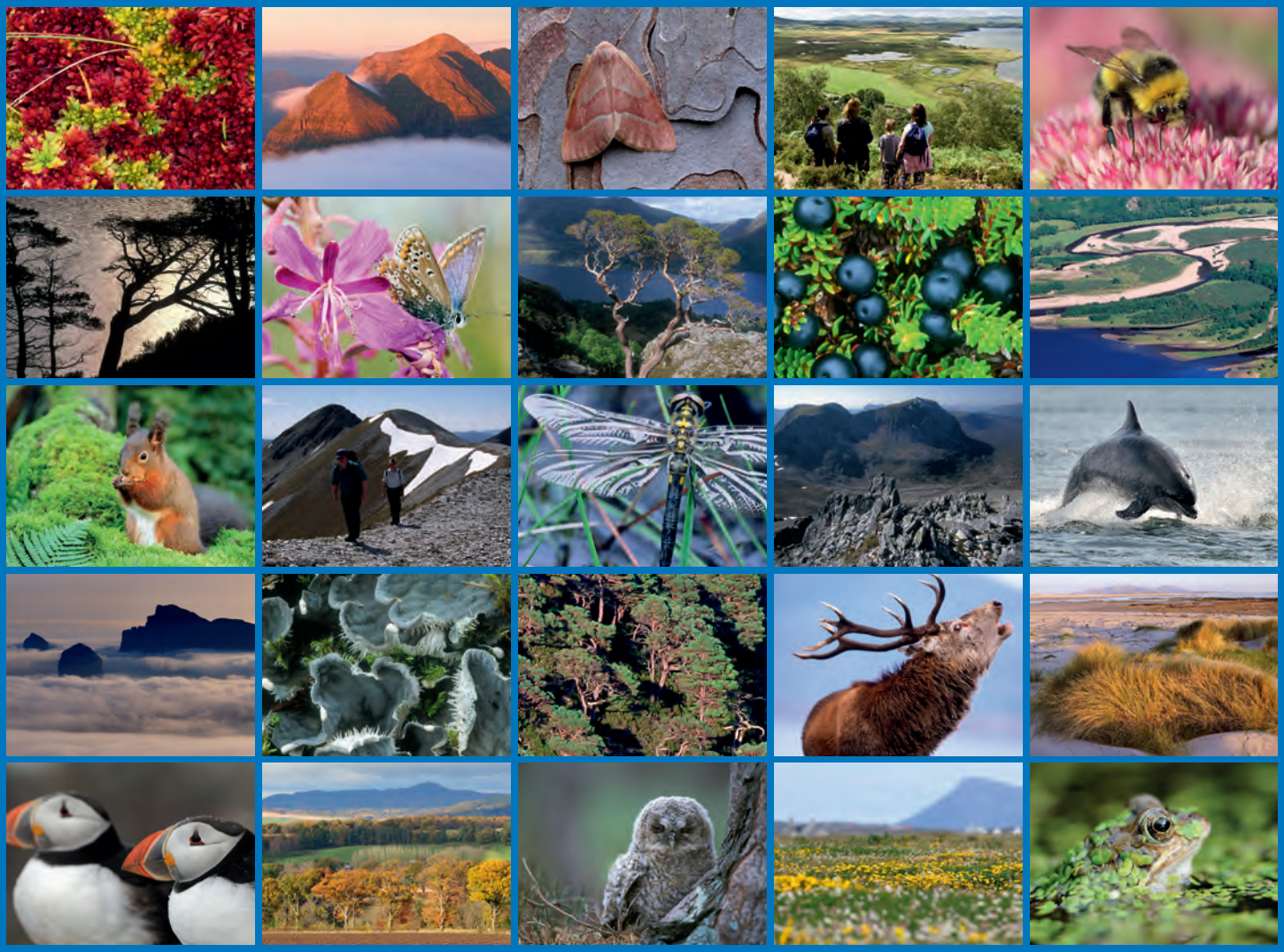
Scottish Natural Heritage
Research Report No. 1180

A woodland profile survey and assessment of herbivore impacts within the Kentra Bay and Moss Site of Special Scientific Interest (SSSI)



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RESEARCH REPORT

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RESEARCH REPORT

Summary

A woodland profile survey and assessment of herbivore impacts within the Kentra Bay and Moss Site of Special Scientific Interest (SSSI)

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Keywords

Kentra Bay and Moss SSSI; oak woodland; Lochaber; herbivore impact assessment; Ardnamurchan DMG.

Background

The upland oak woodland habitat within the Kentra Bay and Moss SSSI has been identified as potentially 'at risk' from herbivore impacts and has therefore merited further investigation. Excessive browsing of seedlings and saplings can prevent the population of trees from regenerating. This survey was designed to assess the age-structure of the population of all species of tree as well as to assess the levels of browsing on seedlings and saplings.

Main findings

In May 2018, the diameters of all trees were measured within 25 sample plots, covering a total of 1.15 ha of ground, which were chosen at random throughout the protected area. The numbers of browsed and un-browsed seedlings and saplings, both small and large, were counted in the same plots. Four of the plots for counting seedlings and saplings were nested within the larger plots giving a total area of 0.99 ha for these life-stages. A total of 274 live trees and 27 dead trees were measured giving an overall stem density of live trees of 239 stems per ha. A total of 2,142 seedlings and 107 saplings were counted giving a density of 2,170 seedlings per ha and 108 saplings per ha. The main findings are as follows:

- The woodland has a low density of live trees (239 stems per ha), but there are abundant seedlings (2,170 per ha), 72% of which were of rowan.
- Downy birch is the most abundant tree in the woodland canopy and makes up 84% of all live trees. Seedlings of birch are the second most abundant (28%) after rowan, but the high levels of browsing on the seedlings and small saplings mean that large sapling densities are only 4% of the downy birch seedling densities.
- Sessile oak trees are the second most abundant species of tree making up only 8% of all live tree stems, but due to their much larger size (inter-quartile range of diameters at breast height 33 to 62 cm), sessile oak trees make up about 37% of the woodland canopy cover.
- Rowan, hazel and holly are very minor components (7%) of the woodland.
- Browsing levels were high on seedlings (34%) and small saplings (48%).

- No seedlings or saplings of sessile oak were found in any of the 25 sample plots.
- The sessile oak population is in danger of disappearing altogether from within the woodland if nothing is done to help establish seedlings and saplings of this species of tree.
- The site is noted for its internationally important assemblages of lichens, mosses and liverworts that depend on the woodland habitat for the humidity maintained by the canopy of the trees. Some of the rarer species of these plants grow on the trunks and branches of hazel, rowan and sessile oak rather birch. There is, therefore, a danger of some of these plants being lost due to the poor representation of hazel and rowan as mature trees as well as the lack of regeneration of sessile oak.
- Browsing by sheep and deer is considered to be responsible for the low levels of recruitment of the next generation of young trees of downy birch and rowan.
- The reasons for the complete absence of oak seedlings may in part be due to poor acorn production and predation of the few acorn as well as browsing of any seedlings that do establish.

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Nomenclature

The scientific names of vascular plants follows that of Stace (2010).

1. INTRODUCTION

The Kentra Bay and Moss Site of Special Scientific Interest (SSSI) is located at the north-eastern end of the Ardnamurchan Peninsula in the west Lochaber district of the Highland region of Scotland (Figure 1). The Kentra Bay and Moss SSSI is listed for a wide variety of features:

- Blanket bog
- Maritime cliff
- Mudflat
- Saltmarsh
- Upland oak woodland
- Bryophyte assemblage
- Lichen assemblage
- Vascular plant assemblage

The whole of the SSSI covers 992.85 ha of which a small area is upland oak woodland. In the last assessment of the condition of the upland oak woodland habitat in February 2008 it was assessed to be in 'unfavourable declining' condition. The condition assessment identified over-grazing and the presence of invasive non-native species as the main pressures on the habitat. The woodland habitat is also considered to be 'at risk' from the impacts of large herbivores, in particular deer. The Site Management Statement, available at https://sitelink.nature.scot/site/836, has identified the following measures to improve the condition of the upland oak woodland:

1. reducing grazing pressure within the woods, in particular in the Creag nan Sgarbh area; and
2. controlling invasive non-native plants such as spruce and rhododendron

1.1 Aims

Appropriate robust and reliable data needs to be collected to inform sound decisions on the management of the woodland habitat within the Kentra Bay and Moss SSSI. One aim of the management of the woodlands is to maintain healthy populations of the trees so that they are self-sustaining and support the other features listed for the SSSI. The key aim of this survey is to implement a fit for purpose baseline survey on the existing woodland profile in terms of life-class and spatial distribution of the trees and the relative nature and extent of current herbivore impacts on the populations of trees within the SSSI. This will provide the data necessary to assess the long-term viability and future of the woodland habitat and if there is a poor age-structure to the population of trees to identify the likely causal factors that are resulting in the lack of regeneration of certain cohorts within the population.

2. METHODS

The condition assessment (SCM) was assessed by SNH using in the 'Common Standards Monitoring' (CSM) guidance and these standard criteria are available at http://jncc.defra.gov.uk/pdf/CSM_woodland.pdf. The site specific targets that are relevant to this survey are:

- Signs of seedlings growing through to saplings to young trees at sufficient density to maintain canopy density over a 10 year period (or equivalent re-growth from coppice stumps).

For any healthy self-sustaining population of organisms there must be more individuals in the younger generations than the older generations, otherwise the population will die out. Although there may be spatial variation in the distribution of older and younger trees within any woodland, for a woodland to sustain itself there must be more younger trees, especially seedlings and saplings, than older trees. The direct measurement of the age of trees is both time consuming and potentially damaging to trees as it requires the removal of a core of the tree in order to count the number of annual growth rings. A much quicker and less invasive approach is to measure the diameter of the trees at a standardised height that is called diameter at breast height or dbh (1.3 m above the ground). However, due to significant variations in rates of growth between trees, a method of classifying trees into age-classes using the size, shape, proportion of dead branches and other physiognomic characteristics was devised by Clifford *et al.* (2004). The characteristics used to place trees into each of these life-classes are given in Annex 3. The life-classes can be summarised as follows:

- Seedling – plants that are no more than 1.3 m tall and usually within the field layer (mainly herbaceous perennials)
- Small sapling – plants that are between 1.3 and 3 m tall
- Large sapling – plants that are between 3 and 5 m tall and usually have a dbh less than 5 cm
- Pole stage tree – dense stands of young reproductive trees more than 5 m tall with dbh 5 to 20 cm, but still not reached full canopy height and spread
- Young reproductive tree – lone young reproductive trees that have dbh values 5 to 20 cm that have still not reached full canopy height and spread
- Mature tree – healthy trees that have reached full height and have a spreading canopy
- Over-mature tree – trees with a spreading canopy that have some dead or dying branches (between 10 and 50% of the canopy)
- Senescent tree – trees where more than 50% of the canopy is dead.
- "Phoenix" trees – trees where the main bole is dead or procumbent and new vigorous shoots coming from the base or from the main trunk
- Dead trees – include standing dead trunks, dead trunks lying on the woodland floor and stumps

2.1 Sampling strategy

Approximately 1% (1.15 ha) of the upland oak woodland habitat was sampled across the southern part of the Kentra Bay & Moss SSSI by taking a total of 25 plots. The sample plots were taken at random within areas known to have some trees present within the SSSI and the location of these plots is shown in Figure 2. The survey was carried out on the 8th May 2018. None of the woodland had deer fences.

2.2 Field survey

2.2.1 Woodland profile

At nearly all of the plots all trees, seedlings and saplings were recorded within a 25.2 metre diameter plot centred on the central post. The diameter of each tree (diameters more than 5 cm) was measured 1.3 metres above the ground (dbh) to the nearest centimetre with either a forestry tape or a tailor's tape measure. The Forestry Commission NFI Survey Manual for measuring tree diameters was followed (FC NFI 15.0). Where a tree had multiple stems at 1.3 m above the ground each one was measured separately and assigned to the tree. The species of tree and its life-class was also noted using the classes described by Clifford *et al*. (2004) (see Annex 3 for details of life-classes).

The Forestry Commission guidance on monitoring even-aged stands of trees suggests that at densities of more than 300 stems per ha, a 11.2 m diameter plot is used, i.e. 100 m^2 (Kerr *et al.*, 2002). Where the densities are between 150 and 300 stems per hectare, a 16 m diameter plot is used, i.e. 200 m^2. In addition, where there was a high density of seedlings and/or saplings, i.e. more than 100 per 25.2 m diameter plot, a smaller plot size of 11.2 m or 16 m diameter centred on the same post were used. It was necessary to reduce the area used for counting the number of seedlings and samplings at seven plots (K3, K6, K7, K10, K11, K16 and K23). A total of 0.987 ha was surveyed for seedlings and saplings.

The plot size was also reduced for counting and measuring trees at plots K7, K10 and K11. This was done because either the densities of the pole stage trees was very high or because the plot size was reduced because of an inaccessible crag being present. This gave a total of 1.147 ha being surveyed for trees.

One or two photographs of the sample plots were taken with a digital camera and the direction of the photograph recorded with a compass.

2.2.2 Herbivore impacts

As browsing on seedlings and saplings is considered to be an important factor in the apparent lack of tree regeneration, the levels of browsing on seedlings and saplings was assessed. This was done by counting the number of seedlings and saplings where the leading shoot was browsed or un-browsed. Where the leading shoot was browsed the plant was classed as being browsed, but some seedlings and many saplings had two or more leading shoots. Also for the larger saplings, especially the saplings of downy birch, there was no clear leading shoots. In these instances a plant was classed as being browsed if more than half the shoots were browsed.

In addition, herbivore impact on five other indicators (basal shoots, epicormic shoots, preferentially browsed species, sward and fraying/ bark stripping was assessed as well using the criteria in Armstrong *et al*. (2014). The indicators and thresholds for the different levels of browsing are given in Annex 3.

If the indicator was absent 'NP' was recorded. Where there were too few epicormic shoots, basal shoots, seedlings or saplings then a 'U' was recorded to indicate it is uninformative. If the indicator was considered to be inappropriate a 'NA' was recorded.

2.2.3 Quality control

Before the assessment was started Dr Headley spent at least one day with each of the other field surveyors (Tom Edwards, Fraser Milne and Gus Routledge) to clarify the methods, the interpretation of the various indicators and the standardisation of the various threshold levels to assign each impact level. Initially several plots were assessed together. When there was a

high level of harmonisation, further sample plots were assessed individually and the results compared. Where appropriate, discrepancies were discussed and adjustments made by the surveyors to their interpretation or judgement of the indicators.

The data was recorded in the field, either on to tablets or paper pro-forma recording sheets.

2.3 Data analysis

2.3.1 Age-structure

The numbers of individuals for each species of tree in each life-class were totalled for each species and then divided by the total area of the plots surveyed to obtain the number per ha. The number of trees in different size classes, i.e. different dbh values, was also calculated using the size classes used by the Forestry Commission (Kerr *et al.*, 2002), as shown below:

- Small trees 5 to 25 cm diameter
- Medium trees 25 to 40 cm diameter
- Large trees 40 to 55 cm diameter
- Very large trees more 55 cm diameter

It has to be borne in mind that these classes are useful for most species of tree, but are much less useful for smaller species or shrubby species, such as hazel.

A minimum diameter of 5 cm was used for small trees as five young reproductive trees had diameters less than 7 cm.

The basal area (m^2 per ha) for each species was also calculated from the individual measures of all stem diameters that were at least 5 cm in diameter. Basal area is used as an indication of the level of shading.

2.3.2 Calculation of browsing impacts

The levels of grazing on the sward and the levels of fraying/bark stripping were not used in the calculations as they do not relate to the levels of browsing on the trees. An overall browsing impact was calculated from each of the individual indicators by ranking the values and taking the median score. To calculate the median value, the number of indicators falling in each impact category was calculated and the central one was taken when these values are ranked in ascending order. For example, if there were five indicators available the value of the 3rd indicator when placed in rank order was taken as the impact category for the sample plot as a whole. When there was an even number of indicators available the mid-point between the two indicators either side of the mid-point was used. In some cases this fell between two categories, such as Moderate and Low. In this instance an impact of Moderate/Low was taken.

2.3.3 Statistical analysis

Although averages and standard deviations were calculated for each variable, as the data is not normally distributed the non-parametric statistics were calculated for the data. These were medians, and 25th and 75th percentiles. The median shows the central tendency in the data and is the central value when all values are ranked in increasing order. The 25th and 75th percentiles are the respective 25th and 75th values when ranked in increasing order and the difference between these two values shows the variation in the data. This is called the inter-quartile range (Sokal & Rohlf, 1969).

As the browsing levels on seedlings and saplings are expressed as percentages, this data requires arcsine transformation before means are calculated. The means and standard deviations are these values when transformed back in to percentages.

3. RESULTS

3.1 Overall number of trees, seedlings and saplings

Only one of the 25 plots, K3, had no live trees within it. A total of 274 were counted and measured in the other 24 sample plots, which gives on overall density of 239 live trees per ha (Table 1). A total of 2,141 seedlings were counted which gave an overall density of 2,169 seedlings per ha and some seedlings were found in all 25 plots (Table 1). A total of 69 small and 38 large saplings were counted in the same plots, which gave a total density of 108 saplings per ha (Table 1). Small and large saplings were found in only 15 and 6 of the sample plots, respectively.

