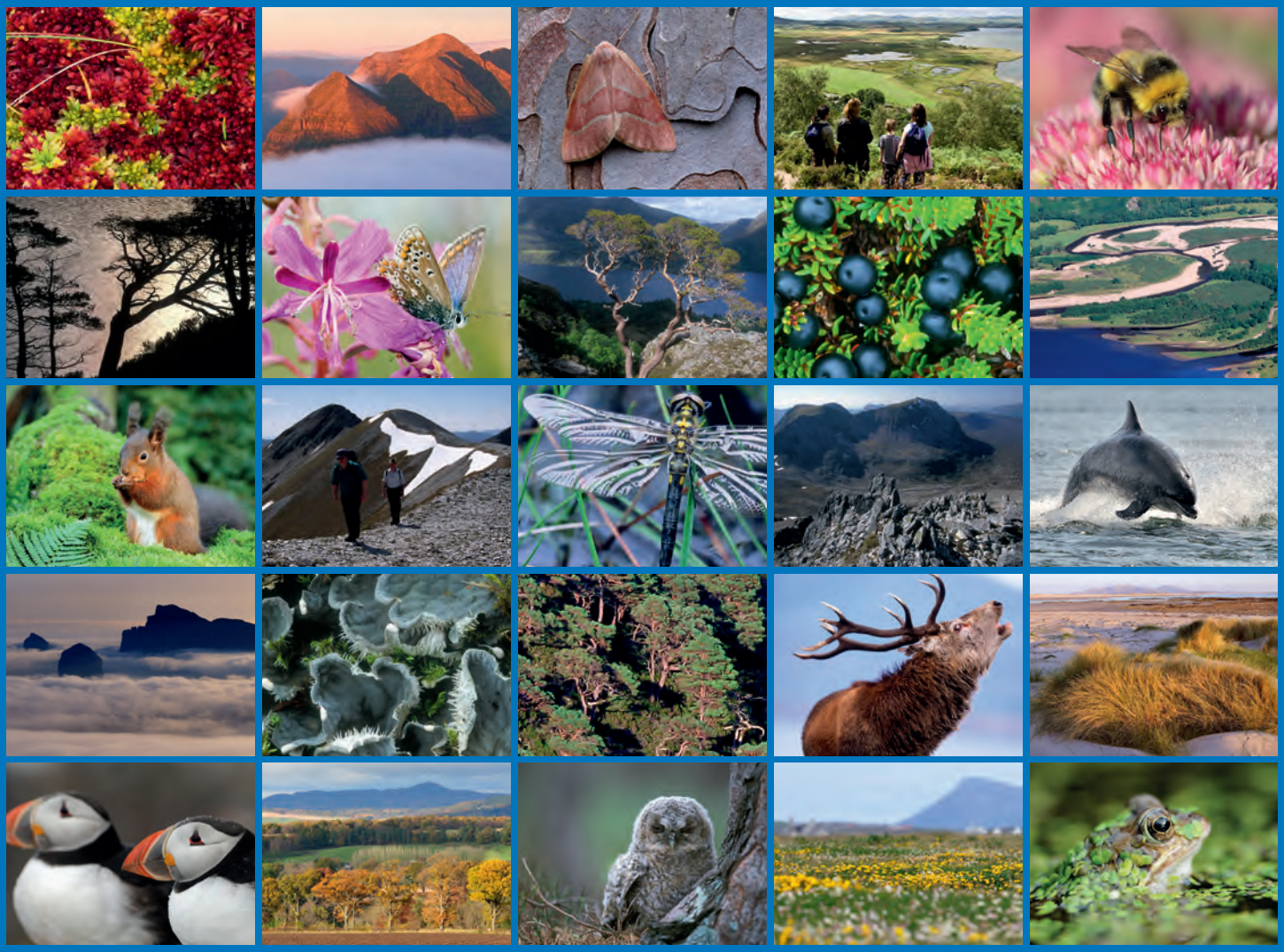
Scottish Natural Heritage
Research Report No. 1182

A woodland profile survey and assessment of herbivore impacts within the East Loch Shiel Deer Management Group part of the Sunart 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 East Loch Shiel Deer Management Group part of the Sunart Site of Special Scientific Interest (SSSI)

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Keywords

Sunart SAC; oak woodland; Lochaber; herbivore impact assessment; East Loch Shiel DMG.

Background

The upland oak woodland habitat within the Sunart 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

The diameter of all species of tree within 84 sample plots chosen at random throughout the protected area was measured in April and May 2018. A total of 3.73 ha of woodland were surveyed for mature trees and 3.41 ha for seedlings and saplings. The numbers of browsed and un-browsed seedlings and saplings, both small and large, were counted in the same plots. A total of 1,171 live trees with a diameter of at least 5 cm and 213 dead trees were measured. A total of 6,372 seedlings and 1,165 saplings were counted. The main findings are as follows:

- The woodland has an overall density of 313 live trees per ha. Seedling densities are on average 1,834 – 1,904 per ha, but there is a high degree of spatial variation in density with the inter-quartile range being from 351 to 2,772 seedlings per ha. Densities of all small and large saplings are lower at 260 and 82 stems per ha, respectively.
- Although sessile oaks dominate the canopy layer (82%) of the woodland they make up only 51% of all the live trees. Downy birch is the second most abundant species of tree making up 41% of live tree stems more than 5 cm in diameter. Collectively rowan, holly, hazel, various willows, ash and alder make up only 8% of the stems of live trees.
- Seedlings of sessile oak were present, but at lower densities (18/ha) than the mature (42/ha) and over-mature (96/ha) life-classes of sessile oak. Only one small sapling and no large saplings of sessile oak were found. Browsing levels on oak seedlings were high at 70%.

- The population of downy birch is moderately healthy with its seedlings at higher densities (348/ha) than the small saplings (177/ha) and large saplings (58/ha) or mature trees (39/ha). Recruitment of seedlings and saplings is, however, spatially very variable and there no birch seedlings in 34 of the 84 sample plots.
- Rowan had the highest densities of seedlings (1,291 – 1,341/ha), but the small and large saplings are at much lower densities (47 and 11 per ha). This is a consequence of the browsing levels on seedlings and small saplings being high at 68% and 31%, respectively.
- Shading by trees is probably only a factor in inhibiting saplings from developing into young reproductive trees across less than 10% of the woodland, as the basal area of trees more than 5 cm in diameter was only greater than 34 m2 per ha in five of the 84 sample plots.
- The sessile oak population is currently not regenerating due primarily to the high levels of browsing.
- The internationally important assemblage of species of lichen, moss and liverwort that grow on the trunks and branches of the large oak trees is, therefore, in potential danger of being depleted in the long term due to the inevitable death and loss of the older larger trees in the long-term.
- Browsing by deer, and to a much lesser extent by cattle, are the only plausible causal factors for the current poor levels of regeneration and recruitment in the sessile oak, rowan, holly and hazel populations.

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Nomenclature

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

1. INTRODUCTION

The Sunart Site of Special Scientific Interest (SSSI) is located around the north and south shores of Loch Sunart which is between the Morvern and Ardnamurchan Peninsulas in the west Lochaber district of the Highland region of Scotland (Figure 1). The Sunart SSSI is listed for a wide variety of features:

- Blanket bog
- Bryophyte assemblage
- Caledonian Igneous
- Chequered skipper (*Carterocephals palaemon*)
- Dragonfly assemblage
- Eelgrass beds
- Lichen assemblage
- Moine
- Moths
- Otter (*Lutra lutra*)
- Saltmarsh
- Tertiary Igneous
- Upland assemblage
- Upland oak woodland
- Vascular plant assemblage

The whole of the SSSI covers 5540.16 ha of which 1,647 ha is upland oak woodland. All but a small area of the SSSI at the eastern end in Glen Tarbert lies within the Sunart Special Area of Conservation (SAC). The Sunart SAC is listed primarily for its Western acidic oak woodland, but the other features for which it has been designated are:

- mixed woodland on base-rich soils associated with rocky slopes;
- wet heathland with cross-leaved heath
- dry heaths;
- reefs; and
- otter.

The Conservation Objectives for the Sunart SAC are to ensure that the following are maintained in the long term:

- Extent of the habitat on site
- Distribution of the habitat within site
- Structure and function of the habitat
- Processes supporting the habitat
- Distribution of typical species of the habitat
- Viability of typical species as components of the habitat
- No significant disturbance of typical species of the habitat

In the last assessment of the condition of the upland oak woodland habitat in November 2009, it was assessed to be in ‘unfavourable no change’ condition. The condition assessment identified over-grazing and the presence of invasive non-native species (*Rhododendron ponticum*) 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 for the SSSI woodland feature lists the following actions that need to take place in order that the woodland can be restored to favourable condition:

- removal of rhododendron and subsequent control of regrowth or seedlings;
- maintain a balance of deer grazing to allow for natural regeneration without the formation of an unduly thick understory;
- encourage the expansion of new native woodland onto appropriate ground around the existing woodland, using natural regeneration where possible or by appropriate planting;
- improving the structure of the woodland by increasing the proportion of saplings and mature trees present for all native species, increasing the quantities of dead wood which is present, and retaining open glades;
- safeguarding against fire damage.

The non-vascular plant features (bryophytes and lichens) for the SSSI are also in unfavourable condition and are dependent on the woodland habitat. The Site Management Statement for the non-vascular plant features within the SSSI also state that:

- the structure of the woodland habitat needs to be maintained or improved;
- the control of regeneration of non-native species (rhododendron) needs to be carried out to improve the condition of the lichen feature.

1.1 Aims

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, including seedlings and saplings, 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 may be resulting in any lack of regeneration in the population of trees. The survey will also identify the presence of rhododendron and whether deer exclosure are having the desired effect in allowing tree regeneration and structure of the woodland habitat.

2. METHODS

2.1 Woodland profile

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 a 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 girth of the trees at a standardised height (1.3 m above the ground). Trees can also be placed into different life-classes by their size, shape and proportion of dead branches (Clifford *et al.*, 2004). The life-classes do not relate directly to the age of the trees, but gives a descriptive indication of the stage in the trees life-history and these 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

2.2 Sampling strategy

Approximately 0.6% of the upland oak woodland habitat was sampled across the whole of the Sunart SSSI by taking a total of 212 plots, of which 84 were within the area covered by the East Loch Shiel DMG. 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. This map shows which plots are within deer exclosures, but some of these fences are no longer effective in keeping red deer out of the ground enclosed.

2.3 Field survey

2.3.1 Woodland profile

The survey was carried out between the 15th April and 31st May, with the vast majority surveyed between the 10th and 13th May. The surveyors navigated their way to the sample plot locations using maps and hand-held GPS receivers (typically Garmin GS12s). No sample plots had to be discarded due to problems of access, but a number had to be moved a certain distance so that they were accessed safely. In every instance the grid reference at the centre of the plot was recorded. The centre of the plot was marked with a wooden post with a numbered tag. Sixty four of the sample plots were within 10 metres of the given grid reference, i.e. within the margin of error for single hand-held GPS receivers working within woodland.

Seventeen plots were between 10 and 20 metres of the grid reference supplied and three plots were between 20 and 24 from the grid reference.

At nearly all of the plots all trees, seedlings and saplings within a 25.2 metre diameter plot centred on the central post was used. 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. Therefore, 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 20 plots (S2, S32, S61, S62, S76, S95, S97, S100, S102, S111, S121, S122, S124, S138, S148, S157, S159, S202, S210 and S211). In some instances it was found necessary to give ranges in the numbers of seedlings or saplings that were unbrowsed and browsed where the numbers exceeded 100 individuals in a plot.

The plot size was reduced for counting and measuring trees at plots S61, S62, S76, S100, S102, S121, S122, S124, S138, S148, S159 and S210. This was done because either the densities of the pole stage trees was very high or because the plot size was reduced to keep within a fence line or because of an inaccessible crag being present.

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

2.3.2 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.

As several plots did not have any seedlings or saplings to assess the levels of browsing, the levels of browsing on basal shoots, epicormic shoots and preferentially browsed species 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. For instance, early in the season where purple moor-grass (*Molinia caerulea*) had not started to grow, but dominated the sward it was not possible to assess the levels of grazing on the sward.

2.3.3 Quality control

Before the assessment was started Dr Headley spent at least one day with each of the other field surveyors (Tom Edwards and Fraser Milne) 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 and 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. Data was checked for consistency and errors corrected. For example standing and lying dead trees in plot S118 were incorrectly placed in life-classes 6.1 and 6.2. Four large saplings were included in the calculation of basal areas and the density of small trees as they had dbh values of 7 or more, but were included in the calculation of large sapling densities.

2.4 Data analysis

2.4.1 Calculation of age-structure

Where ranges in the numbers of individuals of seedlings or saplings were given for a plot, the mid-point value of the range was used to calculate the density of seedlings or saplings for that individual plot. However, the upper and lower values were used to calculate a range in seedling and sapling densities for the population of the species as a whole.

The numbers of individual trees in each life-class were totalled for each species and then divided by the total area of the plots surveyed (3.73 ha for trees and 3.41 ha for seedlings and saplings) to obtain the number of stems 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

A minimum diameter of 5 cm was used for small trees as two trees in the pole stage life-class 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.

2.4.2 Calculation of browsing impacts

The calculation of levels of browsing on seedlings and saplings was a simple calculation of the proportions where there were absolute numbers, but where there were ranges the upper and lower values were used to calculate a range in the percentage of the seedlings or saplings that were browsed.

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.

2.4.3 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 and densities of trees, seedlings and saplings

A total of 1,171 live tree were counted and measured across the 3.73 ha of ground within the 84 plots surveyed. This gives an overall density of 314 live trees per ha. Two plots (S32 and S55) had no live trees within them. One or more seedlings were found in all but two of the 84 sample plots, but small and large saplings were only found in 54 and 30 plots, respectively. A total of 6,252 to 6,492 seedlings and 1,155 to 1,175 saplings were counted giving overall densities of 1,834 - 1,904 seedlings per ha, 258 - 261 small saplings per ha and 81 - 84 large saplings per ha (Table 1).

A total of 161 standing dead trees were measured as well as 37 fallen dead trees and 15 dead tree stumps. The overall density of dead trees was 57 stems per ha (Table 1).

3.2 Species composition

Although there were more rowan (*Sorbus aucuparia*) plants per ha than any other species downy birch (*Betula pubescens*) and sessile oak (*Quercus petraea*) had the highest densities of live trees (Table 1). Of the 1,171 live trees recorded in this survey 53% were of sessile oak and 40% were of downy birch. Other species making up the tree canopy in this survey were hazel (3.6%), holly (0.6%), ash (0.3%), alder (0.2%), unassigned species of willow (0.9%), eared sallow (0.5%) and goat willow (0.1%). The unassigned species of willow was probably grey willow, but because of when the survey was carried out and because of hybridisation in willows being commonplace, it was not possible to assign the bushes to a particular species with any certainty. Beech, Sitka spruce and Norway spruce were also present, but only as seedlings and/or saplings.

3.3 Woodland structure

For any self-sustaining population of plants or animals to be viable it has to produce more offspring than adults and young plants must reach reproductive age at least as quickly as older plants are dying (Begon *et al*., 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 data on the densities of all plants in each of the life-classes shown in Figure 3 approximates to the inverted J-shaped curve (Figure 3). What is striking is that tree seedling densities are much higher than for any other life-class. Although there is a higher density of mature and over-mature trees than either of the pole stage and young reproductive trees. However, the pole stage and young reproductive trees are effectively at the same stage in their life-cycle, but with a different spatial patterning (Figure 3 and Table 1). Therefore, the combined density of these two life-classes is close to that of mature trees at 90.6 trees per ha (Figure 3).

There are, however, very significant differences between the species in the number of plants in the different life-classes (Figure 4). The population of downy birch has a typical distribution of plants in the different life-classes for a self-sustaining population of trees with decreasing densities of plants with each successive increase in life-class from seedling to over-mature trees (Figure 4 and Table 1).