3.2 Extent of woodland habitat

Although this survey was not designed or intended to survey the extent of woodland habitat, it was clear from the survey that the cover of trees appears to be significantly thinner and more fragmented than is indicated on the 1920s Ordnance Survey maps of the area.

3.3 Species composition

Overall, downy birch (*Betula pubescens*) and rowan (*Sorbus aucuparia*) are the most abundant species within the Kentra Bay and Moss SSSI (Figure 3). The total stem density, including seedlings and saplings, of these species was 868 and 1,613 stems per ha, respectively (Table 1). Sessile oak (*Quercus petraea*), holly (*Ilex aquifolium*) and hazel (*Corylus avellana*) are relatively minor components of the woodland making up only 1.5% of all the live seedlings, saplings and trees (Figure 3).

3.4 Woodland structure

The number and density of seedlings was far higher than that for saplings and trees (Figure 4 and Table 1). There are some trees in all life classes, but most of the trees are either mature or over-mature and senescent trees are the least common in the plots surveyed (Table 1 and Figure 4). Although there is good regeneration of seedlings from seed very few survive to the small sapling stage with an apparent overall survival rate of only 3.2%. The survival of small saplings to the large sapling stage is far better with an apparent survival rate of 55%.

When the data is analysed with respect of individual species the situation is far worse for some species. No seedlings or saplings of sessile oak were found in this survey and there is therefore no recruitment of new individuals to young reproductive stage or older (Table 1).

Although rowan had a high density of seedlings the small saplings were only at 1.3% of the density of the seedlings indicating very poor survival rates of the seedlings (Table 1). Rowan saplings were present in only nine sample plots when seedlings of this species were present in all but one sample plot.

Seedlings and saplings of hazel and holly were also equally rare and there appears to no effective recruitment of either these two species as well as that of sessile oak and rowan.

The only species of tree that is effectively recruiting new individuals into the next generation of trees is downy birch (Figure 3). Seedlings of downy birch were present in all but three plots whilst small saplings of downy birch were present in 10 of the 25 sample plots (Figures 5 and 6). Large saplings of downy birch are restricted to the lower slopes near Kentra Bay and were present in only five sample plots (Figure 7). Pole stage and young reproductive trees are also largely restricted to the lower slopes just above Kentra Bay, and all but three of those found in the plots were birch (Figure 8). Pole stage trees are restricted to just six plots (24%) and they are nearly all located at the north-eastern part of the survey area close to the margin of

the woodland by the bay (Figure 8). Young reproductive trees were found in only three plots and two of these were located at the northern edge of the survey area close to the bay (Figure 8).

Mature trees were found in all but six of the plots and all of these plots are in the area of woodland at the southern end of the SSSI on the slopes above Lochan na Creighe Duibhe where over-mature trees are the predominant life-class of tree (Figure 9). Over-mature trees were found in 14 sample plots (Figure 9).

Senescent trees were found in six plots, three of which were in the patch of woodland around Steallan Dubh and three were just to the east of the outflow of the Allt a' Ghoirtein-eorna into Kentra Bay (Figure 10). "Phoenix" trees were found in six plots, five of which were in different plots to the senescent trees and these were located in the southern-most (and highest altitude) patch of woodland and in the woodland towards the eastern of the SSSI (Figure 10). Dead trees were found in 13 sample plots and they were present in most of the patches of woodland, but they were particularly prevalent in the area of woodland between Creag Dhubh and Lochan na Creige Duibhe (Figure 11).

3.5 Size/age distribution

The population of sessile oaks within the Kentra Bay and Moss SSSI is dominated by medium to very large trees with very few small trees present in the population (Table 3 and Figure 12). The absolute densities of trees are low with maximum densities of 120 stems per ha (in plot K16) and a mean density of 25 stems per ha (Table 2). Oak trees are largely absent from the higher land in the southern and western parts of the survey area and are mostly found near to the shore of Kentra Bay (Figure 13).

In contrast to sessile oak the downy birch population is dominated by seedlings and there is a second peak in the small tree size class (Figure 14). The densities of small downy birch trees is higher than the density of small or large saplings (Figure 14).There is no obvious spatial pattern in the distribution of birch trees (Figure 15).

Although all of the rowan and hazel trees measured in this survey were small, this is likely to be expected as these are typically small trees or multi-stemmed bushes (Table 3). Figure 16 shows where the trees of rowan and hazel were found in this survey.

3.6 Basal area

The overall basal area of all live trees that were surveyed was 12.42 m^2 per ha (Table 4). This represents only 0.1% of the ground occupied by the trunks of trees. The median basal area across the 25 plots is 11.7 m^2 per ha and the inter-quartile range is between 5.3 and 16.7 m^2 per ha (Table 2).

Only two plots (K2 and K16, both close to the shore) had basal areas greater than 25 m^2 per ha where shading may be of any significance in inhibiting the establishment of shade-intolerant species of tree (Figure 17).

Downy birch accounts for 61% of the total basal area measured with sessile oak making up 37% (Table 4). Rowan and hazel each account for the remaining 2% of the basal area (Table 4). Most of the basal area is taken up by trees in the mature and over-mature life-classes (Table 4).

The plots with the highest basal areas are located towards the shore of Kentra Bay where there is the highest densities of sessile oak (Figure 17).

3.7 Herbivore impacts

Across all the species surveyed 34% of the seedlings were browsed and 48% of the small saplings were browsed (Table 5). Levels of browsing on downy birch were 45% for seedlings and 39% for small saplings, and for rowan they were 30% on seedlings and 60% on small saplings (Table 5). The higher levels of browsing on the small saplings of rowan than the seedling stage are largely due to the vast majority of the rowan seedlings being very small, typically less than 20 cm tall, and thus not obvious to herbivores (Table 5). There are too few seedlings and saplings of holly and hazel to gain anything meaningful from the levels of browsing on these species.

When the browsing levels are analysed across individual plots the inter-quartile range for browsing on seedlings was between 22 and 71% with the median browsing level being 50% (Table 2). The median browsing level on small saplings was 39% and the inter-quartile range was between 0 and 100% (Table 2). The highest levels of browsing on seedlings and small saplings tended to be in the plots on the higher ground between Creag Dhubh and Lochan na Creige Duibhe (Figures 18 and 19).

Browsing levels on epicormic shoots could not be assessed in the majority of sample plots because they were absent and for seven plots the grazing levels on the sward could not be assessed due to the assessment being carried out too early in the season to see the levels of grazing on the herbaceous species (Table 6). The herbivore impacts assessed vary considerably between different indicators, but the levels of browsing/grazing were generally highest on the seedlings and saplings and preferentially grazed species in the sward (Table 6). Fraying and bark stripping on seedlings and sapling was not observed, but this could have been due to the low number of taller seedlings and saplings. The majority of the overall herbivore impacts were High and the Low or Moderate/Low overall herbivore impacts were observed in the sample plots on the eastern side of the survey area between Bruach na' Maorach and the car park (Table 6 and Figure 20).

3.8 Herbivores

The large herbivores that are present within the Kentra Bay and Moss SSSI that are resulting in most of the browsing impacts on the tree seedlings and/or saplings are sheep and deer (roe and red). One dead sheep was found within the wood near to the bay during the survey.

The counting of deer dung pellet groups in the large plots was found not to be sufficiently consistent to provide any meaningful data. Some of the sample plots were on steep slopes that made it very difficult or unsafe to count deer dung pellet groups.

3.9 Potential for tree regeneration

All areas of the Kentra Bay and Moss SSSI that were surveyed have the potential to support tree regeneration. There are plenty of seed sources for the regeneration of downy birch and rowan, but no sessile oak seedlings were seen in the plots. There are plenty of niches for tree seedlings to establish as shown by the abundance of seedlings found in this survey.

4. DISCUSSION

4.1 Viability of typical tree species

In order that the Kentra Bay and Moss SSSI continues to support the upland oak woodland habitat, there must be viable populations of the species of tree typical of upland oak woodland. This means that there must be a continued replacement of dead and dying oak trees and other species characteristic of the wood (e.g. downy birch, hazel, rowan and holly) with young trees. Any self-sustaining viable population of plant or animal has to produce more offspring than adults as most young individuals die before they get to a reproductive age (Begon, Townsend & Harper, 2006). When the number of individuals in different cohorts is plotted the resultant graph for trees it is normally an inverted J-shaped curve (Gao *et al*., 2017; Edwards & Mason, 2006).

The sessile oak population has an unsustainable population structure within the Kentra Bay and Moss SSSI as the seedling and sapling generations are effectively absent (Figure 12). The small populations of hazel, holly and rowan are also not viable as there is effectively no recruitment of the sapling generations from the seedlings for these species.

Although the downy birch population has a less than perfect inverted J-shaped frequency-size/age distribution curve, it is a viable population as some small saplings are clearly recruited through to the young reproductive and pole stage life-classes of tree (Figure 14). The population structure is less than ideal because the density of the small and large saplings was lower than that of small trees. Assuming steady state conditions in the rates of recruitment and survival of each life-stage of tree the overall survival rate of seedlings to small saplings appears to be only 3.2%, but if the plants get above the browse line of sheep and deer their survival rate to the large sapling stage is about 55%.

4.2 Site Condition Monitoring targets

The nature conservation condition of statutory protected areas is assessed against a number of attributes and targets listed in the Common Standards Monitoring (CSM) issued by the Joint Nature Conservation Committee (JNCC). The relevant targets in the CSM guidance for woodland habitats that could be assessed from the data collected in this survey are as follows:

1. Understorey (2-5 m tall) present over at least 20% of total stand area.
2. Canopy cover present over 30 – 90% of stand area.
3. At least three age classes spread across the average life expectancy of the commonest trees.
4. Some area of relatively undisturbed mature/old growth stands or a scatter of large trees allowed to grow to over-maturity/death on site (e.g. a minimum of 10% of the woodland or 5-10 trees per ha).
5. A minimum of 3 fallen lying trees >20 cm diameter per ha and 4 trees per ha allowed to die standing.
6. Signs of seedlings growing through to saplings to young trees at sufficient density to maintain canopy density over a 10 yr period (or equivalent re-growth from coppice stumps).
7. No more than 20% of areas regenerated by planting.
8. At least 95% of cover in any one layer of site-native or acceptable naturalised species.

The understorey includes the small and large saplings which are present in 64% of the plots, but their cover amounts to well below 5%. The tree canopy cover may well be below the minimum target area of 30% at present, but the survey covered in this report did not aim to measure this variable.

Downy birch and sessile oak are the two commonest species of tree, but only downy birch satisfies target 3 in terms of having at least three age classes spread across the average life expectancy of this species. Sessile oak is completely lacking the juvenile age class and therefore target 3 is not satisfied.

Target 4 is satisfied as there plenty of undisturbed mature/old growth stands of sessile oak and downy birch. There are on average 40 over-mature trees per ha and 7 senescent trees per ha.

Target 5 is also satisfied as there was on average 7 standing dead trees per ha and 10 dead trees with a diameter of at least 20 cm were found in the 1.147 ha of ground surveyed.

It is debateable whether a sufficient number of seedlings and saplings will grow through to young tree stage in the next 10 years to maintain the existing canopy cover. Canopy cover may decrease a little in the next 10 years, but it may be difficult to detect.

Targets 7 and 8 are satisfied as there was no evidence of any trees having been planted and all the trees present are site native species.

Currently the Kentra Bay and Moss SSSI may fail the Common Standards Monitoring assessment for woodlands on the basis that the target for canopy cover of trees is probably below the 30% minimum. The current canopy cover is unlikely to change quickly in the next 5 years. Also, the understorey cover (saplings and shrubs between 2 and 5 metres tall) is almost certainly below the minimum target of 20% as the densities of large saplings is only above 100 stems per ha in four of the 25 sample plots. There is no evidence that this is going to change in the near future without a significant reduction in browsing levels.

4.3 Site Management Statement

It is possible to make comments on the targets for upland oak woodland habitat in the Site Management Statement. It appears that the grazing pressure within the woods, including the area at Creag nan Sgarbh (which is highlighted in the SMS), has not changed in any significant way for some considerable period of time given the lack of regeneration and recruitment of new trees of sessile oak, rowan, hazel and holly. The herbivore impacts in the Creag nan Sgarbh area as well as most of the woodland habitat are High (Figure 20). Therefore, some action needs to be taken to reduce grazing pressures in order that regeneration of sessile oak trees can occur and for the seedlings of other species of tree that are present to reach the large sapling and young reproductive tree stage.

No rhododendron were encountered whilst carrying out this survey, but a survey in 2018 (National Trust for Scotland) found it to be sparsely scattered through most of the wood. Only one Sitka spruce seedling was found in the plots covered in this survey. Both of these species of non-native potentially invasive species have the potential to have a significant impact on the nature conservation interests of this site in the future.

4.4 Reasons for lack of regeneration

The median diameter of all the live sessile oak trees measured was 49cm. Assuming a typical annual radial growth rate of 1.4 mm per annum (Büyüksair *et al.*, 2018), the majority (inter-quartile range) of the trees (33 to 62 cm diameter) were established between about 120 and 220 years ago. Therefore, the sessile oak population was probably mainly established during the peak of the clearances in the nineteenth century when red and roe deer numbers were low. During this period there was an increase in the amount of tree planting for deer parks as well as charcoal and tannin production. Whether the oak trees within the woodland surveyed were planted or not is open to question.

The lack of oak seedlings observed in this survey cannot be attributed to them being overlooked as the survey was carried out when the trees had come into leaf. The absence of even small oak seedlings cannot be attributed to shading by mature trees as acorn germination and initial seedling growth is not affected by this factor. The absence of young seedlings is most likely to be due to either insufficient acorn production and/or predation of the acorns by voles, squirrels and various species of bird (Shaw, 1968). The latter is more likely to be a significant factor when there is a low density of seed producing trees.

The three most likely factors preventing the establishment of tree seedlings and saplings are browsing by large herbivores, insufficient light or disease. There was no evidence that plant pathogens had resulted in the death of any of the sessile oak, downy birch and rowan seedlings and saplings. Low light levels can result in the death of light demanding species of tree, such as downy birch (Price & MacDonald, 2012). The basal area of trees can be used as a surrogate for the amount of light likely to reach the floor of conifer plantations and allow the natural regeneration of trees (Hale 2004). Sessile oak is a moderately shade tolerant species and they tolerate shading levels as low as 50% of ambient light (Jarvis, 1964; Annighöfer *et al*., 2015; Březina & Dobrovolný, 2011). A stand of Scots pine trees with a basal area of about 25 m^2 per ha has light levels reduced to 35% of ambient light (Hale 2004). However, Scots pine is an evergreen conifer and will produce a greater level of shading for the same basal area as sessile oak or downy birch. Only 2 of the 25 plots surveyed had basal areas greater than 25 m^2 ha^{-1}, but no more than 32 m^2 per ha. Therefore, the lack of regeneration of saplings from seedlings cannot be attributed to significant amounts of shading by older trees in the vast majority of the woodland.

Given the lack of evidence for shading and disease for preventing the regeneration of downy birch and rowan within the woodland habitat at Kentra Bay and Moss SSSI it only leaves browsing as the most likely factor. The regeneration of sessile oak and birch within an upland woodland in the Derbyshire Peak District was achieved after sheep were excluded (Pigott, 1983). The RSPB's experience of regenerating the Scots pine woodland at Abernethy was successful when the numbers of red deer were reduced from about 12 per km^2 to below 5 per km^2 (Beaumont *et al*., 1995). The Mar Lodge and Glen Feshie estates have also achieved similar results through major reductions in the densities of red deer (Rao, 2017).

Browsing by sheep and/or deer is effectively the only reason for the poor survival of seedlings through to the small sapling stage. Therefore, browsing levels by larger herbivores are almost certainly limiting the regeneration of hazel, holly, rowan and sessile oak populations within the woodland habitat. Downy birch is probably able to recruit new saplings because it is less palatable and more resistant to browsing pressure than the other species of tree (Armstrong *et al.*, 2014).

4.5 Prognosis

If current levels of browsing continue, the abundance of sessile oak in the upland oak woodland habitat will be gradually reduced as the old and senescing trees die. Currently the only tree that is being recruited in any significant way is downy birch, and as this is species is more resilient to browsing and is also less palatable (see Forestry Commission Scotland woodland grazing toolbox) this species is likely to become the dominant species in the canopy. Therefore, in the long term the woodland is most likely to change from a mixed birch and oak wood to one composed almost entirely of downy birch.

The site is noted for its internationally important assemblages of lichens, mosses and liverworts that depend on the woodland habitat for the humidity maintained by the canopy of the trees. Some of the rarer species of lichen, moss or liverwort grow on the trunks and branches of hazel, rowan and sessile oak rather birch. There is, therefore, a danger of some of these plants being lost due to the poor representation of hazel and rowan as mature trees

as well as the lack of regeneration of sessile oak. The maintenance of extensive canopy of more mature trees is important to maintain the high levels of humidity and to reduce wind speeds which are favourable for the species of lichen, moss or liverwort that grow on the rocks under the canopy of the trees. Therefore, the maintenance of a healthy populations of mature hazel, rowan and oak trees is important for this SSSI. Unlike hazel, rowan and oak, birch does not provide the correct niches to support the more species-rich groups of these organisms.

The woodland habitat is also likely to shrink in size. The woodland is already fragmented on the hill slopes and may have already shrunk in size in some areas. This could be confirmed by examining old aerial photographs of the area and examining historical Ordnance Survey maps.