Populations of rowan and holly are similar in that there are very high densities of seedlings, but there are very few trees in any particular life-class (Table 1). For holly there are very few large saplings or mature trees and is also dominate by seedlings (Figure 4). There is obviously a plentiful supply of rowan and holly seeds but there are very few mature trees producing berries.

In contrast the sessile oak population is dominated by mature and over-mature trees with a significant number of dead trees as well (Figure 4 and Table 1). No large saplings of sessile oak were found in this survey and the combined densities of pole stage and young reproductive trees amounted to only 1.3 stems per ha, which is much lower than that of mature and over-mature trees (Table 1).

As with sessile oak there were very few large saplings of hazel. Some care needs to be used in interpreting the densities of hazel stem densities as this tree naturally coppices, and therefore the numbers of plants may be significantly lower than the data indicates.

The densities of large saplings of Sitka spruce were the second highest after downy birch (Table 1). There appears to be little problem for Sitka spruce seedlings and small saplings in regenerating as far as the large sapling stage.

Although ash trees were at very low densities there is some regeneration of this species with densities of seedlings and small saplings being 10 and 8 stems per ha (Table 1).

For the willows, alder, beech and Norway spruce there were too few individuals to make any sensible comments on the distribution of plants in the different life-classes.

There are too many plots too close together to clearly show the life-class distribution for each plot across the whole area on a single map. The comparison of individual plots in such a way is also not appropriate as there will be inherent spatial variation in the number of trees in different life-classes as different areas of woodland go through regeneration cycles. Therefore, the data is presented for each life-class separately on the map of the SSSI.

Plots with low seedling densities were scattered throughout the area surveyed, but they were especially frequent within the Ariundle NNR in the east of the survey area (Figure 5). The sample plots with moderately high densities of seedlings, in the region of 2,000 to 10,000 per ha, were present in the centre of the survey area between Resipole and Chamuschoirk (Figure 5). The areas with the highest densities of seedlings tended to be those with the highest densities of rowan seedlings (Figure 6). Sixty percent of the plots had some birch seedlings, but those with high densities were relatively infrequent and scattered throughout the survey area (Figure 7). Seedlings of holly were also relatively frequent (58% of plots) and they were at relatively high densities in the central part of the survey area near Chamuschoirk (Figure 8). Oak and hazel seedlings were rarer with seedlings being present in only 19 and 23% of the sample plots, respectively. Only three plots had oak seedling densities above 100 per ha and they were widely scattered throughout the area (Figure 9). The plots with the highest hazel seedlings densities (more than 250 per ha) were also widely scattered (Figure 10).

One or more small saplings of any species of tree were found in 64% of the sample plots and those plots with few or no small saplings were most frequent in the centre of the survey area (Figure 11). The Ariundle NNR had the highest densities of small saplings (Figure 11). Many of the plots with the highest densities of small saplings were those with high densities of rowan or downy birch saplings (Figure 11). Most of the plots within the Ariundle NNR have higher densities of small saplings of downy birch and hazel, but a few of the sample plots scattered across the rest of the survey area had even higher densities of small downy birch saplings (Figure 11). The only plot where at least one sessile oak sapling was found was an un-browsed small sapling in plot (S211) towards the north-eastern end of the Ariundle NNR.

At least one large sapling was found in 36% of the 84 sample plots and the inter-quartile range of densities were from 0 to 60 stems per ha (Table 2). The plots with the highest densities of large saplings were in the Ariundle NNR and at the western end of the survey area near Salen (Figure 12). Large rowan saplings are largely restricted to the Ariundle NNR whilst large saplings of downy birch were found in one or more sample plots throughout the survey area

(Figures 12). An unusually high density (3,756 per ha) of large Sitka spruce saplings were found in plot S122, which is located between Resipole and Salen.

Pole stage trees were found in 42% of the sample plots and in the main they were at their highest density within the Ariundle NNR (Figure 13). Young reproductive trees were present in 27% of the sample plots and some were present in most parts of the survey area (Figure 13). Only five plots had densities of young reproductive trees above 100 per ha.

Mature trees were present in 74% of the plots and the inter-quartile range in the density of mature trees was between 0 and 120 per ha (Table 2). The sample plots with the highest density of mature trees were towards the west of the survey near Salen and at the south-western end of the Ariundle NNR (Figure 14). Over-mature trees were, however, most abundant and frequent in the central part of the survey area around Ceol na Mara and Chamuschoirk (Figure 14). Over-mature trees were present in 80% of the sample plots and were at a similar density to the mature trees (Table 2).

Senescent and “phoenix” trees are at much lower frequencies, 51% and 14% of plots respectively, and at lower densities than for mature and over-mature trees (Table 2). Senescent trees were found in most parts of the survey area, but they were at their highest densities in the central area near Ceol na Mara (Figure 15). There were only five plots where there were more than 50 “phoenix” trees per ha and three of them were located at the north-eastern end of the Ariundle oakwood (Figure 15).

One or more dead trees were found in 67% of the sample plots and the median density was 20 per ha (Table 2). A large proportion, 65%, of the dead trees were of sessile oak. The inter-quartile range in diameter of the dead oak trees was not particular large as it was from 15 to 25 cm. Dead trees were found throughout the survey area and were not concentrated in any particular area (Figure 16).

3.4 Size/age distribution

The population of sessile oaks within the Sunart SSSI has a higher density of medium trees (diameter 25 to 40 cm at 1.3m above the ground (dbh)) than small (dbh = 7 to 25 cm) or large (dbh = 40 to 55 cm) trees (Table 3 and Figure 17). The absolute densities of sessile oak trees are moderate, with a mean density of 164 stems per ha and the highest density of 609 stems per ha observed in plots S102 (Table 2). The near complete lack of small and large saplings means that there is no effective regeneration of the oak tree population (Figure 17).

The downy birch population is dominated by seedlings and small trees (Figure 18). Not surprisingly there are very few large or very large (dbh > 55cm) birch trees (Figure 18). There is no obvious spatial pattern in the distribution of birch seedlings or trees and the plots with the highest densities of birch seedlings do not always have the high densities of live birch trees (Figure 19).

Although there are very large numbers of rowan seedlings only 3.4% get to the small sapling stage and only 23% of small saplings get to the large sapling stage (Figure 20). Consequently the cohort of small rowan trees is only 0.3% of the cohort of seedlings. There was no relationship between the densities of rowan seedlings or saplings and the presence or absence of a mature rowan tree.

The size structure of the hazel population looks to be moderately healthy, but the densities of small and medium sized trees are rather low for an upland oak woodland and there are very few large saplings (Figure 21).

3.5 Basal area

The amount of canopy cover produced by mature trees and therefore the amount of shading shows a strong positive relationship to the area of ground covered by the stem bases of these trees, also known as basal area. The median basal area across the 25 plots is 20.1 m^2 per ha and the inter-quartile range is between 14 and 28 m^2 per ha. This represents 0.2% of the ground occupied by the trunks of trees. Out of the 84 plots surveyed only two plots (S32 and S55) had no live stems with a diameter greater than 5 cm.

Sessile oak accounts for 81% of the total basal area of live trees measured with downy birch making up the vast majority (88%) of the remaining 3.935 m^2 per ha of live basal area (Table 4). Taken together ash, hazel, rowan, holly, willows and alder account for less than 1% of the basal area of all live trees (Table 4). Most of the basal area is taken up by over-mature sessile oak trees (Table 4). The plots where the basal areas were greater than 25 m^2 per ha were found in the central part of the Ariundle oakwood NNR or in the area near Ceol na Mara and Camuschoirk (Figure 22). The highest densities of downy birch seedlings and small saplings were in a plot with a basal area of 34 m^2 per ha (Figure 23). Therefore, even at this level of shading it does not appear to be inhibiting the regeneration of this most light demanding species of tree. Only five plots have basal areas more than 34 m^2 per ha.

3.6 Herbivore impacts

Browsing levels on seedlings, small saplings and large saplings across all the species were 68 to 72%, 27 to 28% and 5%, respectively (Table 5). Levels of browsing on seedlings and saplings of Sitka spruce were significantly lower than those on the deciduous species of tree (Table 5). Browsing of small saplings of downy birch was also much lower than for the small saplings of other species, except for ash (Table 5). Browsing levels on seedlings of sessile oak (70%) are higher than those on downy birch (61 to 67%), but not as high as that observed on holly (99%), hazel (97%), beech (100%) and willow (100%) seedlings.

When the browsing levels are analysed across individual plots the inter-quartile range for browsing on seedlings was between 52 and 100% with the median browsing level being 91%. There are high levels of browsing on seedlings throughout the survey area, except for the deer exclosure within the Ariundle NNR and the area by the A861 to the east of Camuschoirk (Figure 24). The median browsing level on small saplings was 24% and the inter-quartile range is between 0 and 74%.

Browsing levels on epicormic and basal shoots could not be assessed in the majority of sample plots because they were absent and for many 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 vary considerably between different indicators, but the levels of browsing/grazing were generally highest on the seedlings and saplings and preferentially grazed species (Table 6). Fraying and bark stripping on seedlings and sapling was very rarely observed. Overall the levels of browsing/grazing were either in the High, Moderate or Low categories with High impacts being the most frequent (Table 6).

Most of the sample plots within the deer exclosure at the north-eastern end of Ariundle NNR and the one near Salen at the far western end of the survey area have Low overall herbivore impacts (Figures 2 and 26). Although plots within deer exclosures tend to have Low overall herbivore impacts some of the plots outside deer exclosures also have Low herbivore impacts, especially those immediately to the east of Camuschoirk (Figure 27).

3.7 Herbivores

The large herbivores that were observed during the survey within the Sunart SSSI that are resulting in most of the browsing impacts on the tree seedlings and/or saplings are deer (roe and red). No sheep were observed in the area, but cattle do graze inside the woodland at Resipole.

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.

3.8 Potential for tree regeneration

All areas of the Sunart 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 relatively few 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.

3.9 Invasive non-native species

Currently the non-native *Rhododendron ponticum* observed in plots S97 and S196 is not particularly extensive, but this species is widespread and is preventing the regeneration of native broad-leaved species in other parts of the woodland. It must be remembered that the 84 sample plots surveyed covered less than 1% of the broad-leaved woodland within the Sunart SSSI, and therefore this survey cannot necessarily give an accurate estimate of the amount of the woodland affected by this invasive non-native species at a target threshold of less than 1% of the woodland being affected.

Sitka spruce and Norway spruce are also non-native species and these species of tree were found in 14 and 1 plot, respectively. There may be a need to control the Sitka spruce at some stage in the future before the large saplings become seed bearing trees.

4. DISCUSSION

4.1 Viability of typical tree species

In order that the Sunart 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.

The sessile oak population has an unsustainable population structure as the sapling generations are virtually absent or at exceedingly low density (Figure 17). The density of oak seedlings was also very low and lower than that of the mature tree cohort. Therefore, the population of mature and over-mature sessile oak trees cannot effectively be replaced.

In contrast to sessile oak, the downy birch population appears to be viable as there are higher densities of seedlings and small and large saplings than mature trees (Table 1).

The population of rowans is dominated by seedlings and very few of the saplings are getting through to be young reproductive or mature trees (Table 1 and Figure 20). Similarly holly is also not viable due to virtually none of the holly seedlings surviving through to the large sapling or young reproductive tree stage.

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 can 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.

Targets 2, 4, 7 and 8 are satisfied. In terms of target 5 both criteria are met as 43 standing dead stems per ha were counted in this survey and there were 24 fallen lying trees with diameters more than 20 cm. This gives a density of 6.4 fallen lying stems per ha in this size category.

Target 1 is only satisfied in that large saplings (3 to 5 metres tall) were present in 36% of the sample plots, but the understorey cover is well below 20% and probably only amounts to a few percent.

Downy birch satisfies target 3 listed above as there are seedling, saplings and mature trees present for this species. However, sessile oak is largely lacking the sapling and young

reproductive/pole stage generations. These two species are the commonest trees in the Sunart SSSI upland oak woodland habitat and therefore target 3 is not reached.

Target 6 may well be satisfied in that the canopy density will probably be maintained over the next 10 years despite the fact that insufficient numbers of seedlings are managing to grow through to young trees at present to maintain the woodland structure.

4.3 Site Management Statement

It is possible to make comments on some of the targets in the Site Management Statement. This includes rhododendron, which was found to be present in two sample plots (S97 and S196) near Bunalteachan (Figure 2). Rhododendron is frequent along the side of the A861 in this general area.

The balance of deer grazing to allow natural regeneration is not being met as browsing by deer (roe and red) is preventing adequate regeneration of sessile oak, holly, rowan and hazel. Neither is the aim of increasing the proportion of saplings of native species of tree being met. The aim of having sufficient dead wood is certainly been achieved within this part of the Sunart SSSI as a whole.

It is not possible to comment on the extent of woodland habitat within the Sunart SSSI and whether native woodland is expanding onto appropriate ground around the existing woodland habitat.

4.4 Reasons for lack of regeneration

The median diameter of all the live sessile oak trees measured was 32cm. Assuming a typical annual radial growth rate of 1 to 2 mm per annum, the majority (inter-quartile range) of the trees (24 to 41 cm diameter) were established between about 120 and 205 years ago (Büyüksair *et al.*, 2018). Therefore, the sessile oak population was probably mainly established during the peak of the Highland clearances in the nineteenth century when red and roe deer numbers were also 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 and may vary throughout the SSSI.

The lack of oak seedlings observed in this survey cannot be attributed to them being overlooked as the majority of 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 (Jarvis, 1964; Březina & Dobrovolný, 2011). High levels of browsing on the small number of seedlings available in winter are a likely factor contributing to the absence of saplings. The low density of seedlings could also be due to either insufficient acorn production and/or predation of the acorns by voles, squirrels and various species of bird (Shaw, 1968). The presence of a large number of over-mature, senescent and phoenix trees in the population is likely to contribute to a low acorn production. When there is a low supply of acorns the predation of the acorns will be a more important factor in resulting in the low recruitment of seedlings (Shaw, 1968).

The downy birch population within the Sunart SSSI has a less than perfect inverted J-shaped frequency-size/age distribution curve (Figure 18). The cohorts of seedlings and saplings are at lower densities than the generation of small trees (dbh 5 to 25 cm). As birch is a prolific producer of wind dispersed seeds, seed availability is unlikely to be limiting. It is more likely that niches for seedling establishment are more likely to be limiting its regeneration. The apparent survival rates of downy birch seedlings to the sapling stage are relatively good at 51% and the densities of large saplings are 33% of that of small saplings (Table 5).

Browsing by deer is almost certainly limiting the regeneration of rowan, holly and hazel as well as the sessile oak population. This is indicated by the very poor apparent survival rate of rowan (3-4%) and holly (2%) seedlings through to the small sapling stage. Most of the mortality of hazel plants appears to be between the small and large sapling stages (91%) rather than at the seedling stage (50%).

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 can apparently 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 the fact that the maximum density of downy birch seedlings and small saplings was found in a sample plot with a basal area of 34 m^2 per ha, suggests that significant shading does not occur in this type of deciduous woodland up to basal areas of around 34 m^2 per ha (Figure 23). Out of the 84 plots surveyed 30 plots had basal areas greater than 25 m^2 ha^{-1} and only five plots had basal areas above 34 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 sessile oak, downy birch, rowan, hazel and holly within the woodland habitat at Sunart 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).

4.5 Prognosis

If current levels of browsing continue, the dominance of the woodland canopy by oak 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 one dominated by large over-mature sessile oak trees to one dominated by downy birch. The maintenance of a healthy population of large oak trees is important for this SSSI. This is because the upland oak woodland on the Atlantic seaboard of Scotland are internationally important for their epiphytic lichen and bryophyte communities and unlike large oak trees, birch trees do not provide the correct niches to support these support communities. Although hazel, ash and rowan can also support the epiphytic lichen and bryophyte communities, they are much rarer and are also preferentially browsed by deer.