5. CONCLUSIONS

- The populations of sessile oak, rowan, hazel and holly trees within the upland oak woodland at Kentra Bay and Moss SSSI are not currently viable.
- The age structure of these species of tree is poor due to the lack of regeneration of seedlings (especially in the case of oak) and also due to a lack of recruitment of saplings through to young reproductive trees.
- The lack of regeneration of sessile oak is not only due to browsing, but also likely to be due to poor acorn production and high levels of predation of acorns as no seedlings were observed in this survey.
- The lack of recruitment is due to the high levels of browsing on the seedlings and small saplings by sheep and deer.
- Downy birch trees are the only species of tree that is effectively recruiting new young trees in to the next generation.
- If nothing is done to encourage an increase in the regeneration of sessile oak the woodland will gradually change to a pure birch wood and if deer as well as sheep are not excluded the woodland will also decrease in extent and become even more fragmentary.
- Without such interventions the woodland will lose its conservation interest in terms of its epiphytic lichen and bryophyte flora.

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ANNEX 1: TABLES

Table 1. The stem density (stems per ha) of each life-class for each species of tree surveyed across the Kentra Bay and Moss SSSI.

Species of tree	Life stage										
	Seedlings	Small saplings	Large saplings	Pole stage	Young reproductive	Mature	Over-mature	Senescent	"Phoenix"	**Total Live**	Dead
rowan	1574	20	11	0	1	7	0	0	0	**1613**	1
downy birch	593	47	26	21	22	105	34	7	13	**868**	17
sessile oak	0	0	0	1	0	12	7	0	0	**20**	5
hazel	2	1	1	0	1	9	0	0	0	**14**	0
holly	0	2	0	0	0	0	0	0	0	**2**	0
Sitka spruce	1	0	0	0	0	0	0	0	0	**1**	0
unknown species	0	0	0	0	0	0	0	0	0	**0**	1
All species	2,170	70	38	22	24	133	41	7	13	**2518**	24

Table 2. Summary statistics on the data collected from across the 25 sample plots surveyed within the Kentra Bay and Moss SSSI.

Species/ variable	Life-class	Statistic						
		Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
All species density (stems per ha)	Seedling	3,259	3,766	281	682	1,283	6,090	13,703
	Small sapling	108	198	0	0	20	149	914
	Large sapling	30	62	0	0	0	0	200
	Pole	75	281	0	0	0	0	1,320
	Young reproductive	24	52	0	0	0	0	180
	Mature	157	152	0	0	140	241	497
	Over-mature	40	63	0	0	20	50	261
	Senescent	6	14	0	0	0	0	60
	“Phoenix”	12	31	0	0	0	0	140
	All trees	315	369	0	120	221	360	1,726
	All dead trees	28	45	0	0	20	40	203
Downy birch density (stems per ha)	Seedlings	746	1,290	0	100	321	702	5,989
	Small saplings	76	157	0	0	0	100	711
	Large saplings	21	49	0	0	0	0	160
	All trees	274	348	0	80	180	321	1,624
Sessile oak density	Large saplings	2	10	0	0	0	0	50
	All trees	25	39	0	0	0	20	120
Rowan density (stems per ha)	Seedlings	2,511	3,554	0	321	922	3,147	13,703
	Small saplings	26	52	0	0	0	20	203
	Large saplings	9	34	0	0	0	0	160
	All trees	7	17	0	0	0	0	60
Hazel density (stems per ha)	Seedlings	2	8	0	0	0	0	40
	Small saplings	1	4	0	0	0	0	20
	Large saplings	1	4	0	0	0	0	20
	Trees	9	34	0	0	0	0	160
Basal Area (m^2 ha^{-1})	All species	12.5	9.3	0.0	5.3	11.7	16.7	40.8
Browsing (%)	Seedlings	52	13	7	22	50	71	100
	Small saplings	47	42	0	0	39	100	100

Table 3. The stem density (stems per ha) of each size-class of tree for each species surveyed across the Kentra Bay and Moss SSSI.

	Number of stems per ha						
Species of tree	small trees	medium trees	large trees	very large trees	standing dead	fallen dead	dead stump
downy birch	149	49	10	0	3	10	4
sessile oak	3	4	4	7	3	1	1
rowan	8	0	0	0	0	1	0
hazel	10	0	0	0	0	0	0
unknown species	0	0	0	0	1	0	0
All species	169	53	15	7	7	11	5

Table 4. The basal area (m^2 per ha) of each life-class for each species of tree surveyed across the Kentra Bay and Moss SSSI.

Species of tree	Life stage							
	Pole stage	Young reproductive	Mature	Over-mature	Senescent	"Phoenix" trees	Dead	Total live
downy birch	0.196	0.153	4.103	2.160	0.644	0.320	0.747	7.576
sessile oak	0.006	0.000	2.347	2.242	0.000	0.000	0.618	4.595
rowan	0.000	0.004	0.137	0.000	0.000	0.000	0.004	0.141
hazel	0.000	0.005	0.103	0.000	0.000	0.000	0.000	0.109
unknown species	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.000
All species	**0.201**	**0.163**	**6.690**	**4.401**	**0.644**	**0.320**	**1.405**	**12.420**

Table 5. The number of un-browsed and browsed seedlings, small saplings and large saplings for each species of tree surveyed within the Kentra Bay and Moss SSSI.

Species of tree	Seedlings			Small saplings			Large saplings			**All seedlings & saplings**	
	Un-browsed	Browsed		Un-browsed	Browsed		Un-browsed	Browsed			
		number	%		number	%		number	**%**	**number**	**% browsed**
downy birch (*Betula pubescens*)	319	266	45	28	18	39	26	0	**0**	**657**	**43**
rowan (*Sorbus aucuparia*)	1,087	467	30	8	12	60	9	2	**18**	**1,585**	**30**
holly (*Ilex aquifolium*)	0	0	NA	0	2	100	0	0	**NA**	**2**	**100**
hazel (*Corylus avellana*)	2	0	0	0	1	100	1	0	**0**	**4**	**25**
Sitka spruce (*Picea sitchensis*)	0	1	100	0	0	NA	0	0	**NA**	**1**	**100**
All species	**1,408**	**734**	**34**	**36**	**33**	**48**	**36**	**2**	**5**	**2,249**	**34**

Table 6. The number of sample plots with different levels of herbivore impact for each of six indicators in the vegetation within the Kentra Bay and Moss SSSI.

Browsing impact indicator	Herbivore Impact Class					
	High	High/Moderate	Moderate	Moderate/Low	Low	Total
Basal shoots	11	0	7	2	0	20
Epicormic shoots	9	0	0	0	0	9
Seedlings and saplings	13	0	6	3	3	25
Preferentially grazed spp.	13	0	3	3	5	24
Sward	6	1	5	0	6	18
Bark Stripping	0	0	0	0	18	18*
Overall Impact	**14**	**2**	**1**	**6**	**2**	**25**

* one other plot (K4) had some bark stripping

ANNEX 2: FIGURES

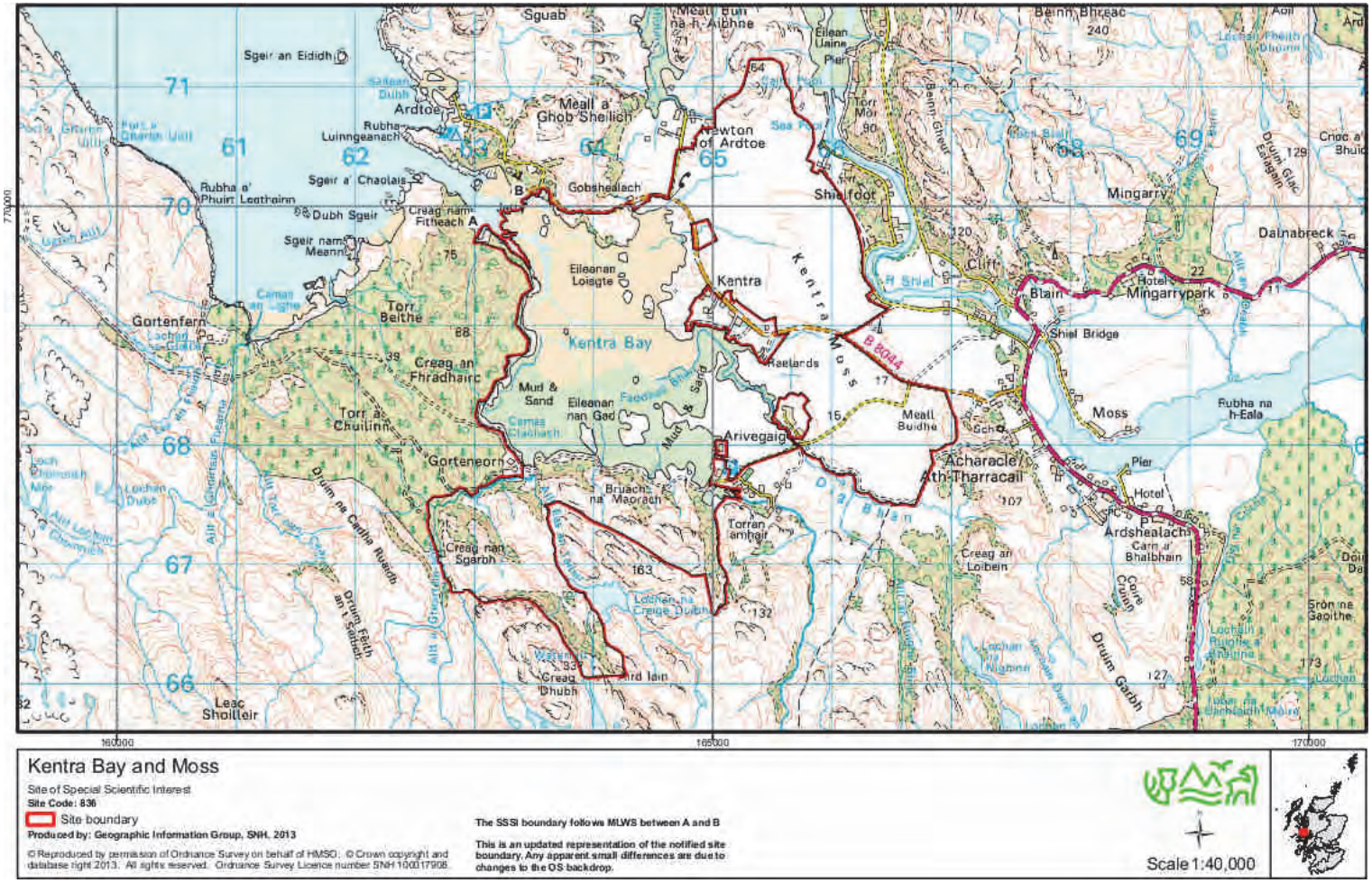

Figure 1. Map showing the location and boundary of the Kentra Bay and Moss SSSI.

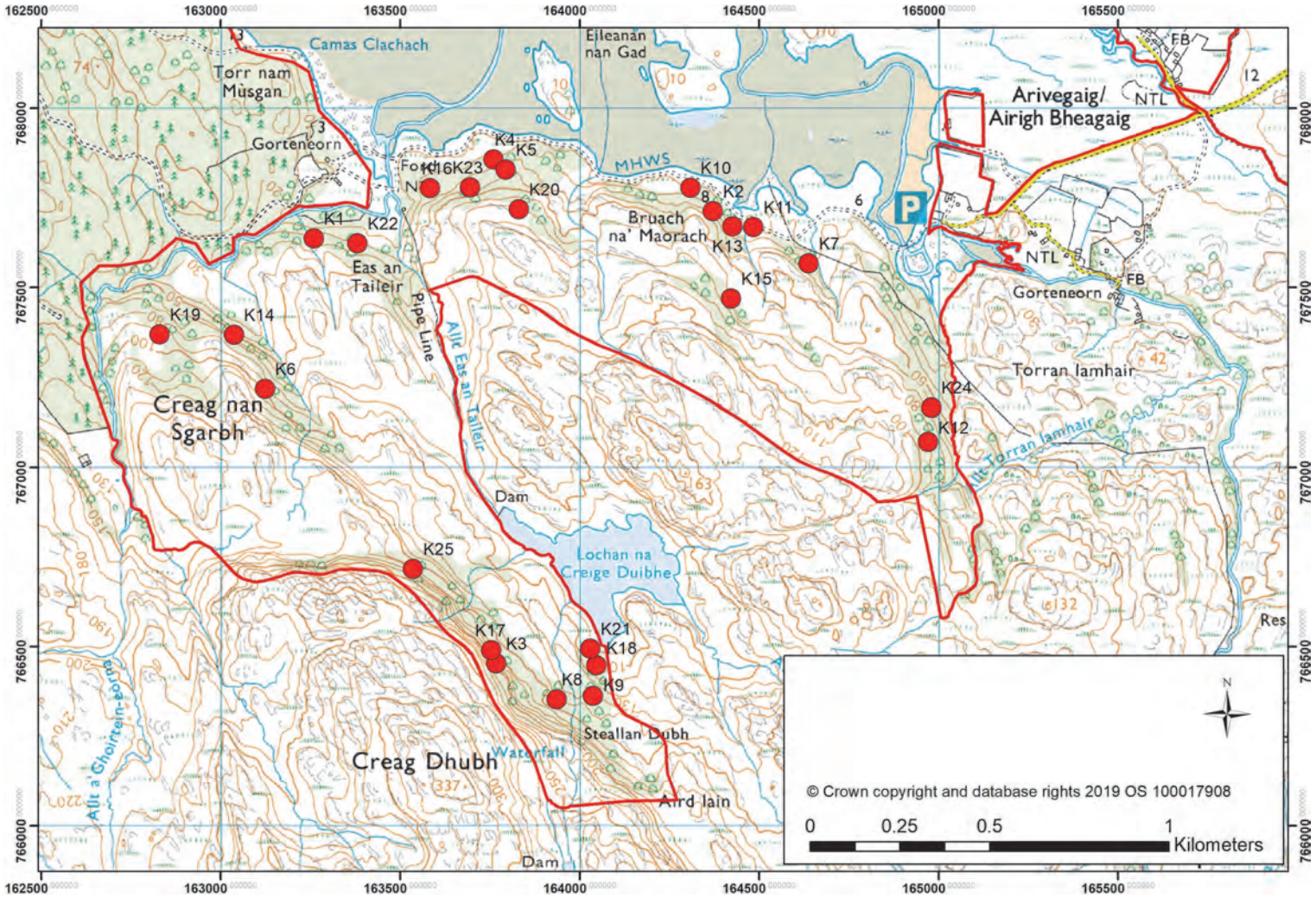

Figure 2. Map showing the location of the 25 sample plots taken to describe the structure and assess the herbivore impacts on the upland oak woodland habitat within the Kentra Bay and Moss SSSI.

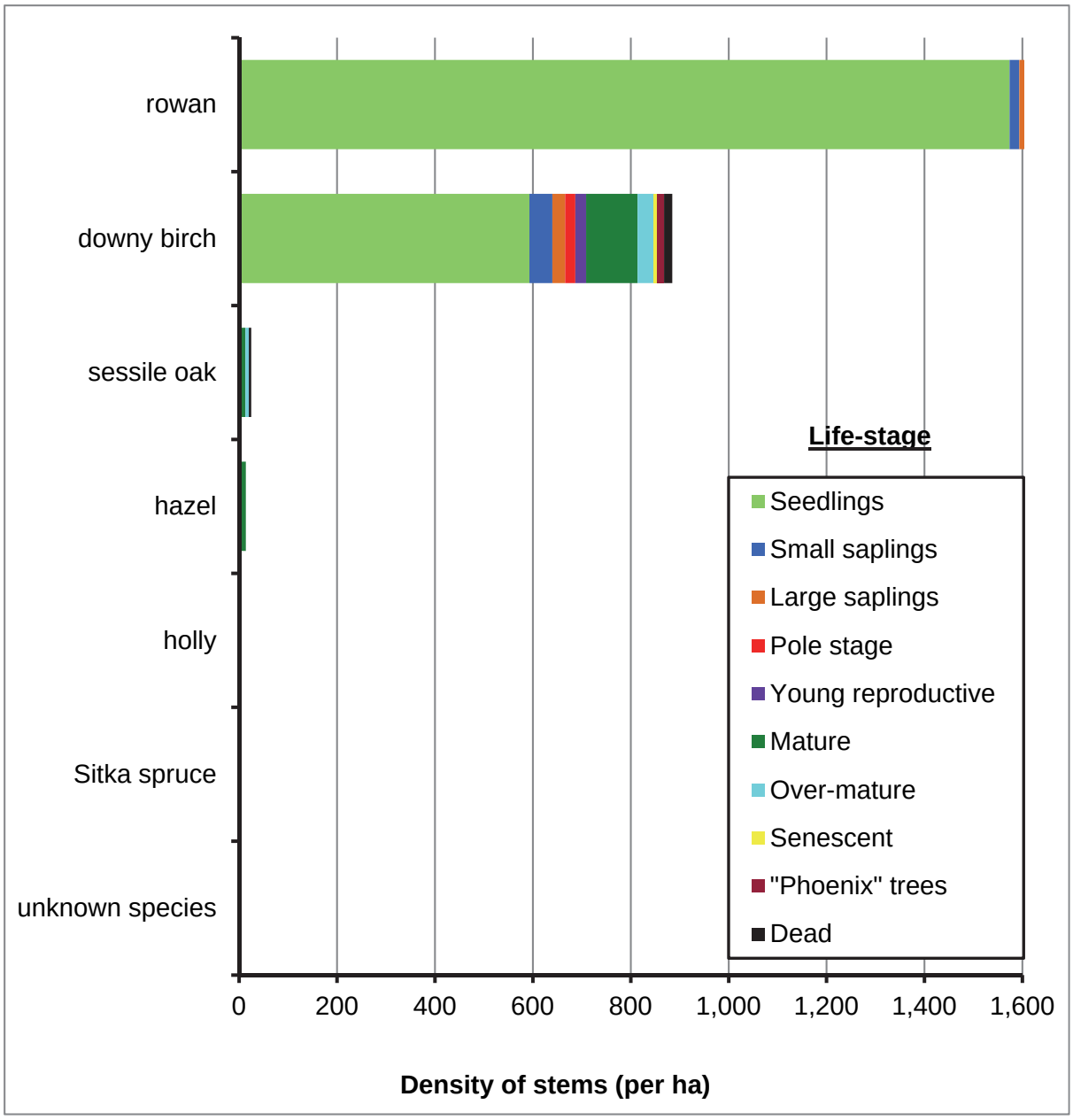

Figure 3. The density of trees in each life-class for each species of tree found in the survey of the 25 sample plots within the Kentra Bay and Moss SSSI.