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

- Taken as a whole the age structure of the Sunart SSSI that lies within the East Loch Shiel DMG is poor, due to a low number of large saplings, pole stage and young reproductive trees.
- More younger trees of sessile oak are needed to replace the ageing and dying population of sessile oak trees.
- Browsing by deer is largely responsible for the low survival of sessile oak, rowan, hazel and holly seedlings through to the small and large sapling stages.
- Although browsing by deer is probably the most important factor responsible for the lack of regeneration of sessile oak, low densities of seedlings in certain parts of the woodland habitat may be due to poor acorn production by the ageing/senescing oak trees in the area.
- If nothing is done to encourage an increase in the regeneration of sessile oak, and other preferentially browsed tree species, the woodland will gradually change to a purely birchwood and if deer as well as cattle are not excluded or the numbers reduced significantly 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.

6. REFERENCES

Annighöfer, P., Beckschäfer, P., Vor, T. & Ammer, C. 2015. Regeneration patterns of European oak species (*Quercus petraea* (Matt.) Liebl., *Quercus robur* L.) in dependence of environment and neighbourhood. *PLoS ONE*, 10(8): e0134935.

Armstrong, H., Black, B., Holl, K. & Thompson, R. 2014. Assessing herbivore impact in woodlands: a subjective method. Forestry Commission, Edinburgh.

Begon, M., Townsend, C.R. & Harper, J.L. 2006. Ecology: From Individuals to Ecosystems. 4th edition. Blackwell Publishing, Oxford.

Beaumont, D.J., Dugan, D., Evans, G. & Taylor, S. 1995. Deer management and tree regeneration in the RSPB reserve at Abernethy Forest. *Scottish Forestry,* July 1995, letters.

Březina, I. & Dobrovolný, L. 2011. Natural regeneration of sessile oak under different light conditions. *Journal of Forest Science*, 57(8), 359-368.

Büyüksair, U., As, N. & Dündar, T. 2018. Intra-ring properties of earlywood and latewood sections of sessile oak (*Quercus petraea*) wood. *Bioresources*, 13(1), 836-845.

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

Edwards, C. & Mason, W.L. 2006. Stand structure and dynamics of four native Scots pine (*Pinus sylvestris* L.) woodlands in northern Scotland. *Forestry*, 79(3), 261-277.

Forestry Commission, n.d. Woodland grazing toolbox: Relative palatability and resilience of native tree seedlings and saplings to browsing. Available at: https://forestry.gov.scot/woodland-grazing-toolbox/grazing-management/foraging/palatability-and-resilience-of-native-trees#

Gao, W.Q., Ni, Y.Y., Zue, Z.M., Wang, X.F., Kang, F.F., Hu, J., Gao, Z.H., Jiang, Z.P. & Liu, J.F. 2017. Population structure and regeneration dynamics of *Quercus variabilis* along latitudinal and longitudinal gradients. *Ecosphere*, 8(4), 1-15.

Hale, S. 2004. *Managing light to enable natural regeneration in British conifer forests.* Information Note 63. Forestry Commission, Edinburgh.

Hamilton, G.J. 1975. *Forest mensuration handbook*. Forestry Commission Booklet 39. HMSO, London.

Jarvis, P.G. 1964. The adaptability to light intensity of seedlings of *Quercus petraea* (Matt.) Leibl. *Journal of Ecology*, 52(3), 545-571.

Kerr, G., Mason, B., Boswell, R. & Pommerening, A. 2002. *Monitoring the transformation of even-aged stands to continuous cover management.* Information Note. Forestry Commission, Edinburgh.

Pigott, C.D. 1983. Regeneration of oak-birch woodland following exclusion of sheep. *Journal of Ecology*, 71(2), 629-646.

Price, A. & MacDonald, E. 2012. *Growing birch in Scotland for higher quality timber*. Timber Development Programme published by Forest Research.

Rao, S.J. 2017. Effect of reducing red deer *Cervus elaphus* density on browsing impact and growth of Scots pine *Pinus sylvestris* seedlings in semi-natural woodland in the Cairngorms, UK. *Conservation Evidence*, 14, 22-26.

Shaw, M.W. 1968. Factors affecting the natural regeneration of sessile oak (*Quercus petraea*) in North Wales: I. A preliminary study of acorn production, viability and losses. *Journal of Ecology*, 56(2), 565-583.

Sokal, R.R. & Rohlf, F.J. (1969). *Biometry: The principles and practice of statistics in biological research*. Freeman & Co., San Francisco.

Stace, C. 2010. *New Flora of the British Isles.* 3rd edition. Cambridge University Press, Cambridge.

ANNEX 1: TABLES

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

Species of tree	Life-class										
	Seedlings	Small saplings	Large saplings	Pole stage	Young reproductive	Mature	Over-mature	Senescent	"Phoenix"	**Total Live**	Dead
rowan	1,291 – 1,341	46.6	10.9	1.1	1.1	1.6	0.5	0.3	0.3	**1,378**	0.0
downy birch	330 – 348	174 – 177	55 – 58	63.3	13.9	31.9	11.0	2.4	1.9	**695.4**	8.6
holly	178.0	3.5	0.3	0.0	0.0	1.9	0.0	0.0	0.0	**183.7**	0.0
sessile oak	17.9	0.3	0.0	0.5	0.8	42.4	95.7	24.1	1.6	**183.3**	37.3
hazel	32.3	16.1	1.5	8.0	0.0	2.7	0.3	0.0	0.3	**61.1**	0.5
Sitka spruce	2.1	6.7	13.5	0.0	0.0	0.0	0.0	0.0	0.0	**22.3**	0.0
ash	8 – 11	7.6	0.0	0.3	0.0	0.3	0.3	0.0	0.3	**18.4**	0.3
unassigned willow	0.6	2.6	0.0	0.0	0.0	2.7	0.0	0.0	0.0	**5.9**	0.0
eared sallow	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	**1.6**	0.0
beech	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.6**	0.0
alder	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.3	**0.5**	0.0
Norway spruce	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.3**	0.0
goat willow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	**0.3**	0.0
unknown species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	10.5
All species	**1,834 – 1,904**	**258 – 261**	**81 – 84**	**74.8**	**15.8**	**83.7**	**107.8**	**27.1**	**4.6**	**2,552**	**57.1**

Table 2. Summary statistics on the data collected from across the 84 sample plots surveyed within the Sunart SSSI that is within the East Loch Shiel DMG.

Species/ variable	Life-class	Statistic						
		Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
Stem density of all species (stems per ha)	Seedling	2,176	3,089	0	351	1,333	2,772	22,133
	Small sapling	386	763	0	0	60	330	4,775
	Large sapling	232	887	0	0	0	60	5,684
	Pole	135	324	0	0	0	107	1,827
	Young reproductive	27	97	0	0	0	20	812
	Mature	101	141	0	0	45	120	812
	Over-mature	106	95	0	20	90	180	348
	Senescent	27	44	0	0	20	40	298
	“Phoenix”	7	22	0	0	0	0	102
	All live trees	402	390	0	235	301	420	1,929
	All dead trees	59	76	0	0	20	100	406
sessile oak density	Seedlings	17	64	0	0	0	0	520
	Small saplings	1	11	0	0	0	0	102
	All live trees	164	143	0	40	140	261	609
downy birch density (per ha)	Seedlings	489	1,303	0	0	60	305	9,692
	Small saplings	252	661	0	0	0	165	4,771
	Large saplings	149	727	0	0	0	25	5,684
	All live trees	188	370	0	0	40	208	1,929
rowan density (stems per ha)	Seedlings	1,446	2,133	0	220	730	1,780	11,680
	Small saplings	82	316	0	0	0	0	2,132
	Large saplings	35	288	0	0	0	0	2,639
	All trees	8	27	0	0	0	0	203
holly density (per ha)	Seedlings	173	410	0	0	20	125	3,060
	Small saplings	3	14	0	0	0	0	120
	Large saplings	1	11	0	0	0	0	102
	All trees	3	13	0	0	0	0	102
hazel density (per ha)	Seedlings	42	146	0	0	0	0	1,218
	Small saplings	42	179	0	0	0	0	1,218
	Large saplings	6	55	0	0	0	0	508
	All trees	21	102	0	0	0	0	914
willows density (per ha)	Seedlings	2	22	0	0	0	0	203
	Small saplings	10	78	0	0	0	0	711
	All trees	14	92	0	0	0	0	812
ash	Seedlings	8	66	0	0	0	0	600
	Small saplings	9	49	0	0	0	0	305
	All trees	3	16	0	0	0	0	102
alder	All trees	2	11	0	0	0	0	102

Table 3. The stem density (stems per ha) of each size-class of tree for each species surveyed across the Sunart 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	109.9	13.7	1.9	0.5	4.6	1.9	2.1
sessile oak	42.6	72.7	34.1	11.8	31.1	5.4	0.8
hazel	10.2	0.5	0.0	0.0	0.5	0.0	0.0
rowan	4.8	0.0	0.0	0.0	0.0	0.0	0.0
unassigned willow	2.9	0.0	0.0	0.0	0.0	0.0	0.0
ash	0.8	0.3	0.0	0.3	0.3	0.0	0.0
eared sallow	1.6	0.0	0.0	0.0	0.0	0.0	0.0
alder	0.5	0.0	0.0	0.0	0.0	0.0	0.0
goat willow	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Sitka spruce	0.3	0.0	0.0	0.0	0.0	0.0	0.0
unknown species	0.0	0.0	0.0	0.0	6.7	2.7	1.1
All species	175.6	87.1	35.9	12.3	36.5	7.2	2.9

Table 4. The basal area (m2 per ha) of each life-class for each species of tree surveyed across the Sunart SSSI.

Species of tree	Life stage							
	Pole stage	Young reproductive	Mature	Over-mature	Senescent	"Phoenix" trees	Dead	**Total live**
sessile oak	0.002	0.010	3.556	11.649	1.987	0.115	1.515	**17.320**
downy birch	0.554	0.209	1.392	1.031	0.084	0.090	0.329	**3.360**
ash	0.001	0.000	0.011	0.113	0.000	0.024	0.001	**0.149**
hazel	0.039	0.000	0.083	0.001	0.000	0.001	0.025	**0.124**
rowan	0.005	0.009	0.021	0.011	0.008	0.011	0.000	**0.065**
holly	0.000	0.000	0.045	0.000	0.000	0.000	0.000	**0.045**
unassigned willow	0.001	0.000	0.044	0.000	0.000	0.000	0.000	**0.045**
alder	0.000	0.000	0.023	0.000	0.000	0.007	0.000	**0.030**
goat willow	0.000	0.000	0.000	0.000	0.012	0.000	0.000	**0.012**
eared willow	0.008	0.000	0.000	0.000	0.000	0.000	0.000	**0.008**
unknown species	0.000	0.000	0.000	0.000	0.000	0.000	0.175	**0.000**
All species	**0.610**	**0.231**	**5.174**	**12.805**	**2.090**	**0.250**	**2.045**	**21.160**

Table 5. The number of un-browsed and browsed seedlings, small saplings and large saplings for each species of tree surveyed within the Sunart 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**
rowan	1,412 – 1,502	2,990 – 3,070	65-70%	110	49	31%	31	5	14%	4,597 – 4,767	64 - 68%
downy birch	401 – 431	725 - 755	61-67%	500 - 510	93	15-16%	180 - 190	8	4%	1,907 – 1,987	42 - 45%
holly	9	598	99%	5	8	62%	0	1	100%	620	98%
hazel	3	107	97%	31	24	44%	5	0	0%	170	77%
Sitka spruce	5	2	29%	19	4	17%	43	2	4%	76	11%
sessile oak	18	43	70%	1	0	0%	0	0	NA	62	69%
ash	22 - 32	6	16-21%	23	3	12%	0	0	NA	54-64	14 - 17%
willows	0	2	100%	1	8	89%	0	0	NA	11	91%
beech	0	2	100%	0	0	NA	0	0	NA	2	100%
Norway spruce	0	0	NA	0	1	100%	0	0	NA	1	100%
All species	1,870 – 2,000	4,475 – 4,585	68-72%	690 – 700	190	27-28%	259-269	16	5%	6,252 – 6,492	67 - 72%

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

Browsing impact indicator	Herbivore Impact Class							Not applicable
	Very High	Very High/High	High	High/Moderate	Moderate	Moderate/Low	Low	
Basal shoots	0	1	18	1	8	1	10	45
Epicormic shoots	0	0	18	0	2	0	10	54
Seedlings and saplings	8	2	32	10	14	4	12	2
Preferentially grazed spp.	7	0	31	3	15	4	13	11
Sward	1	0	11	1	6	2	21	42
Bark Stripping	0	0	1	0	2	0	69	12
Overall Impact	**1**	**1**	**35**	**4**	**16**	**5**	**22**	**0**

ANNEX 2: FIGURES

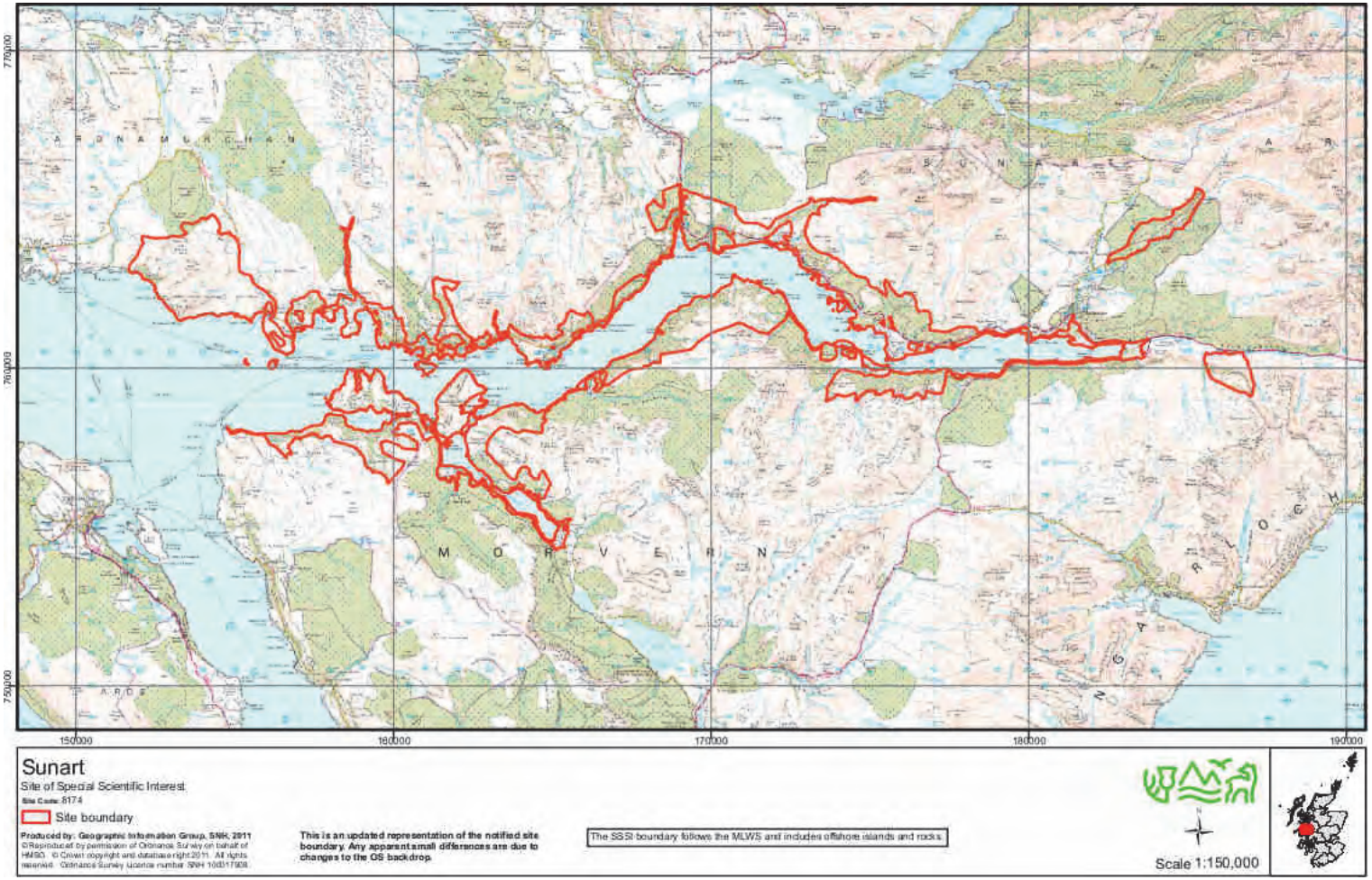

Figure 1. Map showing the location and boundary of the Sunart SSSI.