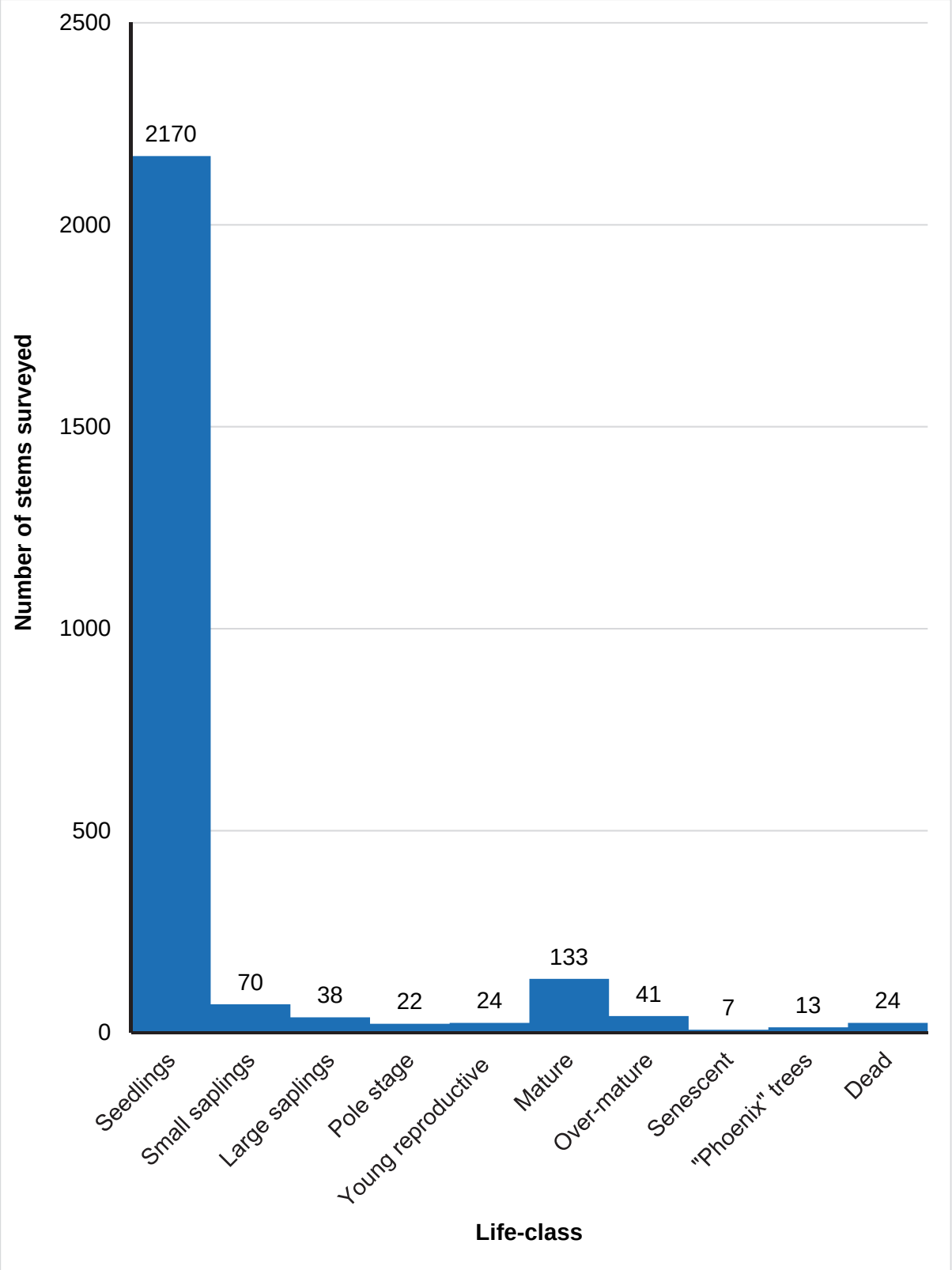

Figure 4. The density of plants in each life-class surveyed across the 25 plots within the Kentra Bay and Moss SSSI.

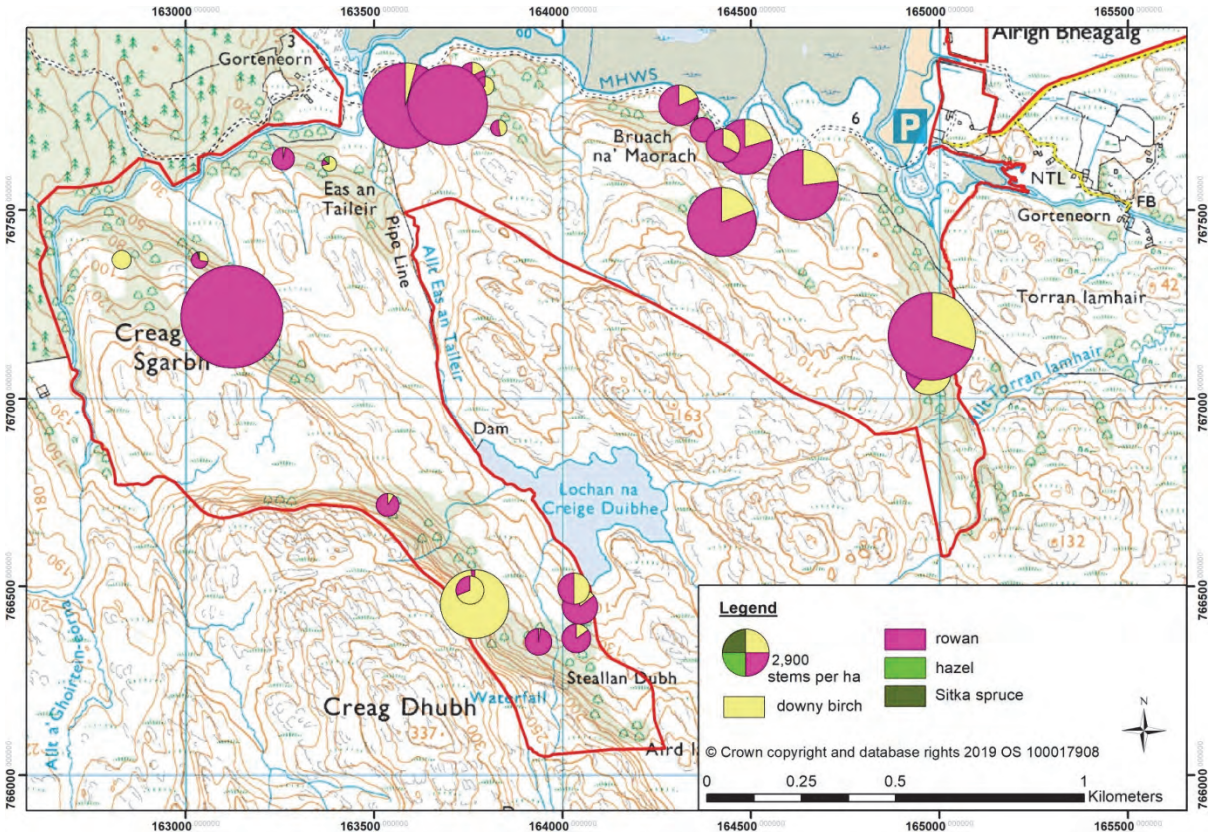

Figure 5. The density of seedlings (per ha) for each species in the plots surveyed across the Kentra Bay and Moss SSSI.

Note: The area of the pies is proportional to the total density of seedlings.

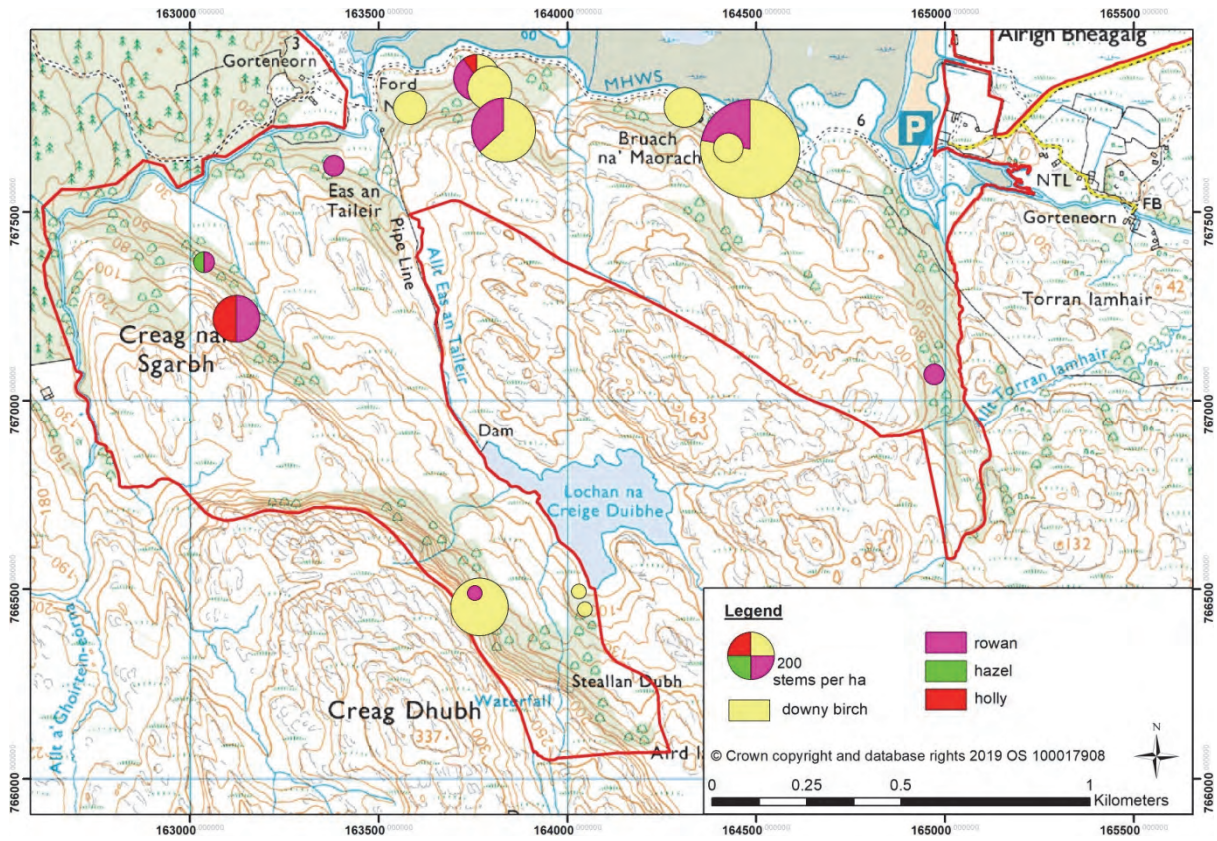

Figure 6. The density of small saplings (per ha) for each species in the plots surveyed across the Kentra Bay and Moss SSSI.

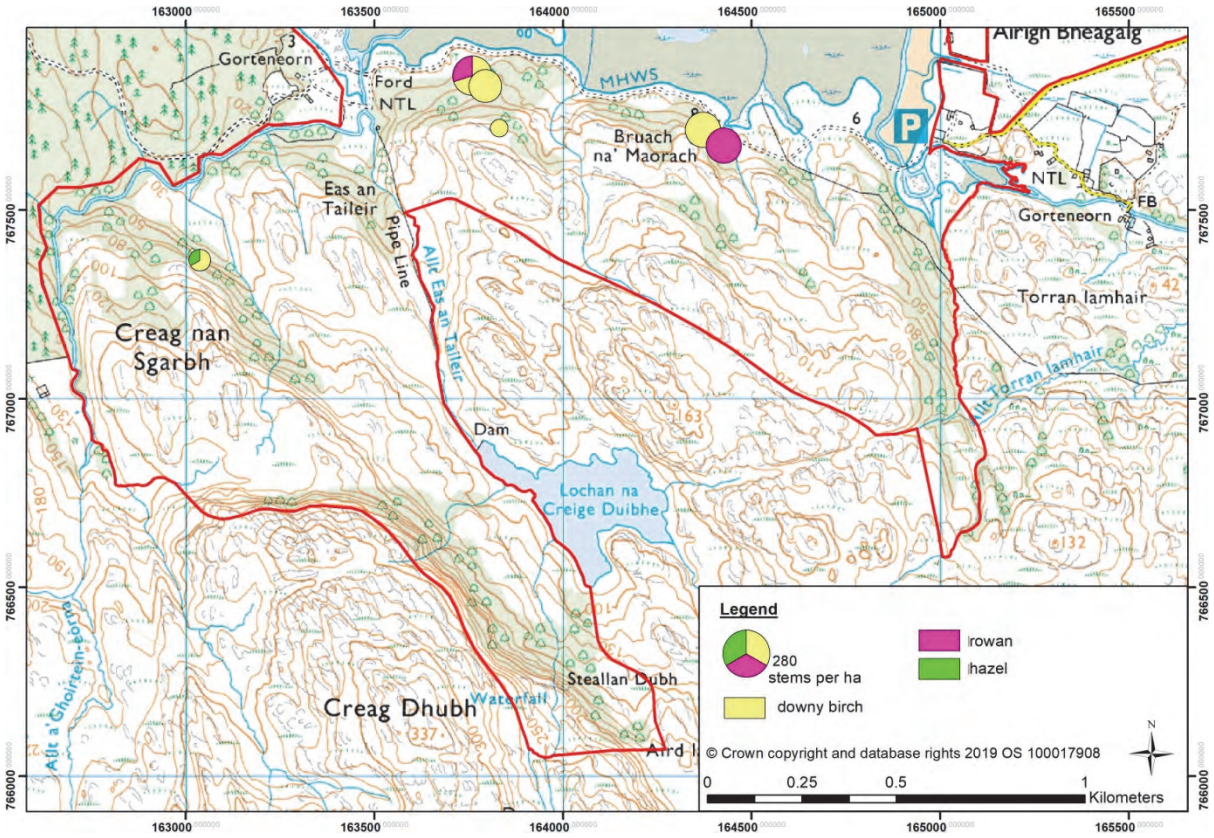

Figure 7. The density of large saplings (per ha) for each species in the plots surveyed across the Kentra Bay and Moss SSSI.

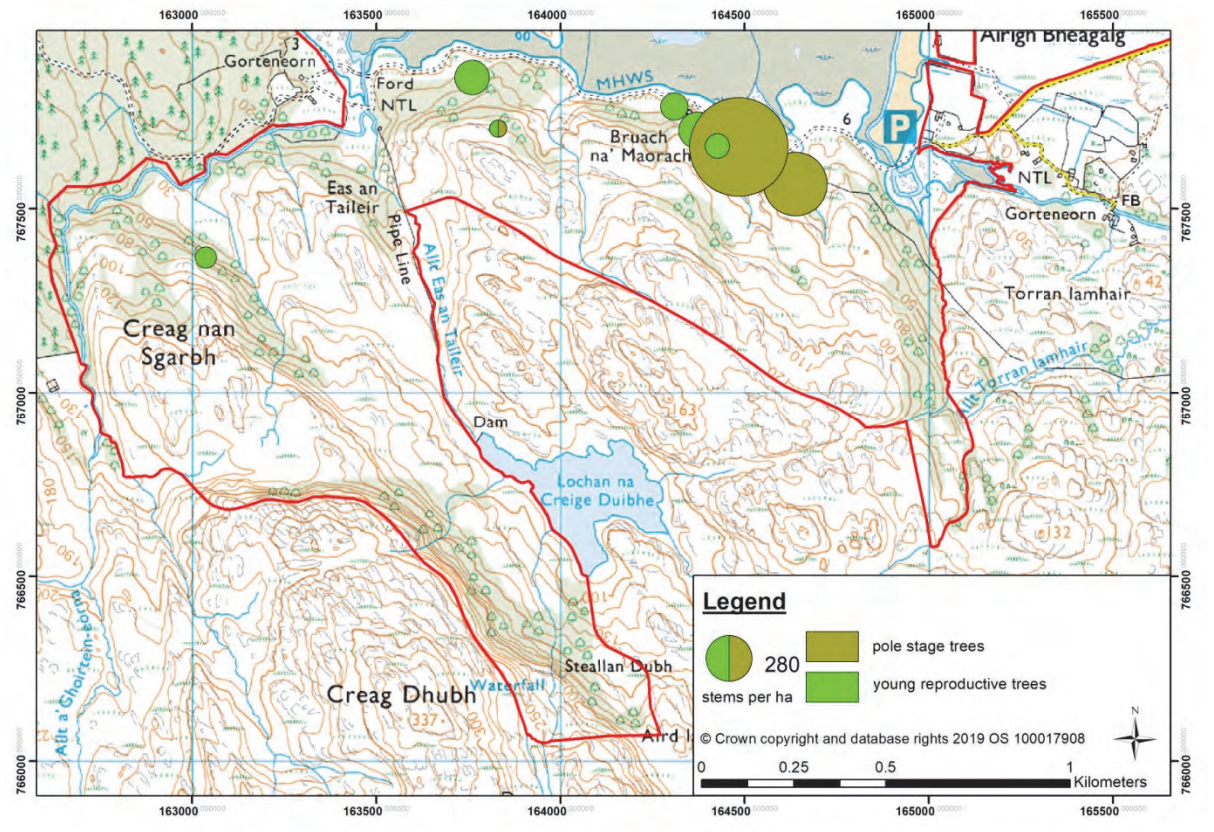

Figure 8. The density of pole stage and young reproductive trees (per ha) in the plots surveyed across the Kentra Bay and Moss SSSI.