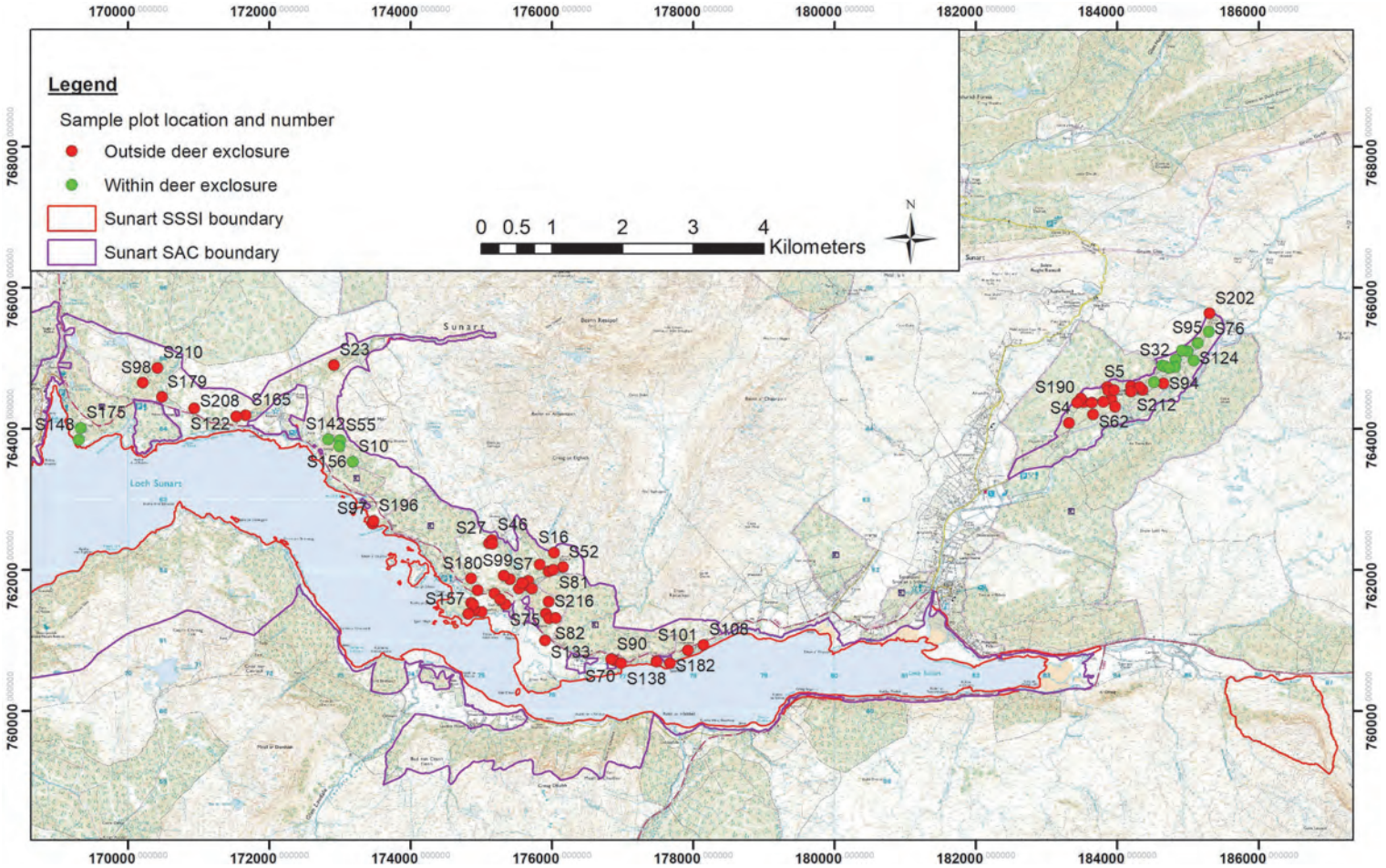

Figure 2. Map showing the location of the 84 sample plots taken to describe the structure and assess the herbivore impacts on the upland oak woodland habitat within the Sunart SSSI. Green and red circles show, respectively, plots within and outside deer exclosures. © Crown copyright and database right 2018. Ordnance Survey 100017908.

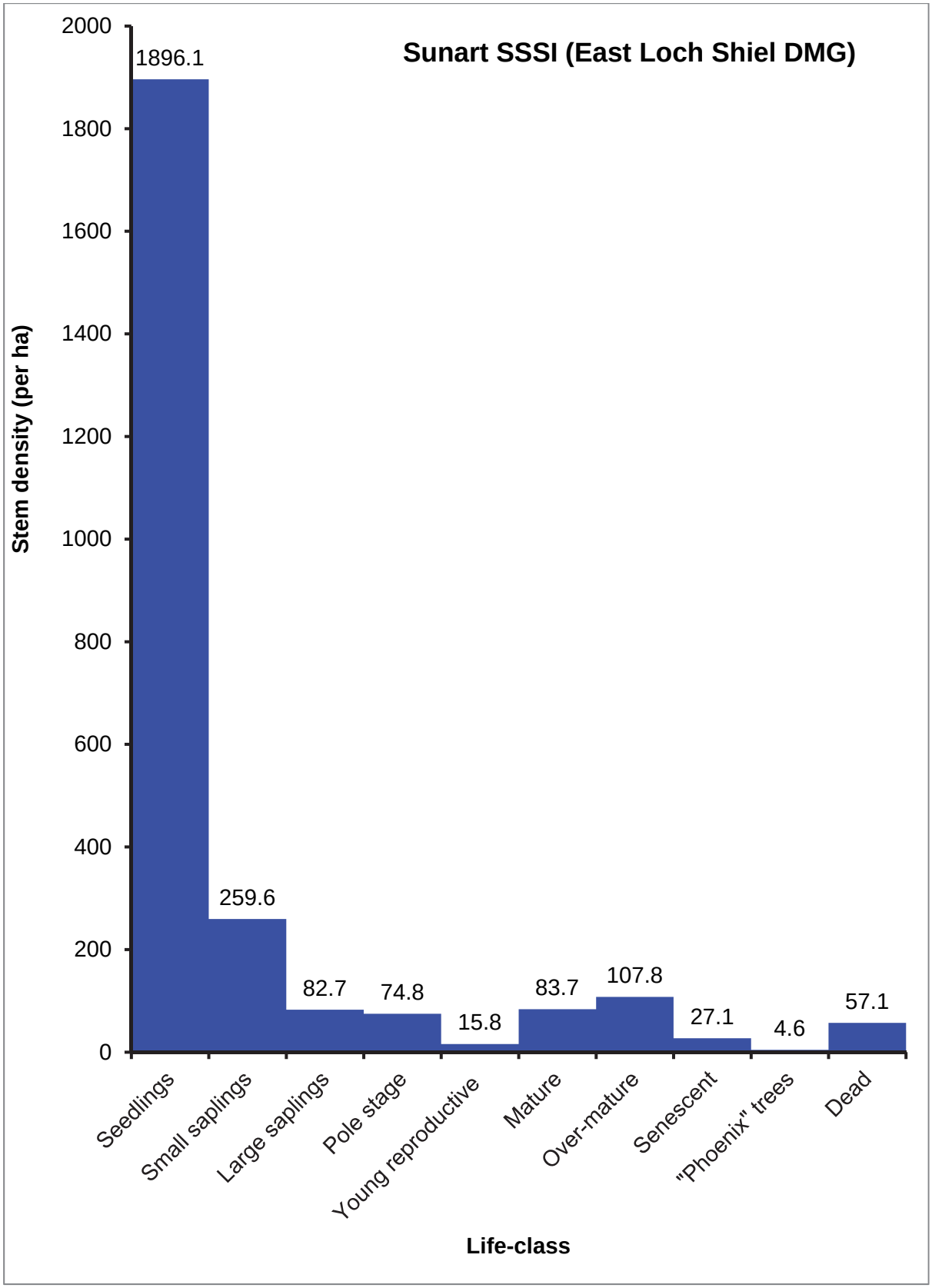

Figure 3. The total number of trees in each life-class counted in this survey of the Sunart SSSI that lies within the East Loch Shiel Deer Management Group.

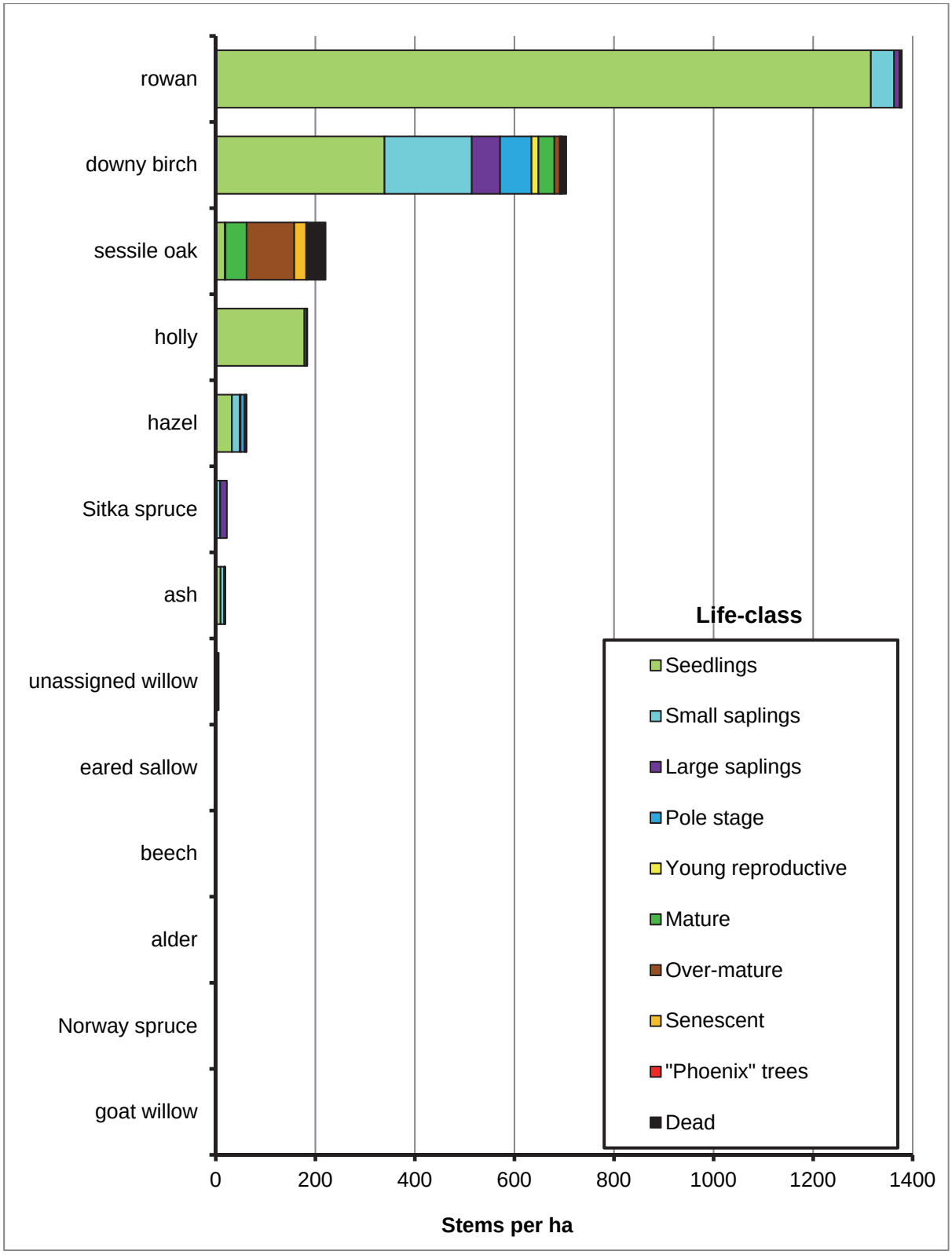

Figure 4. The overall stem density for each life-class for each species of tree that were recorded within the sample plots that were taken within the East Loch Shiel Deer Management Group part of the Sunart SSSI.

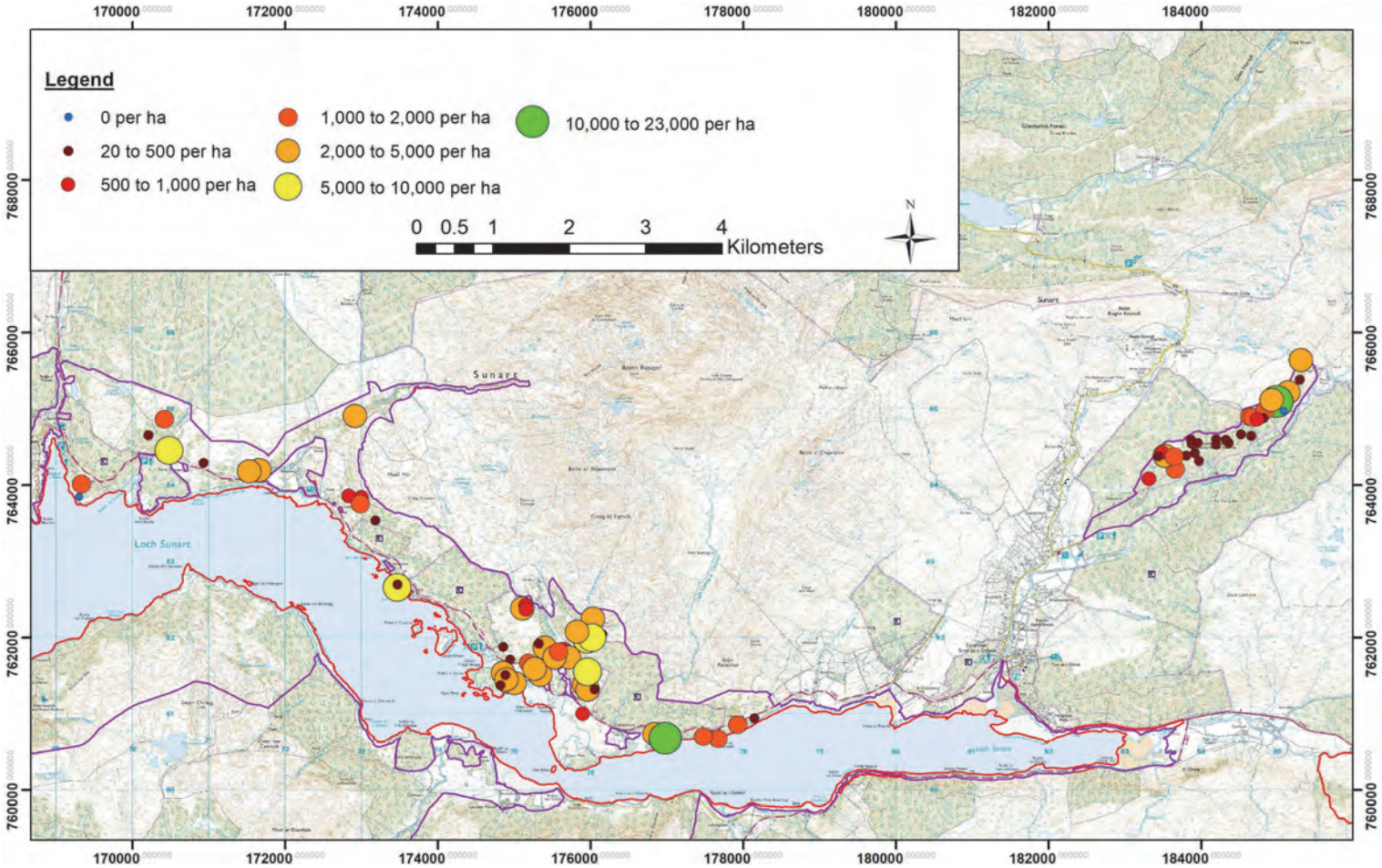

Figure 5. The density of all seedlings (per ha) in the plots surveyed across the Sunart SSSI that is within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

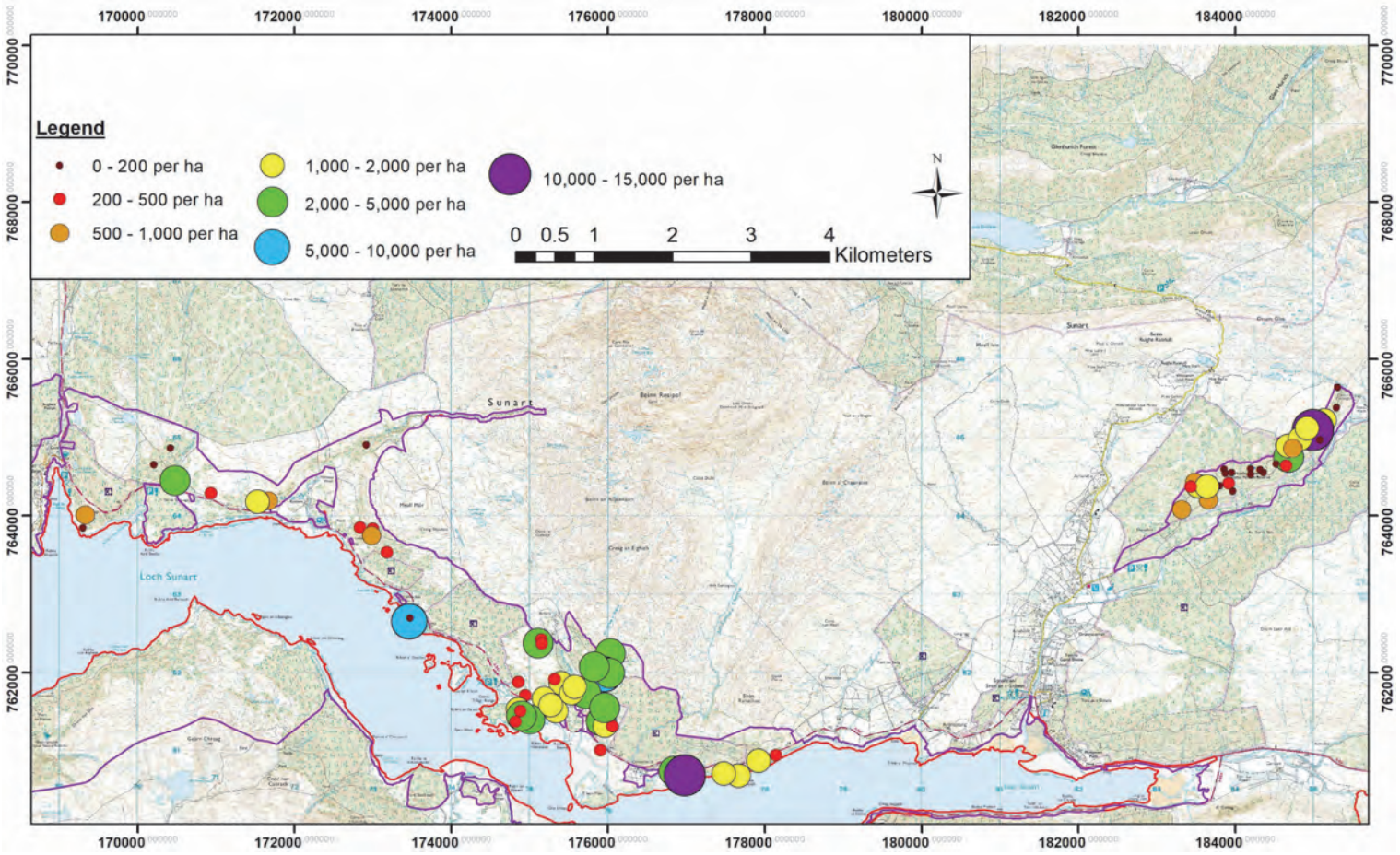

Figure 6. The density of rowan seedlings (per ha) in the plots surveyed across the Sunart SSSI within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

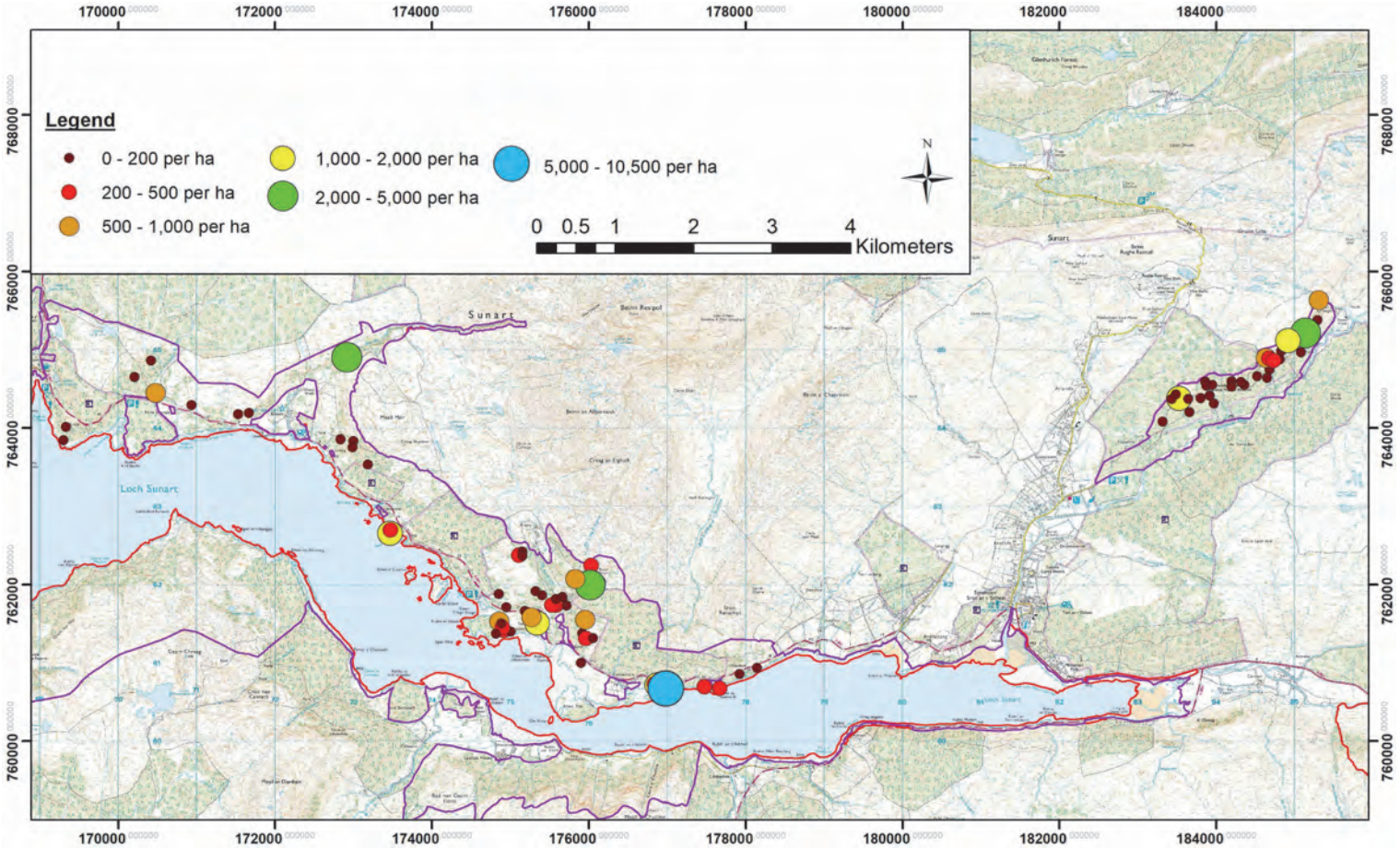

Figure 7. The density of birch seedlings (per ha) in the plots surveyed across the Sunart SSSI that lies within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

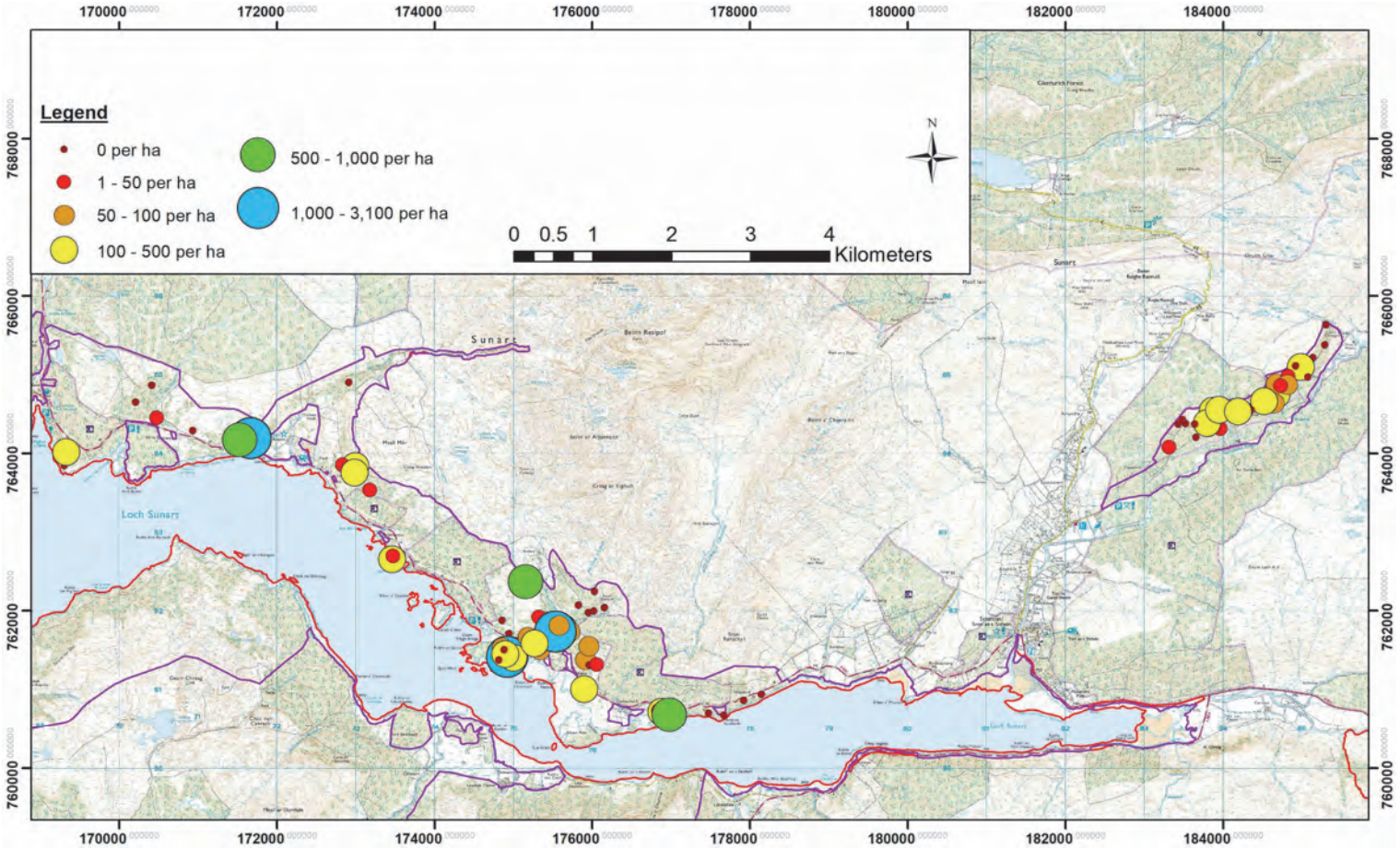

Figure 8. The density of holly seedlings (per ha) in the plots surveyed across the Sunart SSSI that lies within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

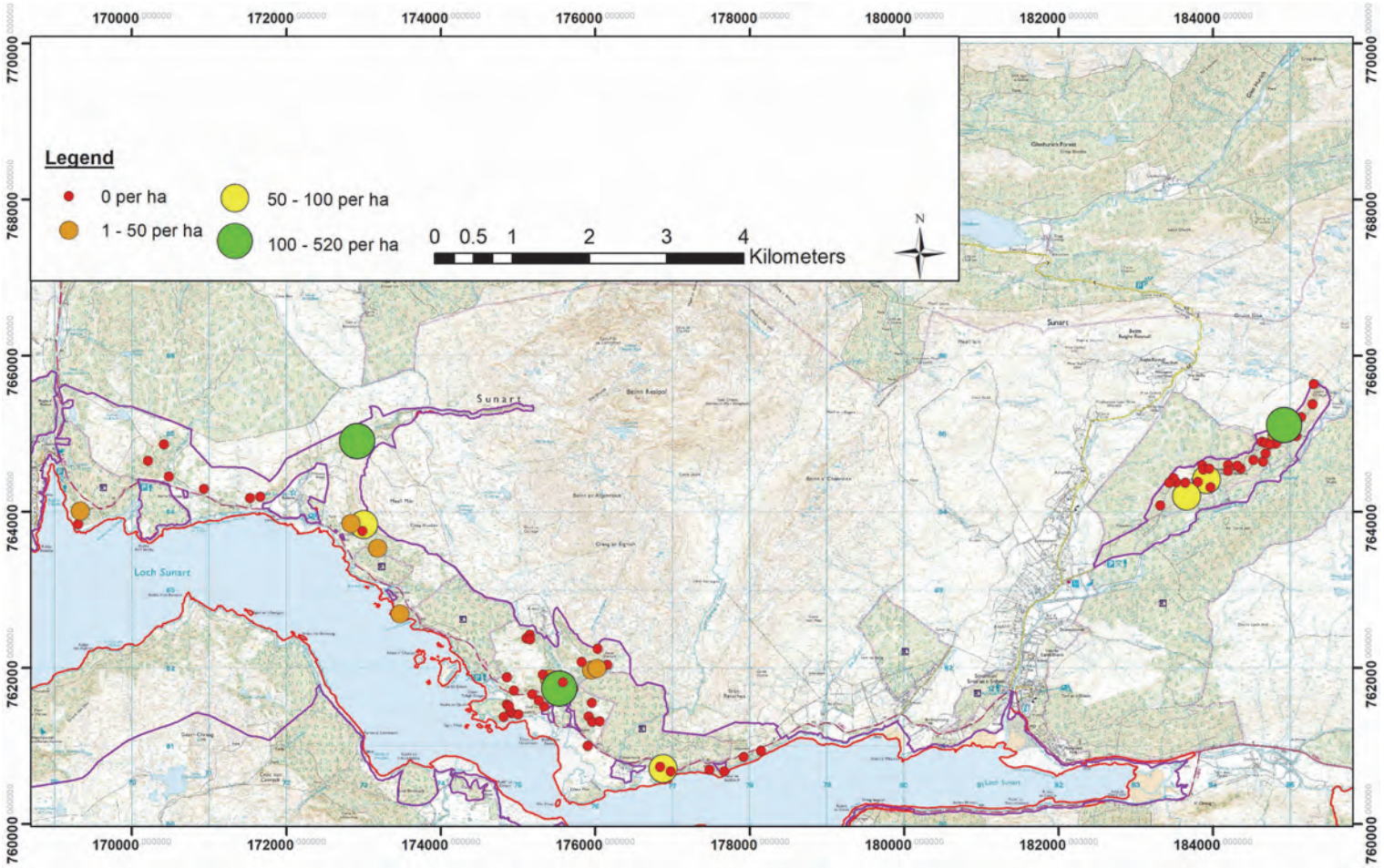

Figure 9. The density of oak seedlings (per ha) in the plots surveyed across the Sunart SSSI that lies within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