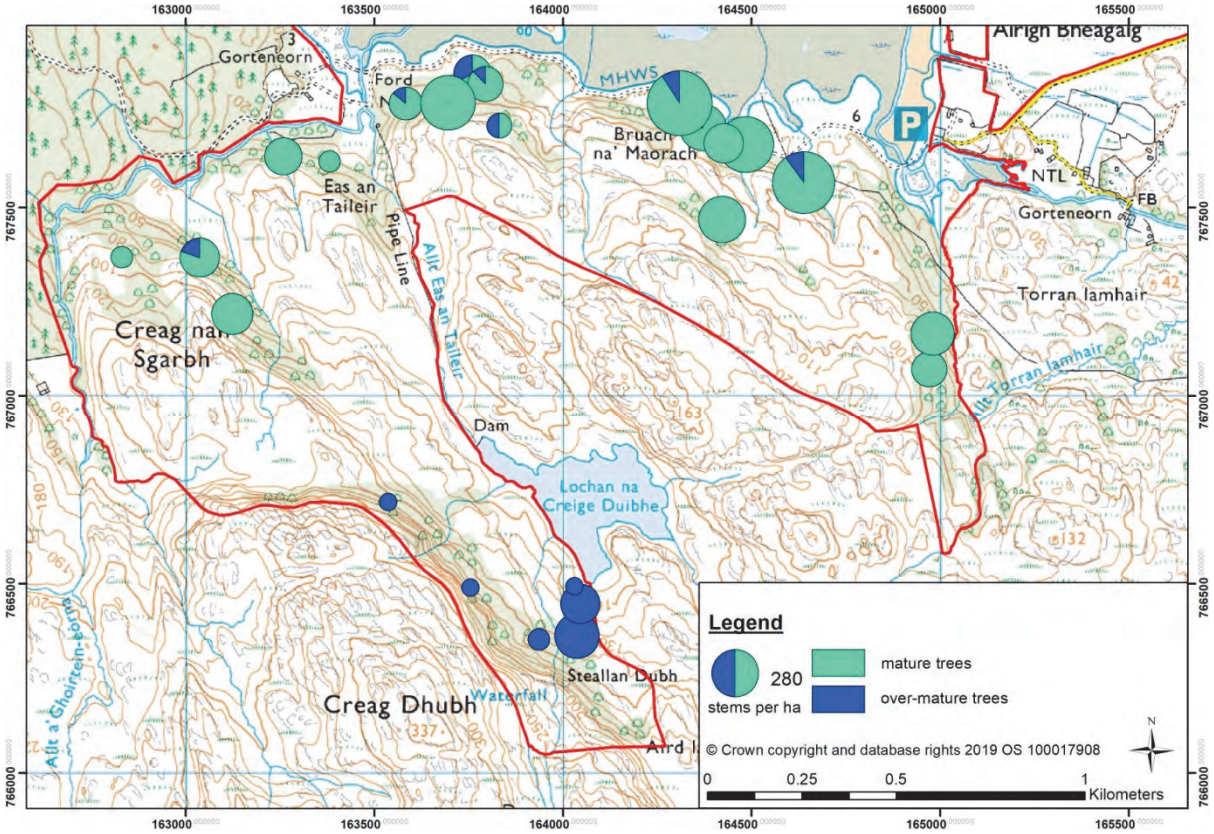

Figure 9. The density of mature and over-mature trees in the plots surveyed across the Kentra Bay and Moss SSSI.

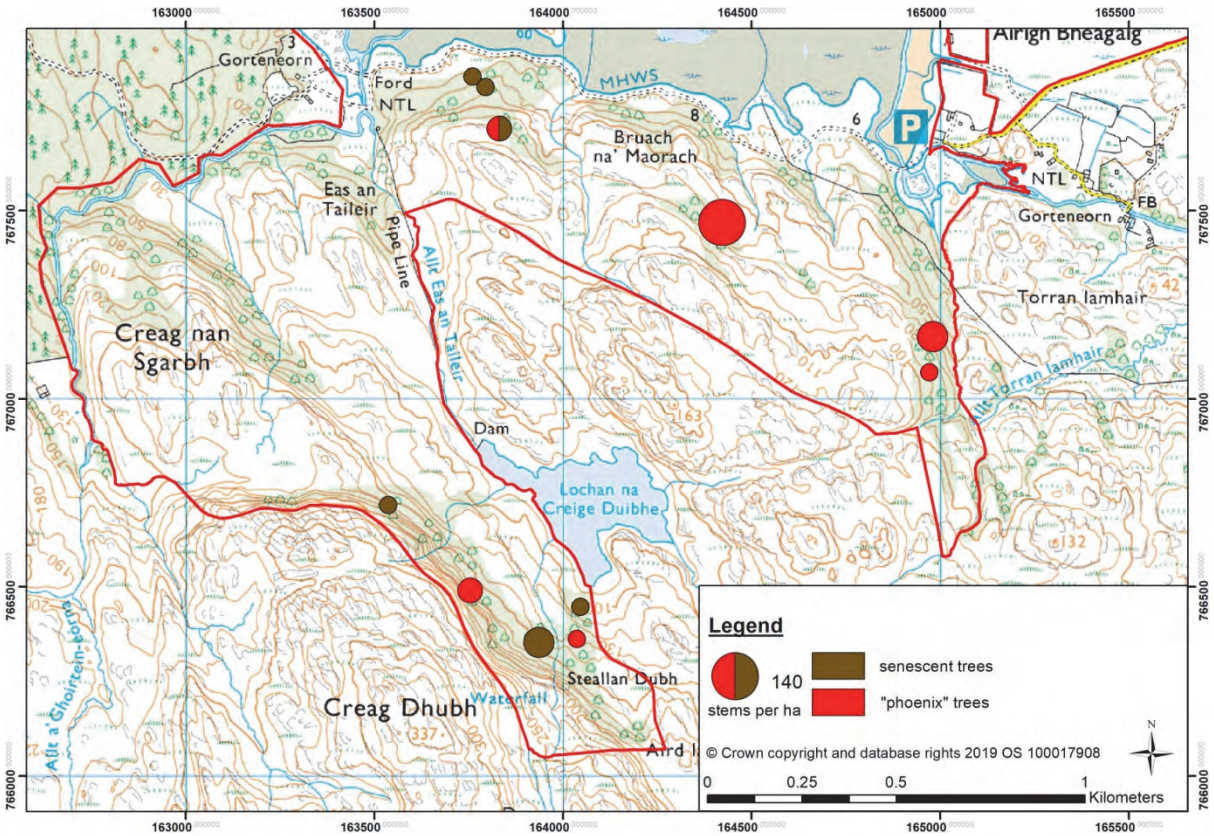

Figure 10. The density of senescent and "phoenix" trees in the plots surveyed across the Kentra Bay and Moss SSSI.

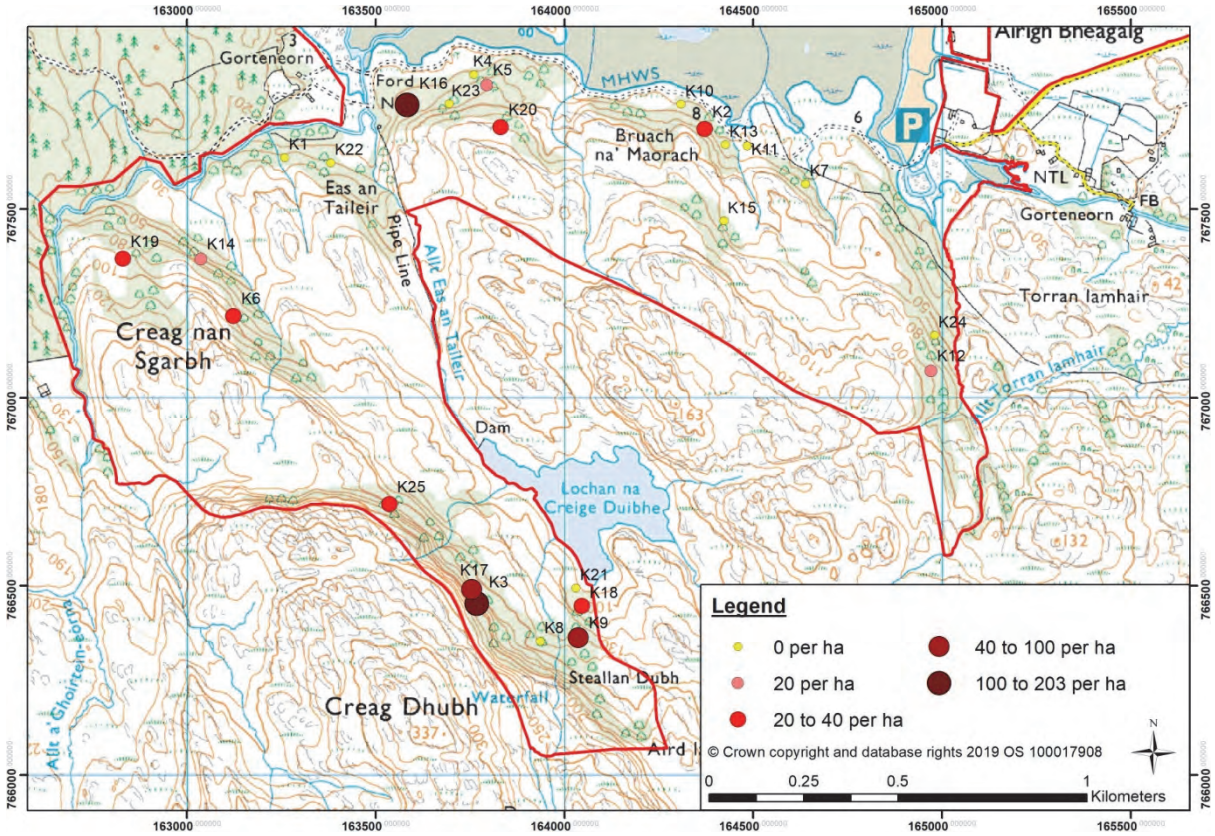

Figure 11. The density of dead trees in the plots surveyed across the Kentra Bay and Moss SSSI.

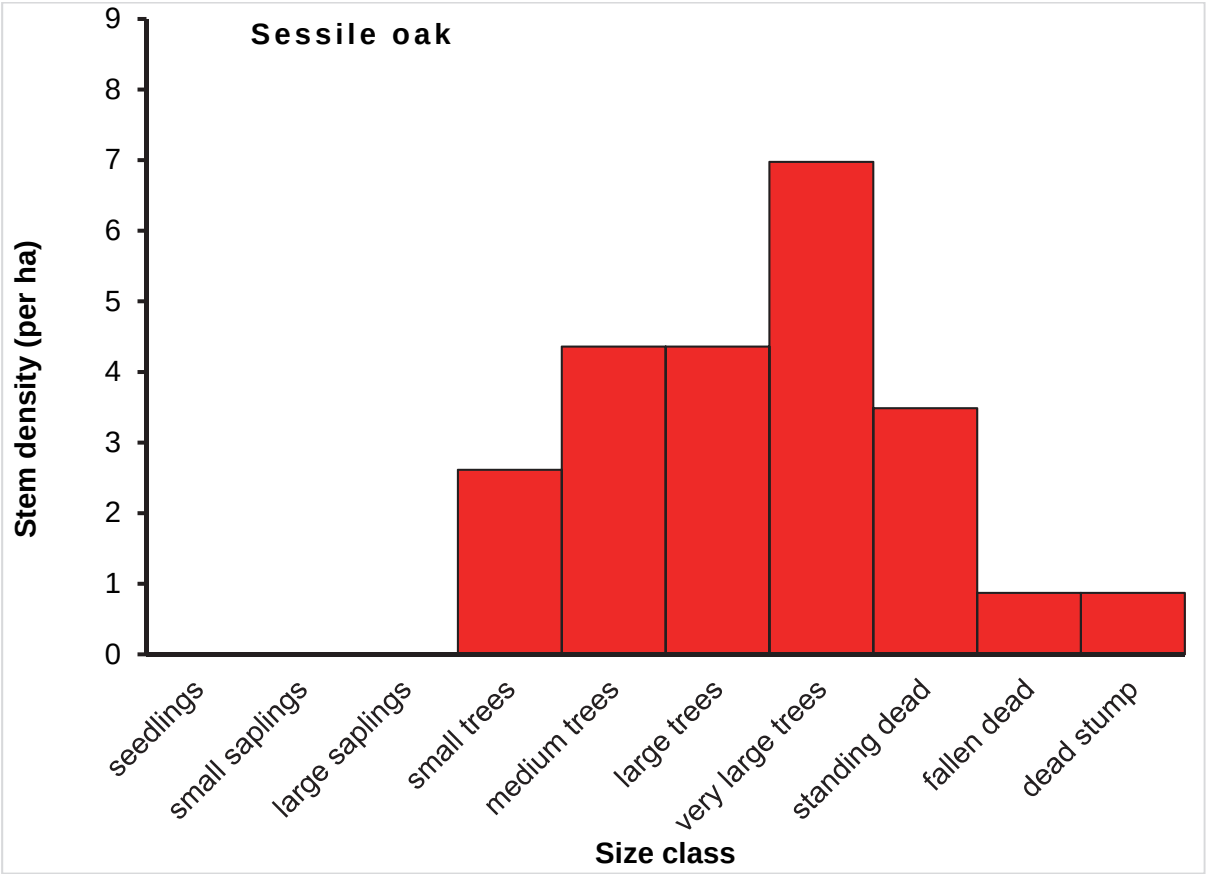

Figure 12. The size distribution of sessile oak trees surveyed within the Kentra Bay and Moss SSSI.

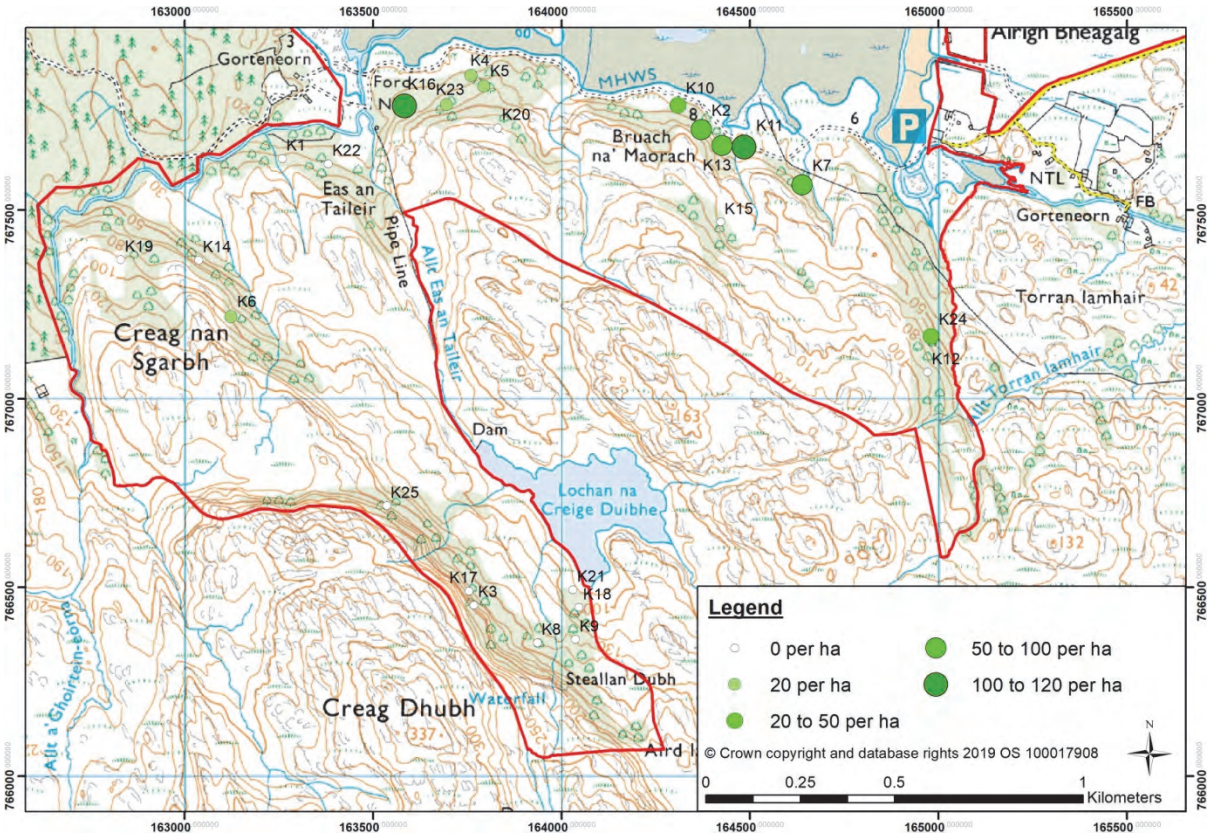

Figure 13. The density of sessile oak trees within the Kentra Bay and Moss SSSI.

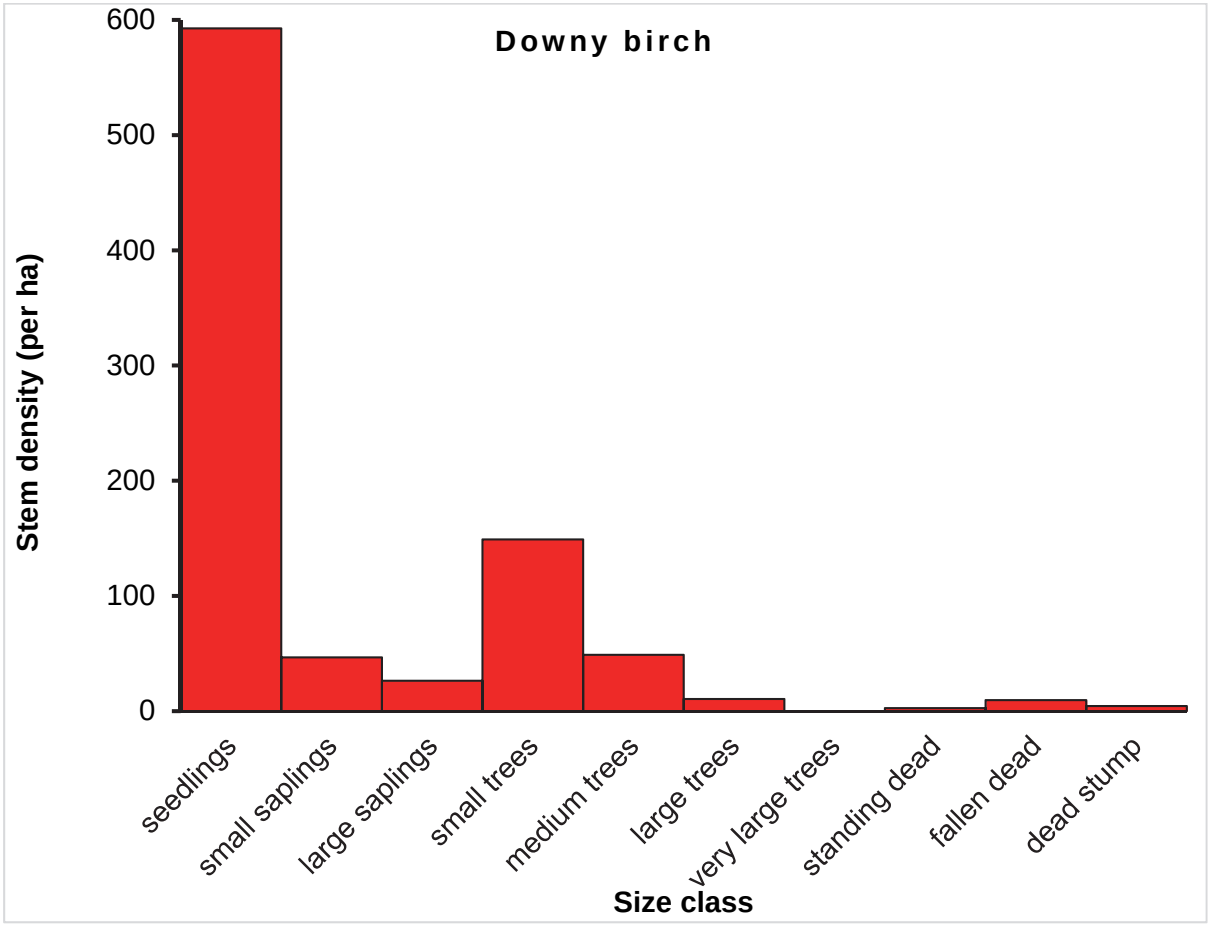

Figure 14. The size distribution of downy birch trees surveyed within the Kentra Bay and Moss SSSI.

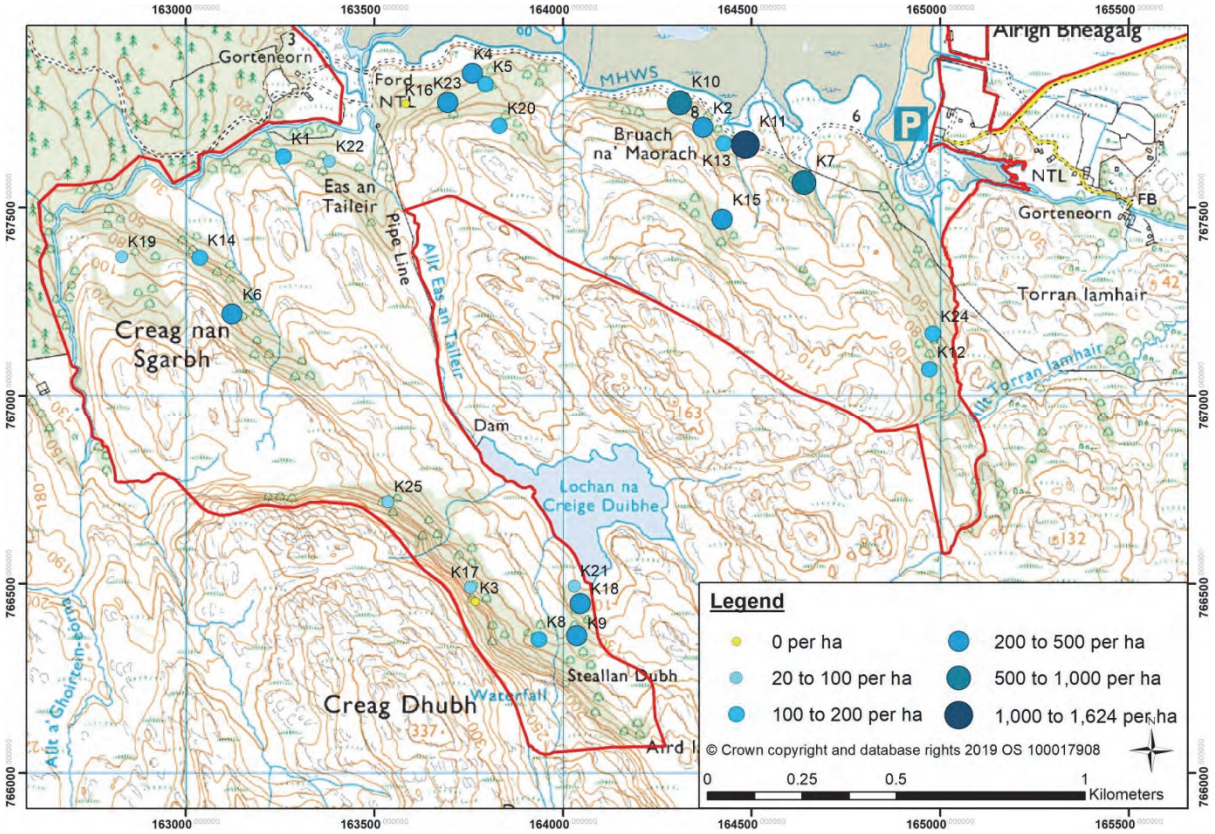

Figure 15. The density of downy birch trees within the Kentra Bay and Moss SSSI.

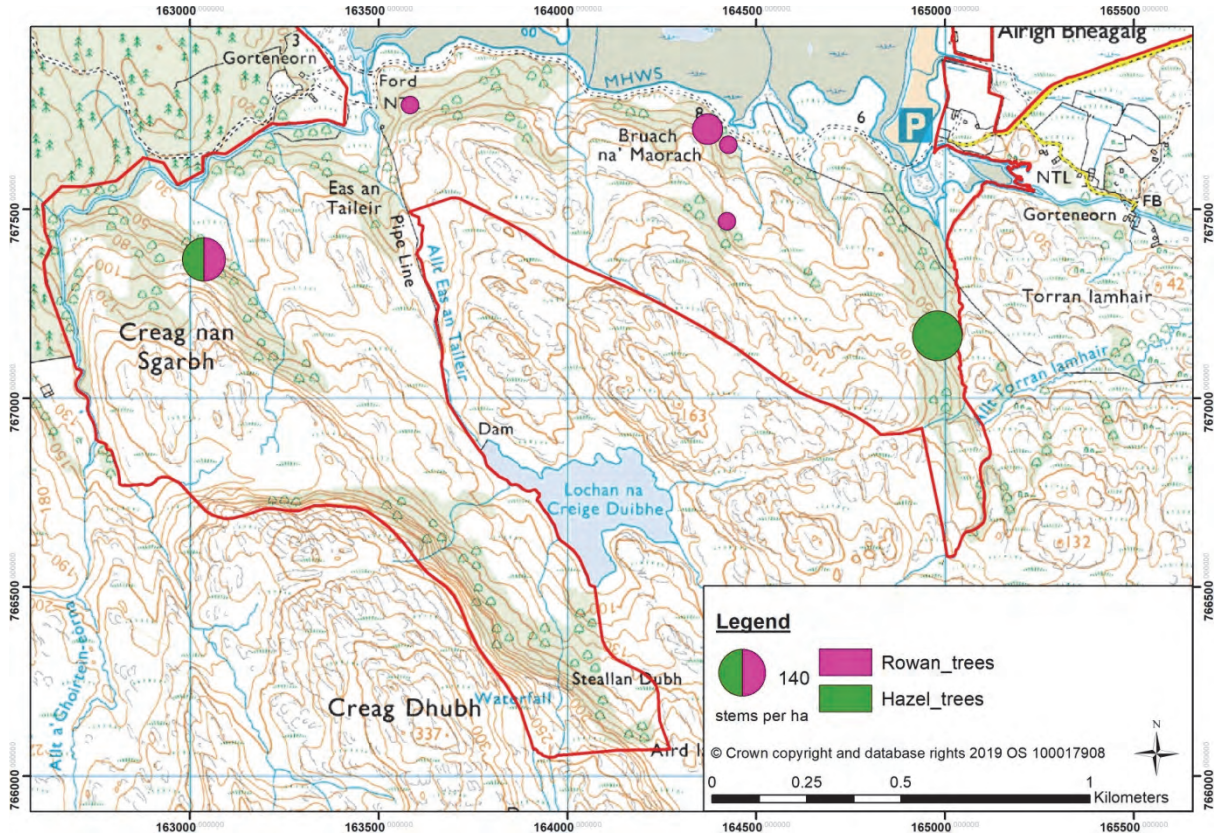

Figure 16. The location and density of rowan and hazel trees within the Kentra Bay and Moss SSSI.

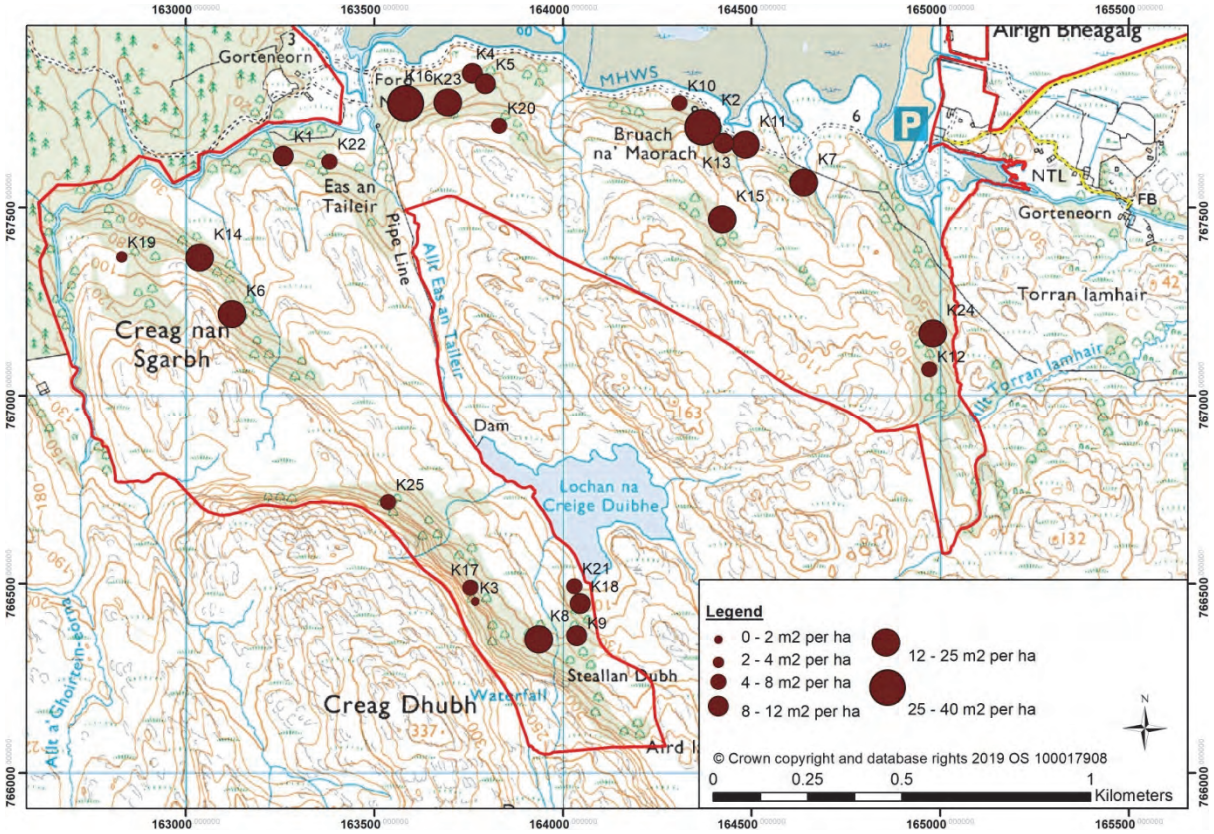

Figure 17. The basal area (m^2 per ha) of all trees within the 25 plots surveyed across the Kentra Bay and Moss SSSI.

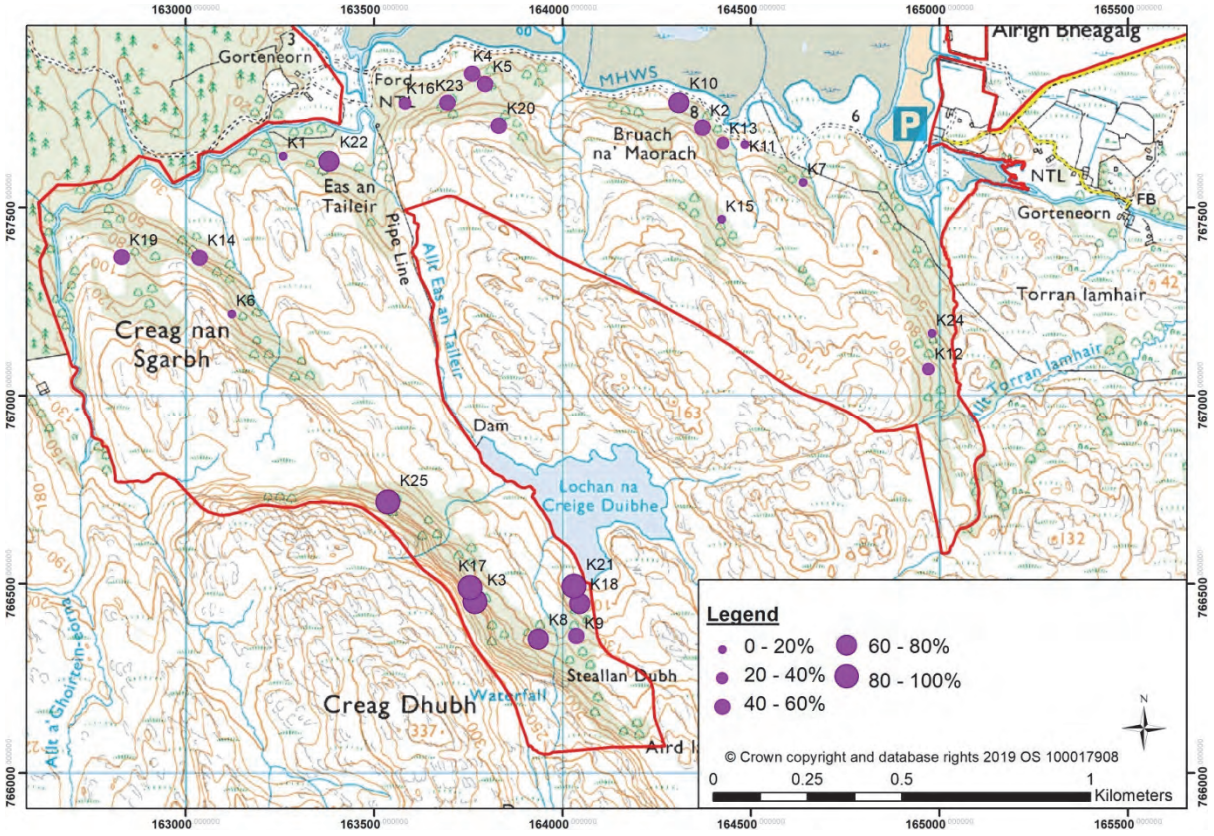

Figure 18. The levels of browsing on seedlings in the plots surveyed across the Kentra Bay and Moss SSSI.