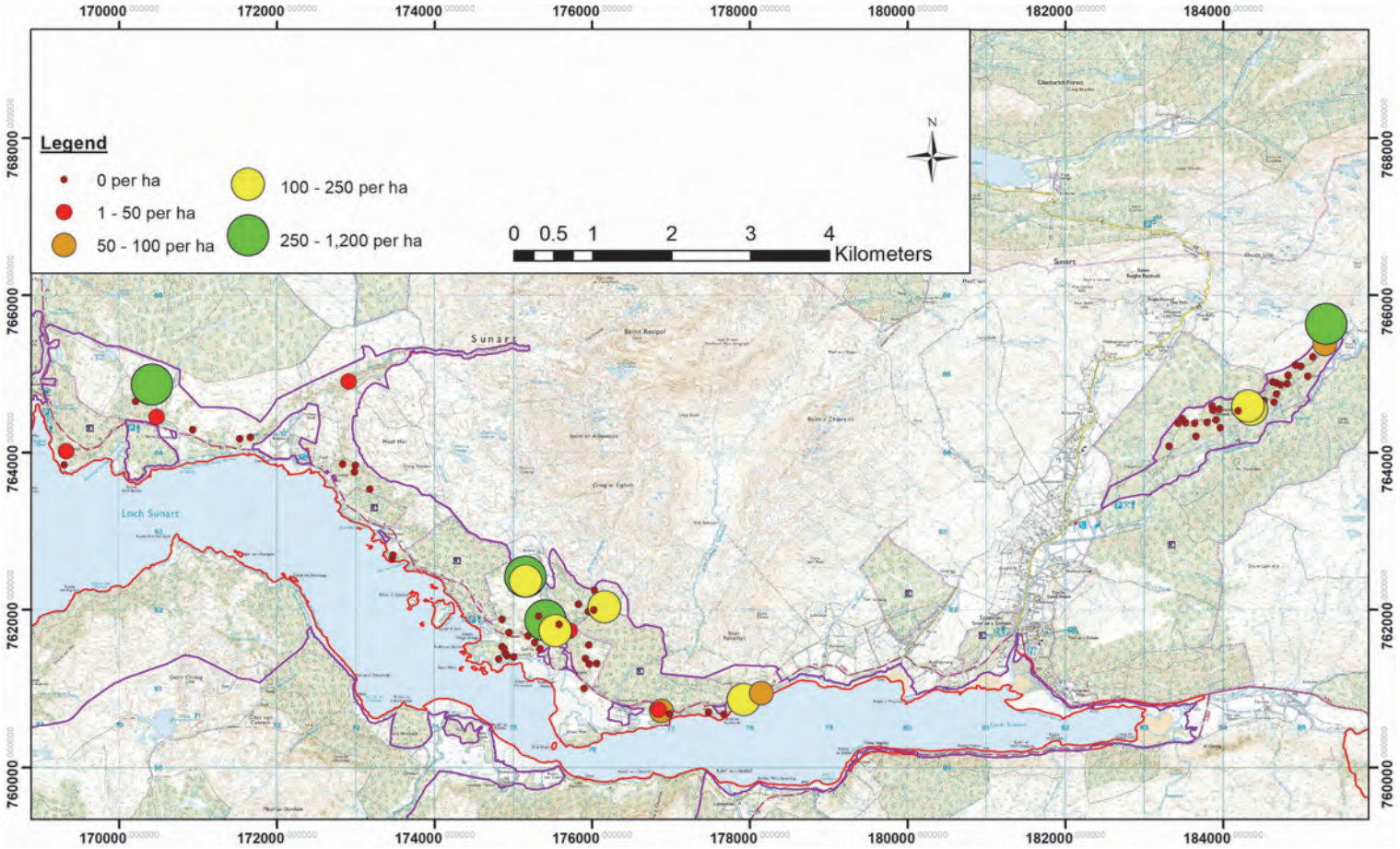

Figure 10. The density of hazel seedlings (per ha) in the plots surveyed across the Sunart SSSI that lie within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

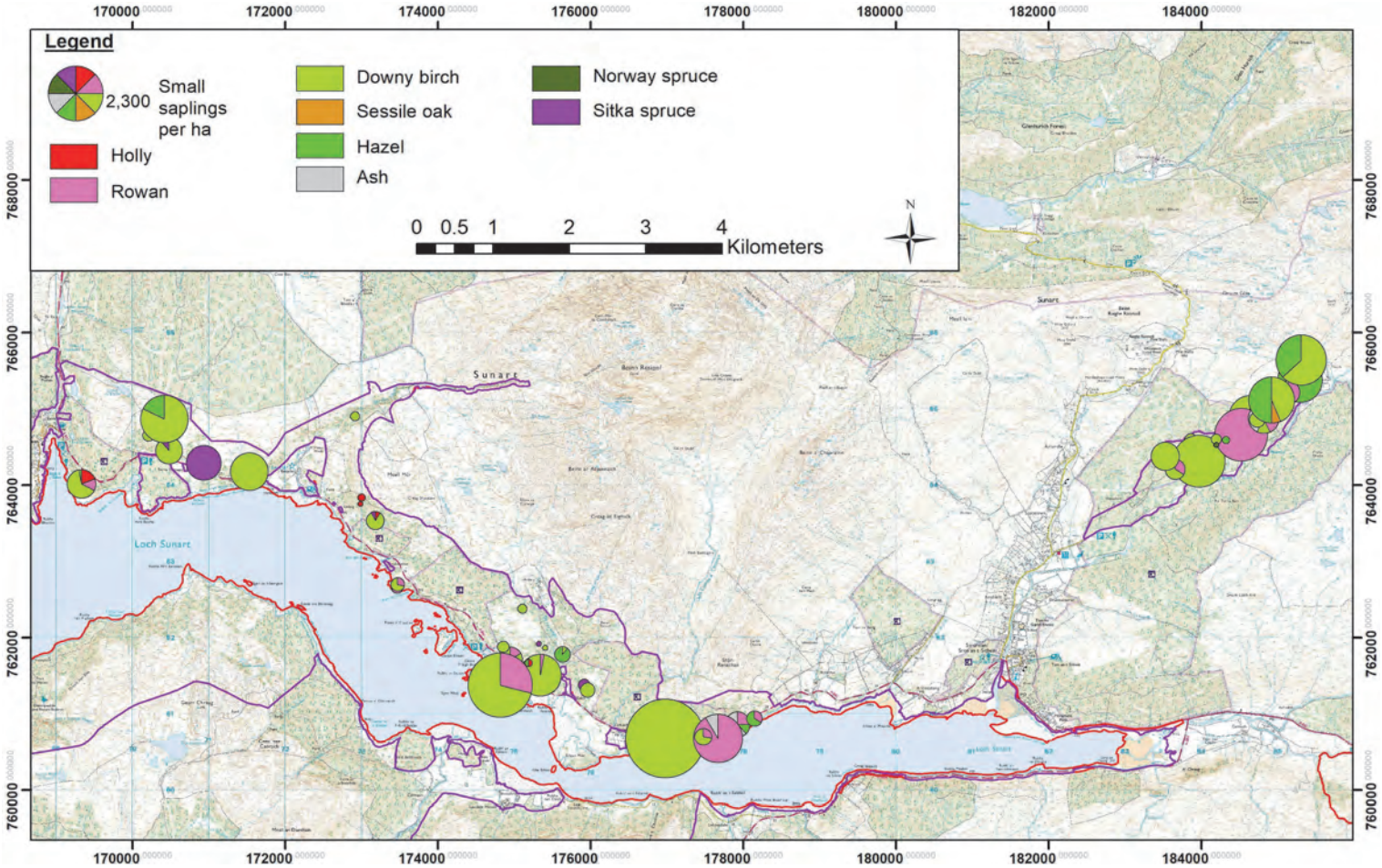

Figure 11. The density of small saplings (per ha) in the plots surveyed across the Sunart SSSI that lies within the East Loch Shiel DMG. The area of the pie charts is proportional to the sum of the densities of small saplings for each component species present. © Crown copyright and database right 2018. Ordnance Survey 100017908.

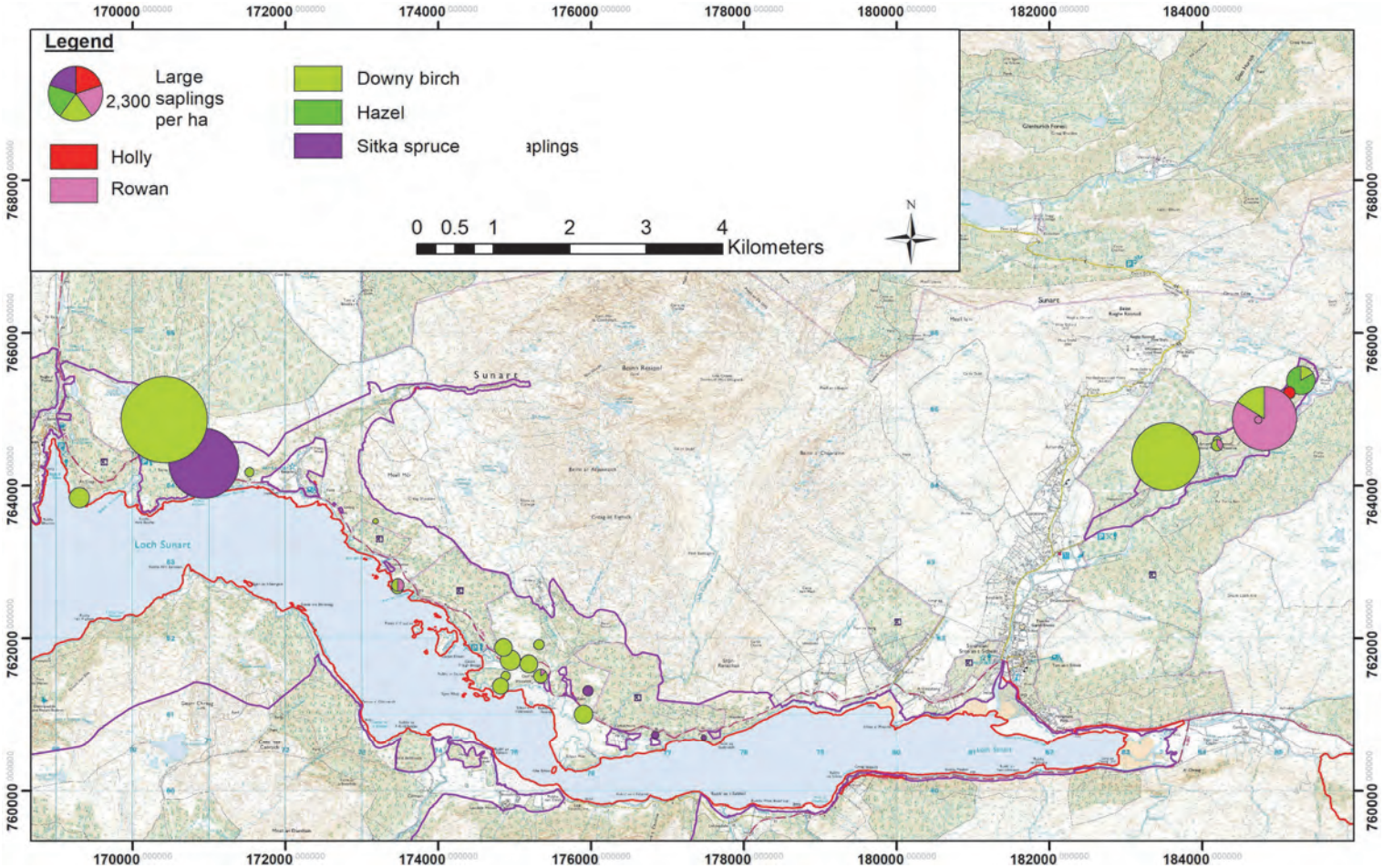

Figure 12. The density of large saplings in the plots surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG. The area of the pie charts is proportional to the sum of the densities of large saplings for each component species present. © Crown copyright and database right 2018. Ordnance Survey 100017908.

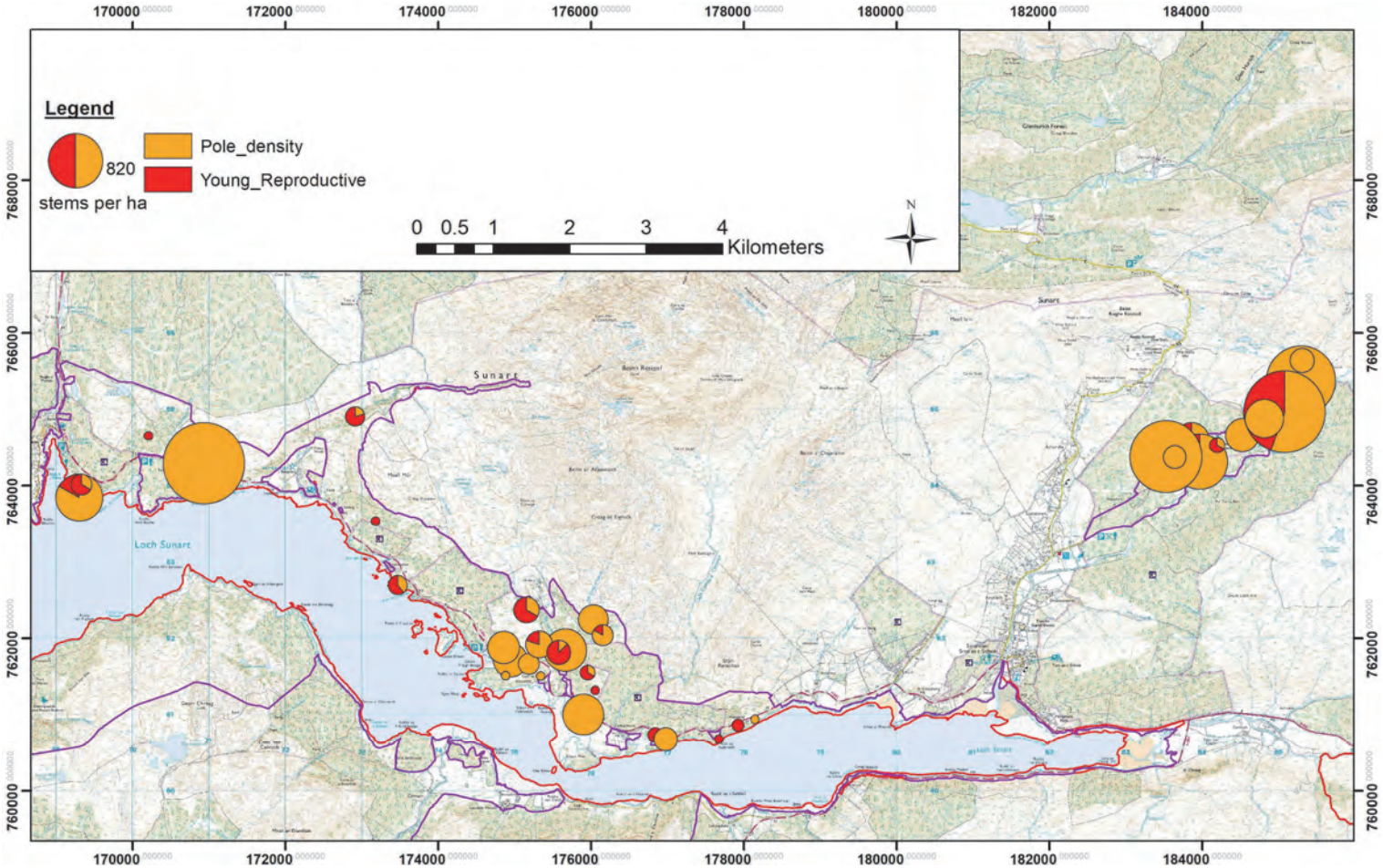

Figure 13. The density of pole stage and young reproductive trees in the plots surveyed within the Sunart SSSI that lies within the East Loch Shiel DMG. The area of the pie charts is proportional to the sum of the densities of pole and young reproductive trees. © Crown copyright and database right 2018. Ordnance Survey 100017908.

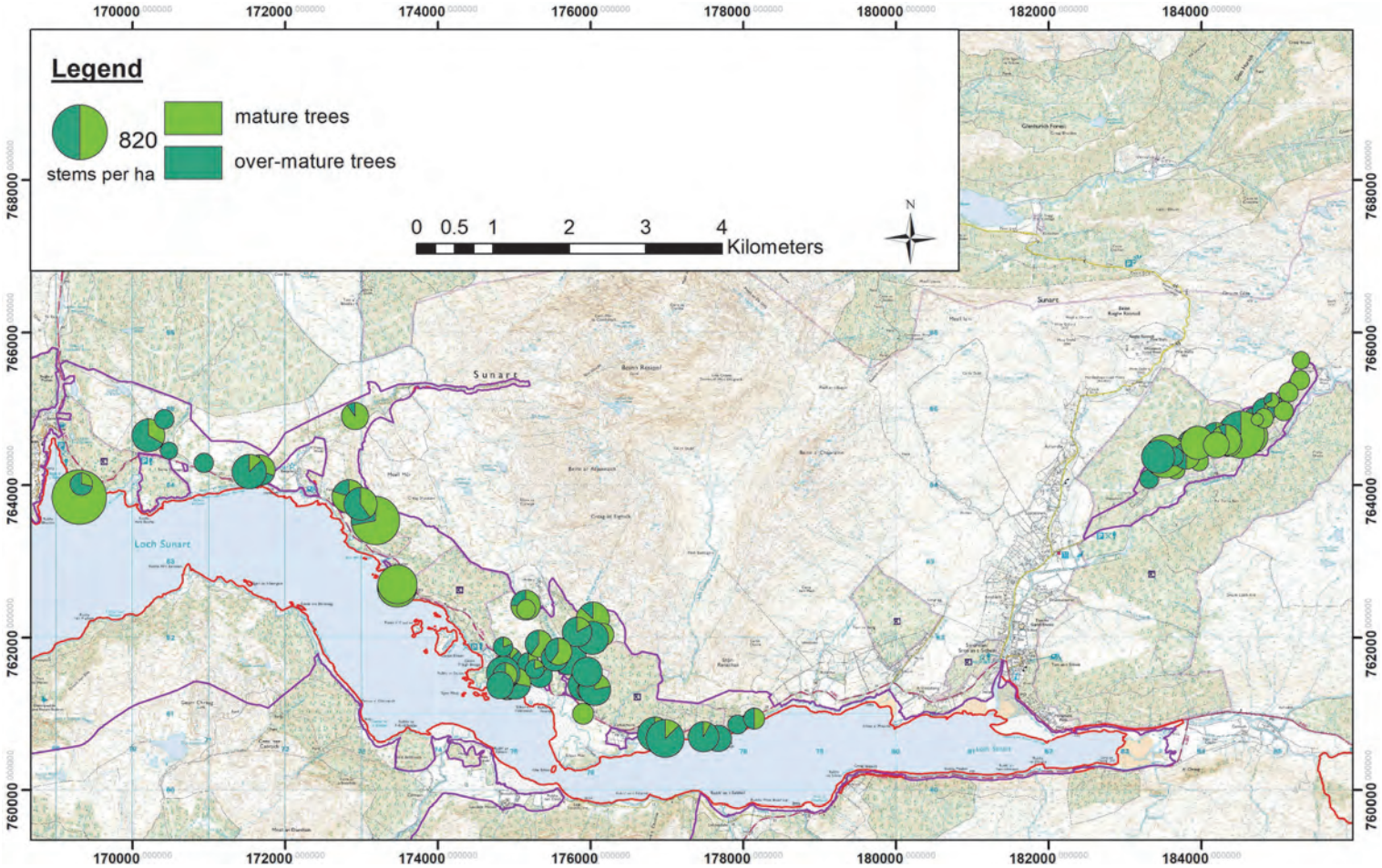

Figure 14. The density of mature and over-mature trees in the plots surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG. The area of the pie charts is proportional to the sum of the densities of mature and over-mature trees. © Crown copyright and database right 2018. Ordnance Survey 100017908.

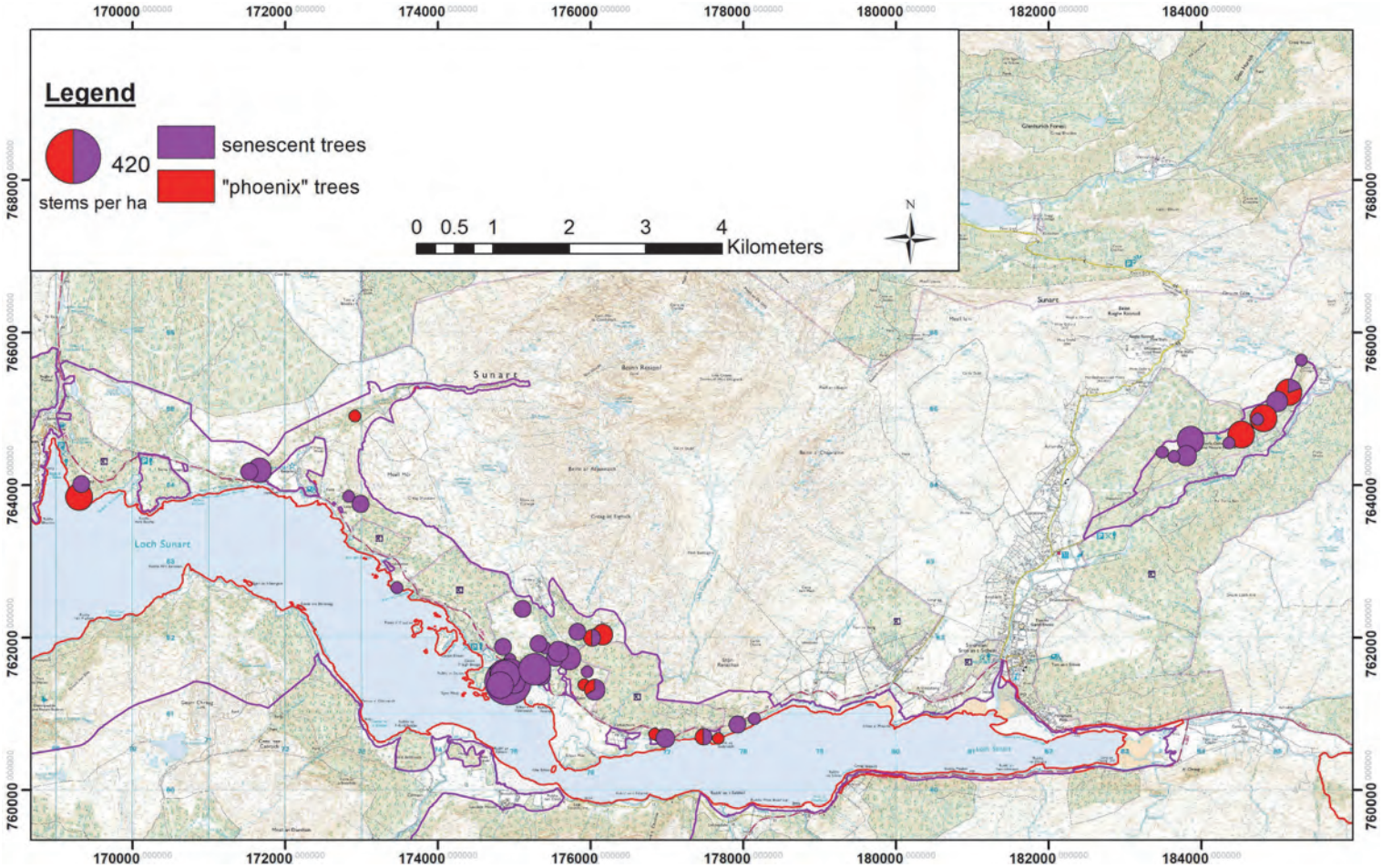

Figure 15. The density of senescent and "phoenix" trees in the plots surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG. The area of the pie charts is proportional to the sum of the densities of senescent and "phoenix" trees. © Crown copyright and database right 2018. Ordnance Survey 100017908.

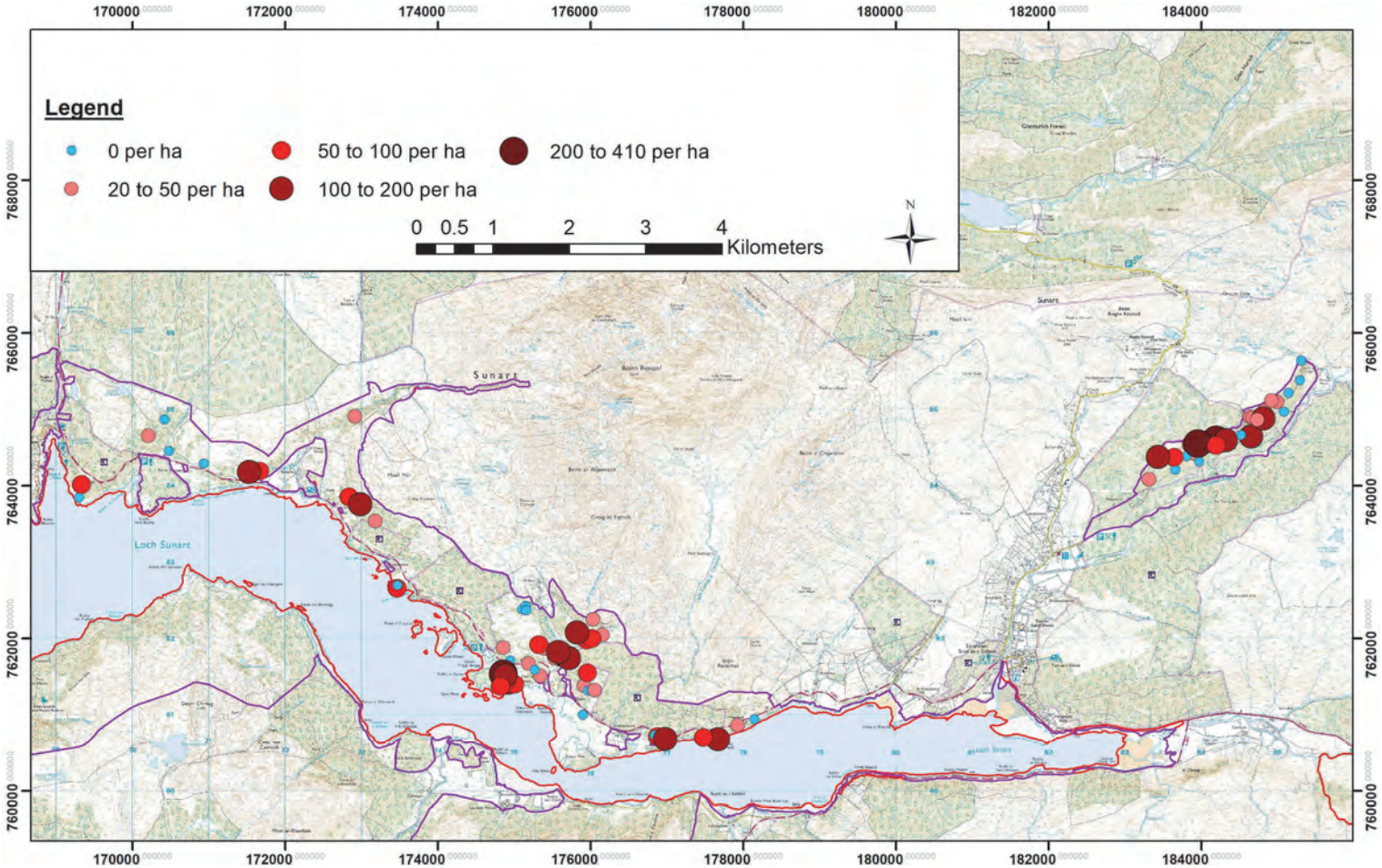

Figure 16. The density of dead trees in the plots surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

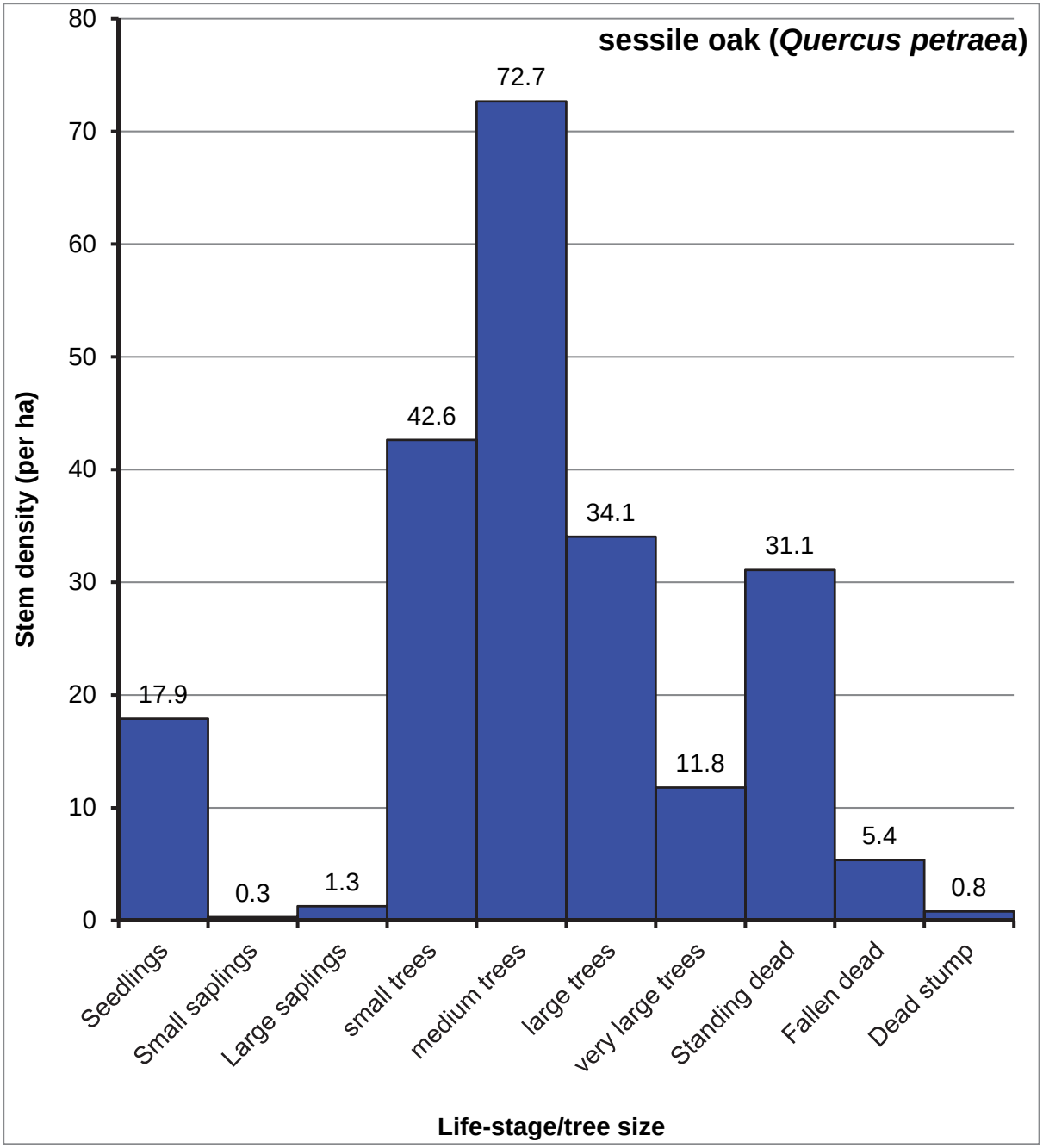

Figure 17. The size distribution of the sessile oak population surveyed within the Sunart SSSI that lies within the East Loch Shiel DMG.