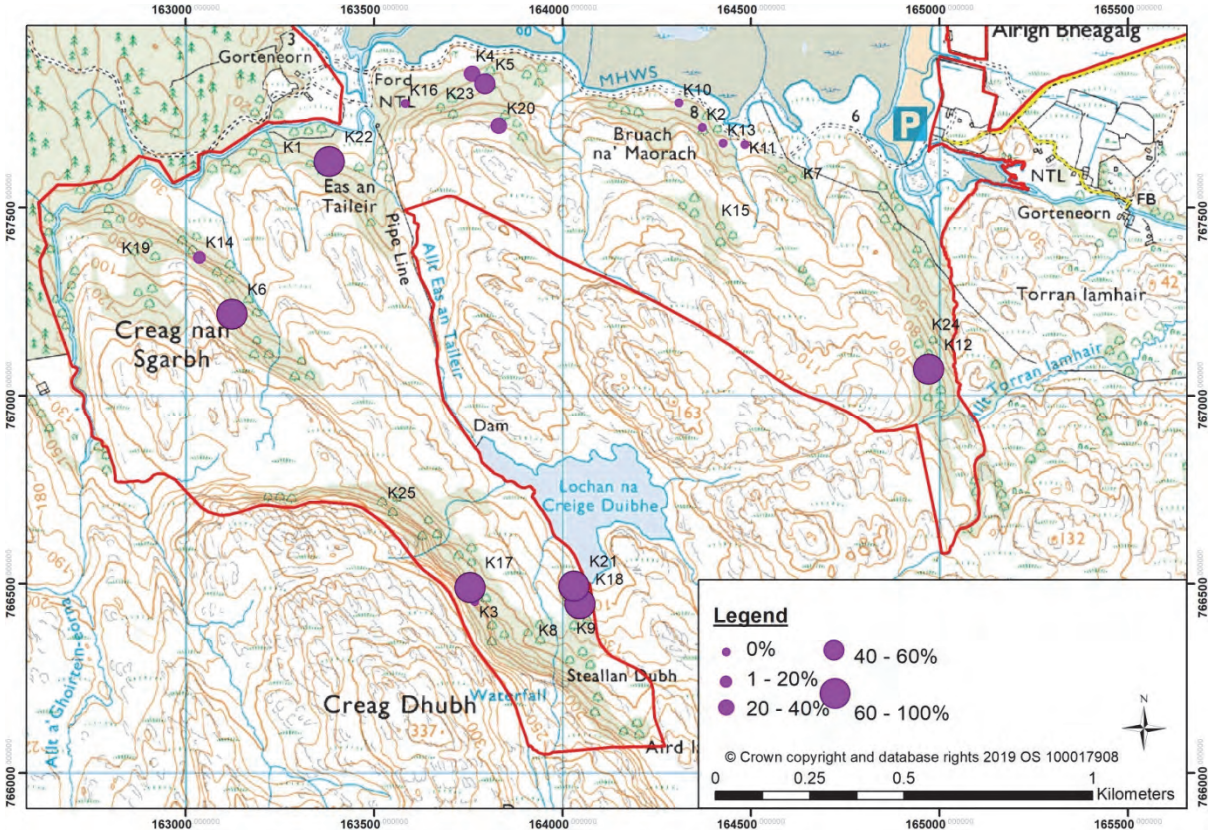

Figure 19. The levels of browsing on small saplings in the plots surveyed across the Kentra Bay and Moss SSSI.

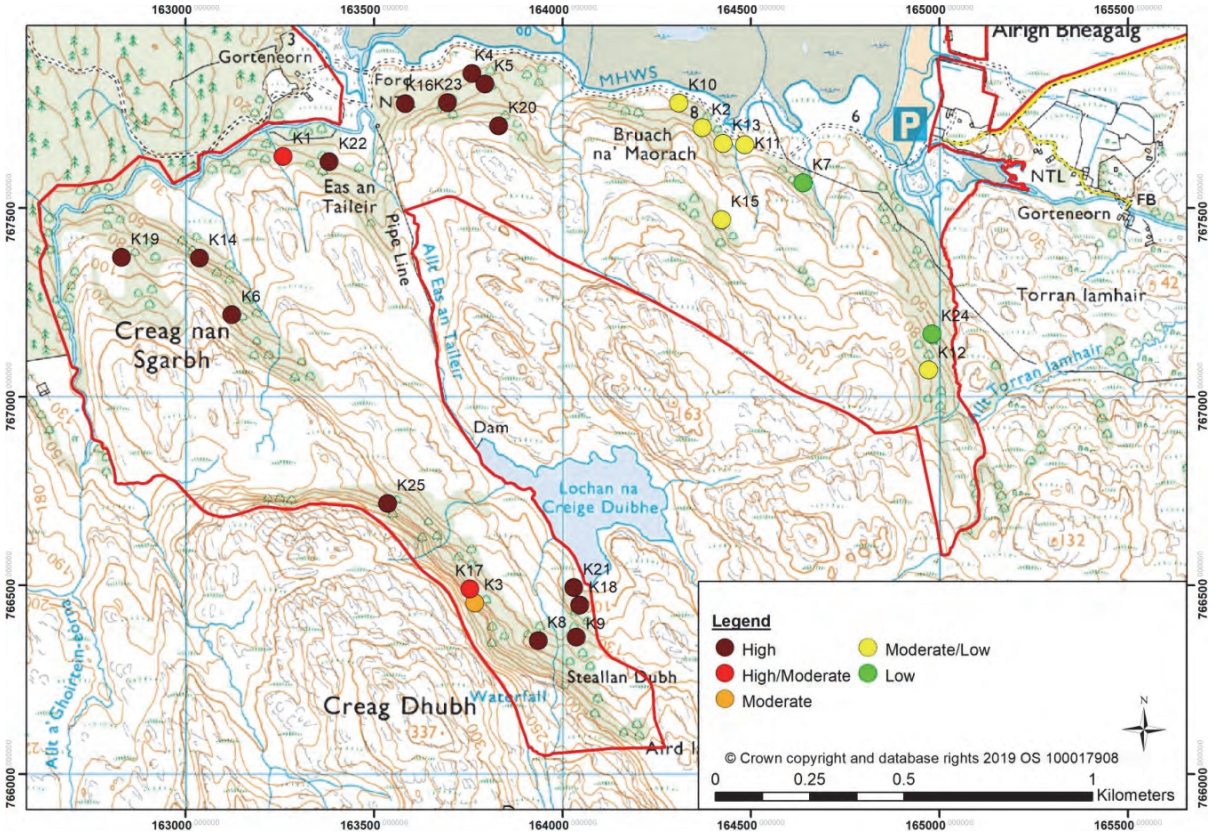

Figure 20. Overall herbivore impacts in each of the sample plots surveyed across the Kentra Bay and Moss SSSI.

ANNEX 3: METHODS USED FOR ASSIGNING LIFE STAGE CLASSES AND LEVELS OF BROWSING

Table 7. Life Stage Classes for Broad-leaved trees (Birch, Alder, Rowan) (After Clifford, 2004).

Tree Life Stage:	Tree sub-class:	Descriptor:	Stand type/conditions:	Biodiversity characteristics:	Stand process:
1. Seedling	1.1 Small seedling	All seedlings **at or below the predominant field layer vegetation height,** Includes newly germinated seedlings of the year & **"oscars**" which have repeatedly been browsed back to field layer height or below	Fragmented canopy, usually with large gaps, & woodland stand edges	Generally high biodiversity in sheltered canopy gaps with increased woodland edge habitat, particularly birds and lepidoptera. Biodiversity generally reduced on exposed woodland edges.	**Stand initiation/regeneration**
	1.2 Large seedling	Seedlings above field layer vegn height, **up to 1m tall**;	Fragmented canopy, gaps & woodland stand edges		
2. Juvenile non-reproductive	2.1 Small sapling	Young trees **1m - 3m height;** usually not yet seed producing	Both dense drifts & scattered individuals in canopy gaps & at stand edges		
3. Young reproductive	3.1 Large sapling	Young trees **3m - 5m in height** usually seed producing DBH usually < 5 cm	Either in dense patches but with branches of established trees not yet fully interlocking, or as small patches or scattered individuals		
	3.2 Pole stage	Seed producing young trees **usually over 5m in height**, where canopy has closed DBH range usually **5 – 20 cm**	Dense stands & patches with fully interlocking branches [thicket]	1. Low light levels, declining biodiversity; 2.some deadwood formation through self thinning	**Stem exclusion**
	3.3 Young reproductive [non-thicket]	Seed producing young trees **usually over 5m in height** DBH range usually **5 – 20 cm**	Lone trees & small scattered groups in canopy gaps & at stand edges		
4. Mature reproductive	4.1 Mature	Seed-producing trees where growth has begun to significantly slow down. **Usually over 5m height & 20 cm DBH[1]**,not falling into the preceding or following classes; **crown usually spreading and at its maximum development** May be **canopy die-back up to 10%** due to competition for light or wind damage	1. Usually scattered open-crowned individuals [often poor form] but 2. Occasionally closer grown stands of better form	1.Some deadwood habitat provided on standing tree and forest floor from wind thrown branches; 2.Canopy provides nesting & feeding sites for birds & invertebrates; 3.Sap-runs developing; 4. Bryophytes, fungi & lichens on bole/bark	**Dynamic Equilibrium**

5. Over-mature	5.1 Early canopy decline	Trees **usually over 5m** height, with spreading canopy; **Canopy 10-20% dead** with reduced seed production [Any reduction likely to be proportional to crown size]	Usually more open conditions, where wind has begun to de-limb trees Characteristic of conditions with low stocking & little/no recruitment of earlier life stages; wood beginning to look Moribund	1. Increase in standing and fallen deadwood; 2. Torn branches & broken limbs; 3.rot-holes developing on tree & saprophytic fungi fruiting 4. Crown dieback → increased light to bole → more opportunities for epiphytes!	**Canopy breakup**
	5.2 Mid-canopy decline	Trees **usually over 5m** height, with spreading canopy; **Canopy 20-50% dead** with consequent much reduced seed production			
6. Senescent post-reproductive	6.1 Heavy canopy decline	Trees **usually over 5m** height, with spreading canopy much ravaged by wind & pathogens; **Canopy 50-99% dead** with markedly reduced seed production proportional to loss of canopy	Often [but not always] very open stand with large canopy gaps, with or without recent regeneration	As above sub-class with significant increase in standing & fallen deadwood habitat on/around trees	
7. "Phoenix" trees	7.1 Main bole dead [usually stump]	**Main bole of tree dead** & usually decaying; **new growth [usually vigorous] from base**			**Canopy rejuvenation**
	7.2 main bole procumbent	**Usually wind thrown** tree with main bole lying along forest floor & **vigorous branches growing more or less vertically**		Displaced root plate often provides additional niches, including "safe sites" for seedling trees	
8. Dead	8.1 Standing dead	Three classes as broad indicators of time elapsed since death: 1.Most bark still on tree [recent dead], bole still hard 2. <80% & >20% bark still on tree, surface of bole hard or becoming softer with decay 3. <20% bark still on tree, surface of bole usually soft [long dead]	Often degrading fragmented stands of large old trees with significant wind throw: but: includes smaller specimens resulting from competitive exclusion in dense stands and: Steep scree slopes with a mobile substrate where trees have been uprooted	Bio-diversity likely to be high for recently dead trees [bark still on tree] with larger stem diameters, which are more typical of fragmented open stands.	**Death, decay & nutrient cycling**
	8.2 Fallen dead	Three classes as broad indicators of time elapsed since death: 1.Most bark still on tree [recent dead] 2. <80% & >20% bark still on tree, surface of bole hard or just softening 3. <20% bark still on tree, surface of bole mostly soft [long dead]			

	8.3 Stumps with no fallen trunk/bole evident	Two classes as broad indicators of past history/management: 1.Stumps from past logging operations [clean cut surface] but in varying stages of decay depending on when cut 2.Torn stumps resulting from wind ”snap”, where trunk has either been removed for firewood or completely decayed	Various but typical of open stands of old wide-crowned trees. Where straightest large specimens have been removed for timber		

N.B. Maturity is defined as the point at which growth starts to slow down significantly.

Table 8. Life Stage Classes for Scots Pine (After Clifford, 2004).

Scots Pine Life Stage:	Tree sub-class:	Descriptor:	Stand type/conditions:	Biodiversity characteristics:	Stand process:
1. Seedling	1.1 Small seedling	All seedlings **at or below the predominant field layer vegn height,** Includes newly germinated seedlings of the year	Fragmented canopy, gaps & woodland stand edges	Generally high biodiversity in sheltered canopy gaps with increased woodland edge habitat, particularly birds and Lepidoptera. Biodiversity generally reduced on exposed woodland edges.	**Stand initiation/regeneration**
	1.2 Large seedling	Seedlings above field layer vegn height, **up to 1m tall**; **usually conical form**	Fragmented canopy, gaps & woodland stand edges		
2. Juvenile non-reproductive	2.1 Small sapling	Young trees **1m - 3m height;** not yet producing **significant** quantities of seed, (**usually conical form**	Both dense drifts & scattered individuals in canopy gaps & at stand edges		
3. Young reproductive	3.1 Large sapling	Young trees **3m - 5m in height** usually coning/seed producing **usually conical form** **DBH usually < 7cm**	Either in dense patches but with branches of established trees not yet fully interlocking, or as small patches or scattered individuals		
	3.2 Pole stage	Seed/cone producing young trees **usually over 5m in height** where canopy has closed; **usually conical canopy form** **DBH range usually 7– 30 cm**	Often dense stands & patches with fully interlocking branches [thicket], but also lone trees & small groups in canopy gaps & at stand edges	1. Low light levels, declining biodiversity; 2.some deadwood formation through self thinning	**Stem exclusion**
4. Mature reproductive	4.1 Mature	Seed/cone-producing trees **usually over 5m height & 30cm DBH**[1] not falling into the preceding or following classes; **crown usually spreading rather than conical and at its maximum development** May be **canopy die-back up to 10%** due to competition for light	1. Scattered open-crowned individuals [often poor form] or 2. closer grown stands of first progeny [better form] around "pioneer trees"	1.Some deadwood habitat provided on standing tree and forest floor from wind thrown branches; 2.Canopy provides nesting & feeding sites for birds & invertebrates; 3.Sap-runs developing; 4. Mosses, lichens on bark (but greater development of bryophytes on overmature trees	**Dynamic Equilibrium**
5. Over-mature	5.1 Early canopy decline	Trees **usually over 5m** height, with spreading canopy; **Canopy 10-20% dead** with reduced coning/seed production [Any reduction likely to be proportional to crown size]	Usually more open conditions, where wind has begun to de-limb trees	1. Increase in standing and fallen deadwood; 2. Torn branches & broken limbs; 3.rot-holes developing on tree & saprophytic fungi fruiting	**Canopy breakup**

	5.2 Mid-canopy decline	Trees **<u>usually over 5m</u>** height, with spreading canopy; **<u>Canopy 20-50% dead</u>** with consequent further reduction in coning/seed production		4. Crown dieback → increased light to bole → more opportunities for epiphytes!	
6. Senescent post-reproductive	6.1 Heavy canopy decline	Trees **<u>usually over 5m</u>** height, with spreading canopy much ravaged by wind & pathogens; **<u>Canopy 50-99% dead</u>** with markedly reduced coning/seed production proportional to loss of canopy	Often [but not always] very open stand with large canopy gaps, with or without recent regeneration	As above sub-class with significant increase in standing deadwood habitat on each tree	**Canopy breakup**
7. Dead	7.1 Standing dead	Three classes as broad indicators of time elapsed since death: 1.Some needles & all bark still on tree [recent dead] 2. >20% bark still on tree, surface of bole hard 3. <20% bark still on tree, surface of bole soft [long dead]	Often degrading fragmented stands of large old trees with significant windthrow; <u>but</u>: includes smaller specimens resulting from competitive exclusion in dense stands <u>and</u>: Steep scree slopes with a mobile substrate where trees have been uprooted	Bio-diversity likely to be high for recently dead trees [bark still on tree] with larger stem diameters, which are more typical of fragmented open stands. Epixylic lichens an important feature of pinewood biodiversity, restricted to decorticate trees. Overall lichen diversity appears to be much higher for dead pines than live ones!	**Death, decay and nutrient cycling**
	7.2 Fallen dead	Three classes as broad indicators of time elapsed since death: 1.Some needles & most [>80%] bark still on tree [recent dead] 2. <80% & >20% bark still on tree, surface of bole hard, even though heartwood may be soft and rotting. 3. <20% bark still on tree, surface of bole usually soft [long dead]			
	7.3 Stumps with no fallen trunk/bole evident	Two classes as broad indicators of past woodland history and management: 1. Stumps from past logging operations [clean cut surface] but in varying stages of decay depending on when cut 2. Torn stumps resulting from wind ”snap” where trunk has either been removed for firewood or completely decayed	Various but typical of open stands of old wide-crowned trees. Where straightest large specimens have been removed for timber		

<u>NOTES</u>: 1. Maturity is defined as the point at which growth starts to slow down significantly. FC Yield class models can provide an approximate guide to minimum DBH at the age of Maximum mean annual volume increment [MAI], the point at which growth begins to slow down. However, these cannot be reliably applied to trees in conditions of environmental stress such as exposure and poor drainage, where maturity may be reached at much smaller size [DBH].

Table 9. Guidance table for determining species of grazing animal present (after Thomson, 2006).

Animal (plus code)	Signs	Dung (droppings)	Tracks and Pathways	Min ht of grazed sward	Browsing characteristics (a)	Bark stripping characteristics (b)	Max ht of (a) and (b)	Comments
Sheep (S)	White wool snagged on fences/ shrubs.	Roundish but angular and irregular shape. Smooth surface, shiny when fresh.	Slots rounded at tips. Broader and more rectangular than for deer.	3cm	Ragged ends to bitten-off shoots which are always eaten.	Occasionally. Young to pole stage trees. Can be severe in seriously over-grazed woods. Diagonal incisor marks.	1.5m	Avoids less palatable species in spring (eg rushes). Impact can be uniformly spread over large areas in most regions.
Goats (G)	Black and white wool snagged on fences.	As for sheep.	As for sheep.	6cm	As for sheep.	Can be severe with small/ medium sized trees/shrubs killed. Diagonal incisor marks.	1.5m	Confined to very few areas. Rocky outcrops/ledges are required for shelter and foraging. Can negotiate most fencing with ease.
Cattle (C)	Trampled tall vegetation. Rubbed trees. Poaching.	Large round pats.	Widely splayed deep slots. Pathways 0.3m wide.	6cm	Roughly torn and pulled up vegetation. Trampled standing areas for ruminating.	Rubbed trees only	2.0m	Are often sheltered in woodlands in winter where poaching of soil surface around supplementary feeding stations can occur.
Ponies/ horses (P)	Trampled vegetation. Rubbed trees. Barked stripped trees.	Coarse fibrous heaps.	Rounded hoof marks. Pathways 0.3m wide.	2cm	Nipped favoured vegetation close to ground. Less woody growth.	Individual trees of any age can be stripped in patches.	2.0m	Rarely found or sheltered in close-canopied woodland.
Roe deer (RO)	Frayed young trees. Hair in barbed wire fencing.	Short blackish cylindrical and pointed at one end. Smooth surface, shiny when fresh.	Well used narrow pathways. Slots pointed and together at tips.	4cm	As for sheep. New bramble and birch shoots favoured.	Rarely strips but frayed stems (ie young bendy trees with bark rubbed off by antlers) frequent on edges.	1.1m	Most likely deer species in the uplands. Impacts may be acceptable where other herbivores absent, due to social spacing.

Animal (plus code)	Signs	Dung (droppings)	Tracks and Pathways	Min ht of grazed sward	Browsing characteristics (a)	Bark stripping characteristics (b)	Max ht of (a) and (b)	Comments
Fallow deer (F)	As for roe, and chewed/ thrashed plastic tree shelters.	As for roe, but larger with striations and less uniform shape for older males.	As for roe, but pointed tips more splayed (seen at wet muddy crossings).	4cm	As for sheep. Bramble leaves in winter, shoots in spring. Ash also favoured.	Young pole sized trees or stools of favoured species. Bark eaten. Vertical incisor marks. Some frayed young trees.	1.8m	Less likely than red or roe in the uplands. Impact may be heavy but variable due to social spacing, use of favoured traditional areas and degree of disturbance.
Red deer (RE)	As for roe and wallows in wet hollows.	As for fallow, but larger and more fibrous and brownish.	As for fallow but more poached pathways in places.	4cm	As for sheep/roe.	As for fallow.	1.8m	Common in some upland regions. Impacts may be uniformly heavy over large areas. Favours wet, boggy woodlands.
Rabbits (R) and hares (H)	Holes, dunging tumps. Very short vegetation in patches.	Roundish and fibrous. Deposited in favoured areas.	Narrow vegetated pathways. Pad marks evident in snow/frost.	1cm	Sharp angled, knife-like cut ends to bitten shoots which can be left uneaten (NB always left uneaten in hares).	Areas of young/medium aged smooth barked trees and shrubs. 3-4mm wide diagonal incisor marks in pairs. Bark patches removed often not eaten.	0.5m	Locally at very high densities on dry, calcareous free draining slopes mostly on the east side of the Pennines.

Table 10. Current Herbivore Impacts (current /recent = since the start of the last growing season). Taken from Armstrong et al. (2014).

Indicator	Very High	High	Medium	Low	No impact
Basal shoots Includes all accessible shoots sprouting from tree bases.	**All species** very heavily browsed. NB. Where large herbivores have been rare or absent in previous years there may be basal shoots that are now too large to browse.	**Palatable species** very heavily browsed. **Unpalatable species** heavily browsed.	**Palatable species** heavily browsed. **Unpalatable species** lightly to moderately browsed.	**Palatable species** lightly to moderately browsed. **Unpalatable species** generally unbrowsed, some lightly browsed.	**All species** unbrowsed.
Epicormic & lower shoots Includes all shoots on tree trunks (epicormic), lower branches or fallen trees that are within reach of herbivores.	A very obvious and well maintained browse-line on all trees, with plenty of evidence of recent browsing to shoot tips. Shoots below the browse-line difficult to find on palatable tree species because they are browsed close to the trunk. Even woody shoots of less palatable species are moderately to heavily browsed.	An obvious browse-line on all trees that have live lower branches with most or all shoot tips browsed. All but the most unpalatable shoots below the browse-line (e.g. old woody birch shoots) moderately to heavily browsed.	A browse-line starting to develop (i.e. evidence of some recent browsing to shoot tips) on most or all tree species. The presence of some unbrowsed lower branches may interrupt the horizontal browse-line. Most shoots below the browse-line lightly browsed with a few browsed moderately to heavily.	Shoot tips within the reach of large herbivores unbrowsed on all but the most palatable tree species.	No sign of *recent* browsing on any live shoots within reach of large herbivores.
Bark stripping & stem breakage dbh = diameter at breast height (1.3 m above ground)	>50% of live stems, and recently fallen branches, showing recent bark stripping that may be severe. One tree species (e.g. rowan) can have all accessible live stems stripped by deer. >50% of live stems of saplings <5 cm dbh may be snapped by cattle and /or red deer.	20-50% of live stems, and recently fallen branches, showing recent bark stripping. One tree species (e.g. rowan) can have all accessible live stems stripped by deer. 20-50% of live stems of saplings <5cm dbh may be snapped by cattle and /or red deer	<20% of live stems, and recently fallen branches, showing signs of recent bark stripping. Sometimes one individual tree is badly bark stripped. <20% live stems of saplings <5 cm dbh may be snapped by cattle and /or red deer. One tree species (e.g. rowan) may be heavily targeted.	Recent bark stripping generally hard to find. There may be one stripped or frayed tree. Occasional stem snapping by cattle and /or red deer.	No recent bark stripping or stems snapped by large herbivores.
Seedlings & saplings Seedlings = <50 cm tall. Saplings = 50-200 cm tall. "Old seedlings" = trees < 50 cm tall that may be many years old but	**"Old seedlings**" very heavily browsed into a topiaried form. Other seedlings, of all species, will only be present if in their first growing season.	**Seedlings** of unpalatable species and all "old seedlings" moderately or heavily browsed. Seedlings of palatable and browse-sensitive	**Seedlings** of unpalatable species unbrowsed or lightly browsed. Those of palatable species moderately or heavily browsed	**Seedlings** of unpalatable species generally unbrowsed but some may be lightly browsed. Seedlings of palatable species generally lightly	Numerous seedlings present provided that there is an adequate seed source, suitable ground conditions, and an absence of very dense

Indicator	Very High	High	Medium	Low	No impact
adverse conditions, usually browsing pressure, prevent them from growing upwards	All will be browsed the following winter. **Saplings** battered by very heavy browsing, with many woody side shoots browsed back or snapped. Leaders of saplings undamaged only if they cannot be reached by herbivores.	species are likely to be absent (apart from possibly first year seedlings in the growing season). If they are present, they will be very heavily browsed. **Saplings** of all species heavily browsed. Leaders of saplings undamaged only if they cannot be reached by herbivores.	**Saplings** of unpalatable species lightly to moderately browsed. Those of palatable species moderately to heavily browsed. Groups of birch, alder and willow saplings may have some unbrowsed leaders. Otherwise, leaders undamaged only if they cannot be reached by herbivores.	browsed but some may be moderately browsed. Most **saplings** of palatable species lightly browsed. Most saplings of unpalatable species unbrowsed.	shading. These will be unbrowsed by large herbivores. **Saplings** of all species (if present) un-browsed.
Preferentially browsed or grazed plants Vegetation other than trees; primarily species listed as "very palatable" in Table 4. Score as "Not applicable" if there are no accessible preferentially browsed or grazed plants can be identified.	All accessible shoots heavily to very heavily browsed /grazed. No unbrowsed accessible runners of palatable species e.g. honeysuckle, bramble. There may be some growth of the current year's shoots in the growing season.	Accessible shoots generally heavily browsed /grazed but some of the most preferred species may be very heavily browsed /grazed. No unbrowsed accessible runners of palatable species e.g. honeysuckle, bramble.	Accessible shoots moderately to heavily browsed /grazed. Some, more preferred, species may be heavily browsed while others are unbrowsed e.g. bramble browsed but blaeberry unbrowsed. No unbrowsed accessible runners of palatable species e.g. honeysuckle, bramble.	Accessible shoots generally lightly browsed /grazed but there may be some shoots or individual species moderately browsed /grazed or unbrowsed /ungrazed. There may be some unbrowsed runners of palatable species e.g. honeysuckle, bramble.	No browsing /grazing on accessible shoots. Depending on the time since large herbivores have been present, there may be long unbrowsed runners /climbers or a dense tangled field layer obscuring views through the wood.
Sward Ground cover vegetation. This may include preferentially grazed species Rank = tall, dense vegetation, sometimes with a well-developed understorey of mosses or herbs. Score as 'Not applicable' if the ground cover is < 5%.	Unpalatable species such as rushes and tussock-forming grasses (e.g. tufted hair-grass, purple moor-grass) heavily grazed. If grazing limited to autumn/winter, unpalatable species may be only lightly grazed. Palatable species very heavily grazed. Flowering herbs of palatable species hug the ground, flower stalks difficult to find.	Unpalatable species moderately grazed. If grazing limited to autumn/winter, unpalatable species may be only lightly grazed. Palatable species heavily grazed. Flowering herbs of palatable species hug the ground, flower stalks difficult to find. In the growing season, spring flowering herbs	If palatable species are abundant, unpalatable species will be ungrazed. If palatable species are rare or absent, unpalatable species will be lightly grazed, except where livestock have been put into the wood at the start of the spring, At this time many unpalatable species are relatively palatable and they may be heavily grazed.	Unpalatable species ungrazed. They may form a rank field layer more than 10 cm tall that shades the ground layer vegetation beneath. Palatable species rarely or lightly grazed.	All sward species ungrazed. There may be a rank and tussocky sward with abundant leaf litter, and /or a high proportion of woody herbs (e.g. bramble) or heathy species in the sward, depending on site characteristics such as soil, exposure and light availability.

Indicator	Very High	High	Medium	Low	No impact
	N.B. In the growing season, spring flowering herbs may be ungrazed even where winter impacts were very high.	may be ungrazed even where winter impacts were high.	Palatable species moderately grazed.		
Ground disturbance Animal disturbance = trampling, pathways or wallows. Score as "Not applicable" if the ground is composed of boulders or scree. N.B. plant litter is very quickly mineralised in moist, very rich woodlands and soil may be bare in spring. The lack of vegetation in these cases is not due to animal disturbance.	**Wet ground** >75% devoid of vegetation due to animal disturbance. **Dry ground**: > 50% devoid of vegetation due to animal disturbance. Where deer are the main herbivore, disturbance may take the form of frequent wide, heavily used pathways and /or, on wet, open ground, there may be kicked out clods of turf and *Sphagnum* and well-defined deer wallows.	**Wet ground**: >50% devoid of vegetation due to animal disturbance **Dry ground**: 20-50% devoid of vegetation due to animal disturbance. There may be heavier disturbance around feeding areas and pig shelters. . Where deer are the main herbivore, disturbance may take the form of frequent pathways that are partially or wholly unvegetated.	**Wet ground:** 10-50% devoid of vegetation due to animal disturbance.. **Dry ground**: 10-20% devoid of vegetation due to animal disturbance. There may be heavier disturbance around feeding areas and pig shelters. Where deer are the main herbivore, disturbance may take the form of occasional pathways.	Occasional areas of ground devoid of vegetation due to animal disturbance. There may be heavier disturbance around feeding areas and pig shelters. Where deer are the main herbivore, disturbance may take the form of occasional pathways.	No areas of ground devoid of vegetation due to animal disturbance.

Score as *"Not applicable"* if there are none of the attributes available for assessment, i.e. no basal shoots or epicormic shoots or no stems suitable for bark fraying, etc.

Table 11. Guide to Browsing Rates

Variable	Very Heavy	Heavy	Moderate	Light
Browsing on tree basal shoots Estimate % of current shoot growth removed based on the ratio of shoot diameter to length.	> 90% of the current year's growth removed. Short stubby stems, difficult to see on some species. Most older woody shoots browsed.	50% -90% of the current year's growth removed. Some older, woody shoots browsed.	10% -50% of the current year's growth removed. No older, woody shoots browsed.	<10% of the current year's growth (only shoot tips) removed.
Browsing on other tree shoots i.e. seedlings/saplings, epicormics, lower branches.	All outer shoots removed (including many old, woody shoots) and remaining growth old and woody with short internodes.	>80% of the current year's growth removed. Older, woody growth removed from some shoots	30-80% of the current year's growth removed. Older, woody growth removed from some shoots	<30% of the current year's growth removed
Browsing /grazing on preferred plants and sward	All of leading shoots browsed or leaves grazed.	>75% of leading shoots browsed or leaves grazed	25-75% of leading shoots browsed or leaves grazed	<25% of leading shoots browsed or leaves grazed.

Table 12. Relative palatability of non-tree plants (herbaceous perennials and small woody perennials)

Season	Very palatable	Moderately palatable	Unpalatable
All year	bramble, honeysuckle, ivy, blaeberry, **greater woodrush,** common bent, red fescue, Yorkshire fog	*hard fern, b*og myrtle, heather (ling), bell heather, sheep's fescue	hard fern, greater woodrush, purple moor-grass, mat grass, tufted hair-grass, soft and sharp-flowered rush, cross-leaved heath
Spring - Summer	As above. In addition: valerian, meadowsweet, angelica, dog's mercury, raspberry, *buckler ferns*	devil's-bit scabious, **purple moor-grass, soft and sharp-flowered rush,** *lemon-scented fern, lady fern*	buckler ferns, lemon-scented fern, lady fern, primrose

***bold = cattle only**, *italics* = *deer only*, Normal font = all other large herbivore species. More detailed information can be found http://scotland.forestry.gov.uk/woodland-grazing-toolbox/habitat-condition/assessing-habitat-condition/palatability

Table 13. Palatability of key field layer species.

Taken from http://scotland.forestry.gov.uk/woodland-grazing-toolbox/habitat-condition/assessing-habitat-condition/palatability

Palatability of key field layer species - Ground layer and small field layer herbs			
Species	**Latin name**	**Palatability**	**Comments**
Dog's mercury	*Mercurialis*	High	Particularly attractive to sheep. May remain untouched by deer
Devil's-bit scabious	*Succisa pratensis*	Medium	
Heath bedstraw	*Galium saxatile*	Low	A species of low palatability, heath bedstraw is often the first species to assert itself through abundant flowering following the fencing out of large herbivores
Tormentil	*Potentilla erecta*	Low	
Primrose	*Primula vulgaris*	Low	
Bluebell	*Hycainthoides non-scripta*	Low	High for muntjac deer
Wood sorrel	*Oxalis acetosella*	Low	

Palatability of key field layer species - Ferns			
Species	**Latin name**	**Palatability**	**Comments**
Buckler ferns	*Dryopteris sp*	Medium	High for deer in the spring
Lady fern	*Athyrium felix-femina*	Medium	
Lemon scented fern	*Oreopteris limbosperma*	Medium	
Hard fern	*Blechnum spicant*	Low	Moderately palatable for deer. May be relatively more palatable on nutrient-poor soils
Bracken	*Pteridium aquilinum*	Low	Bracken is toxic, especially to cattle, but young fronds may be browsed in late spring

All species of moss and lichen are of very low palatability.

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