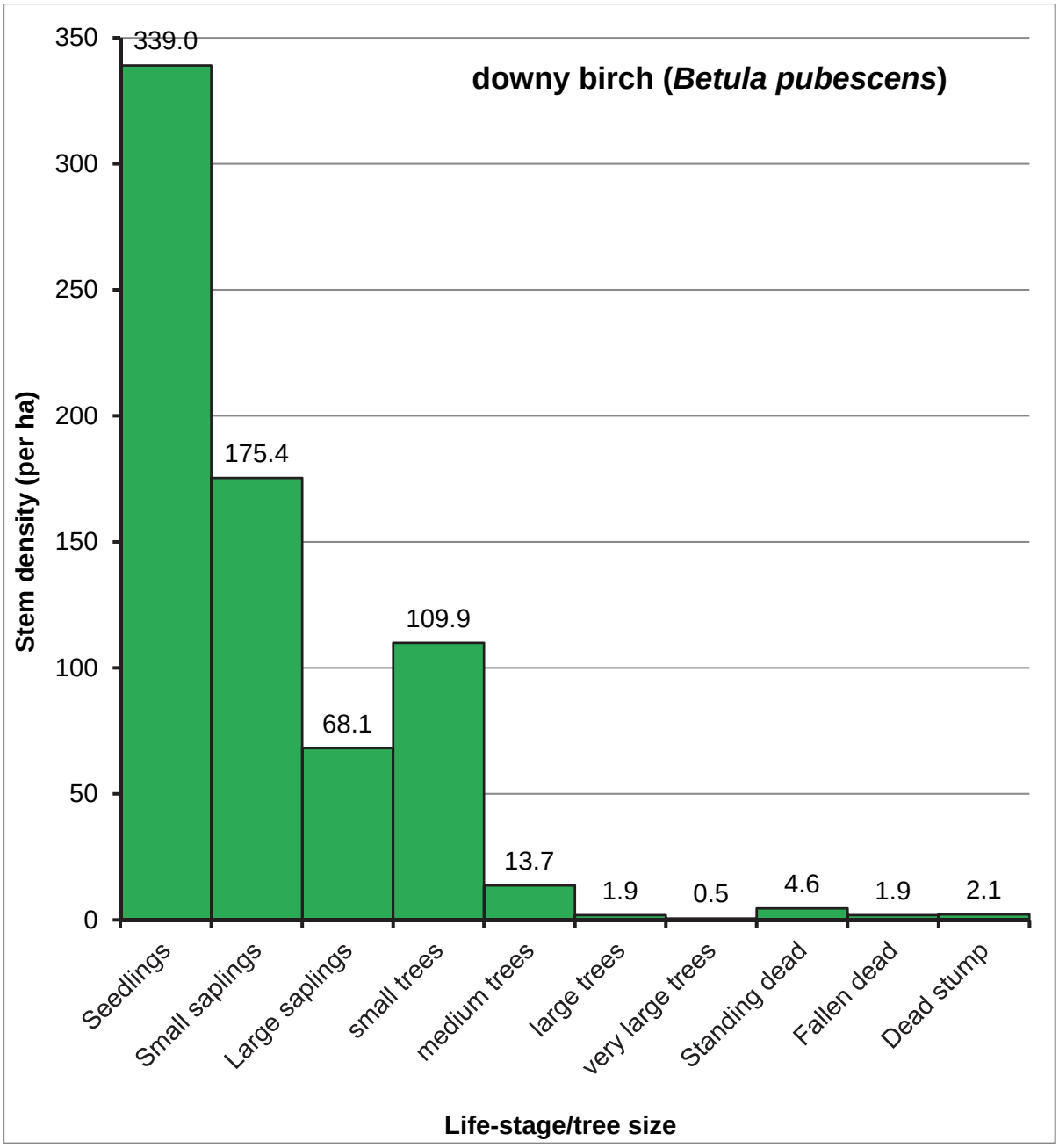

Figure 18. The size distribution of the downy birch population surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG.

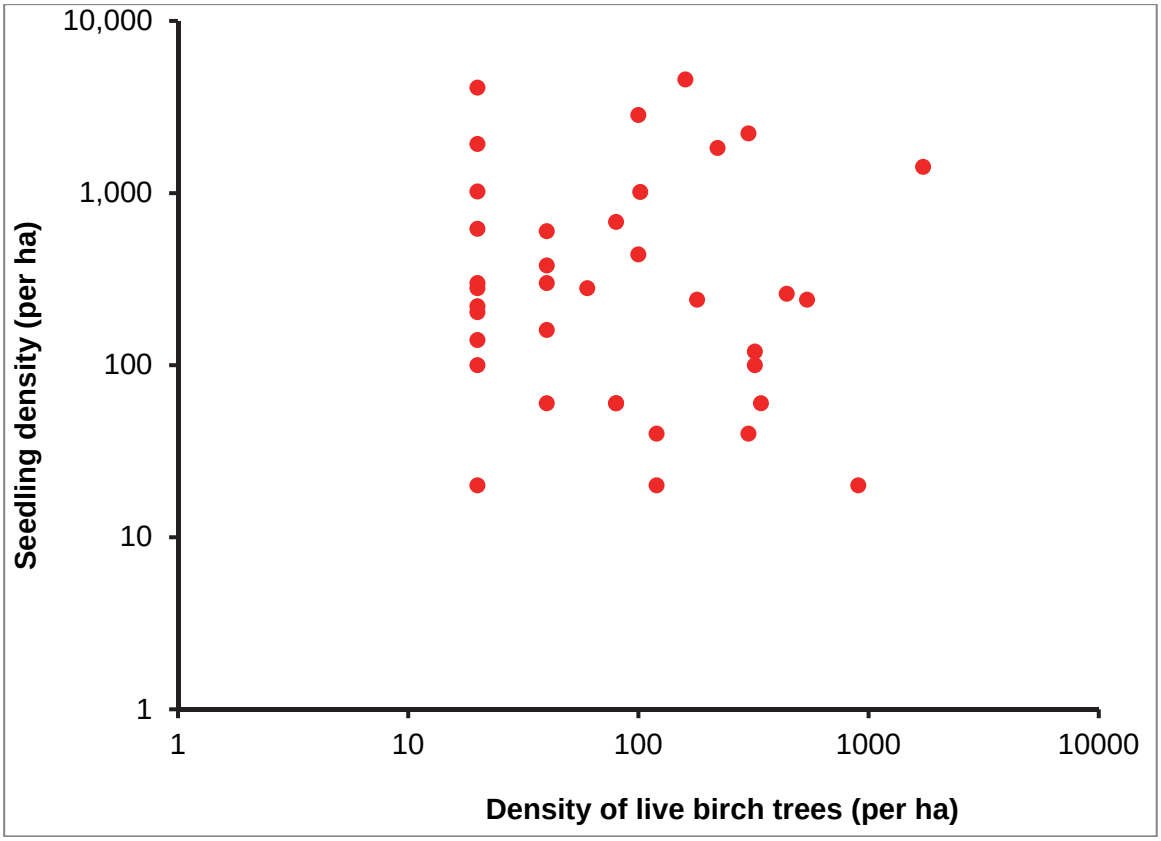

Figure 19. The relationship between the density of birch seedlings (per ha) and the density of live downy birch trees (per ha) in the plots. Note that both scales are plotted on a logarithmic scale.

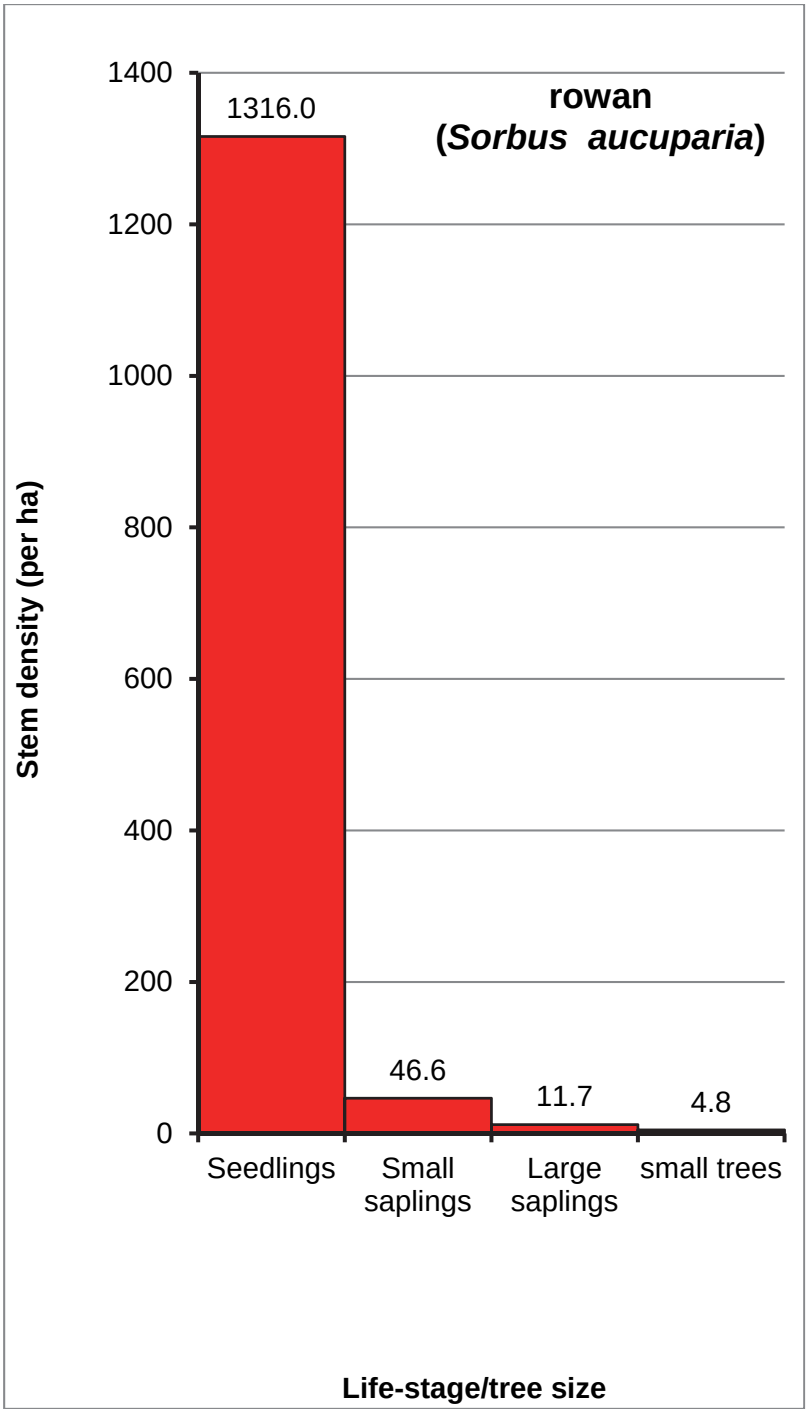

Figure 20. The size distribution of the rowan population surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG.

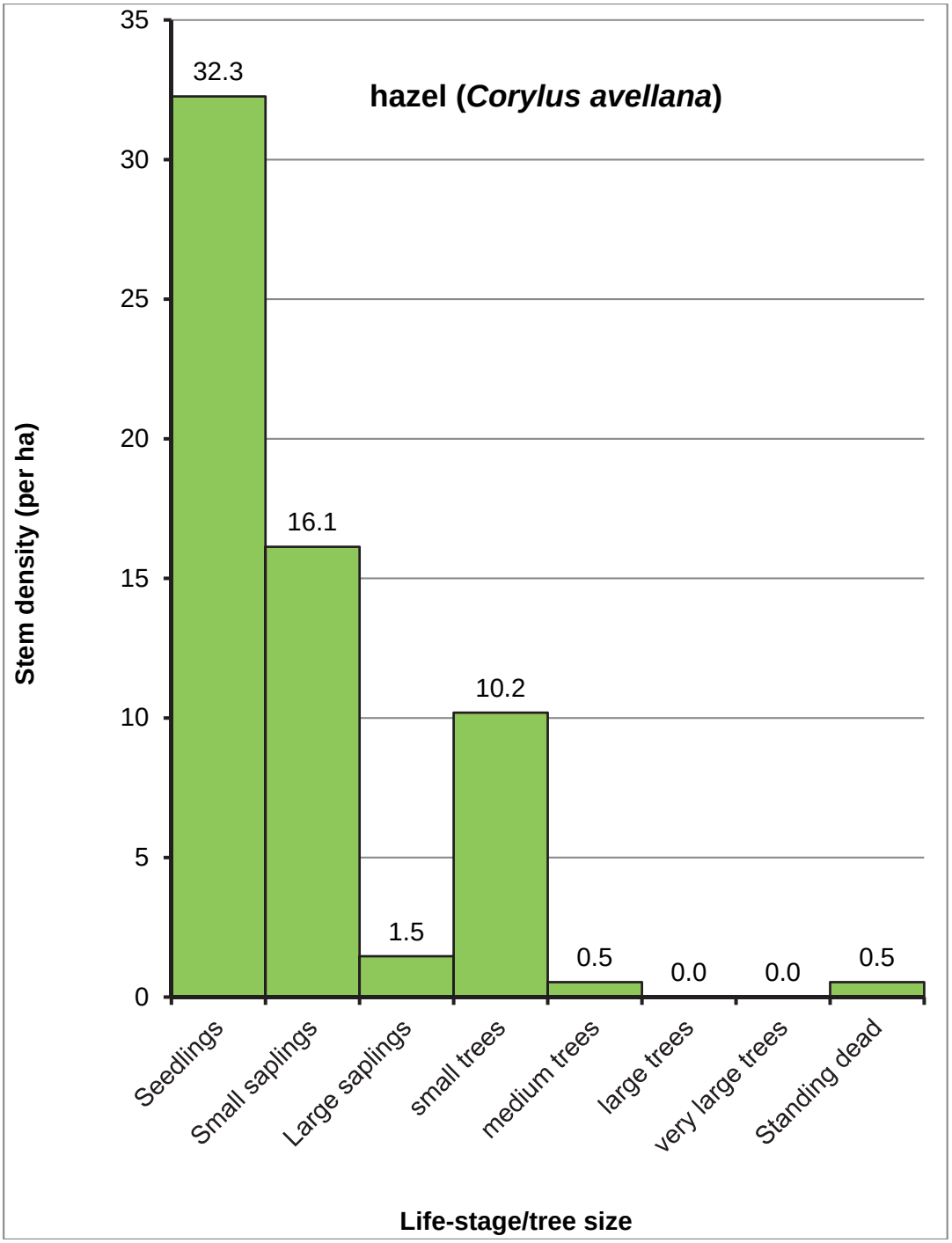

Figure 21. The size distribution of the hazel population surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG.

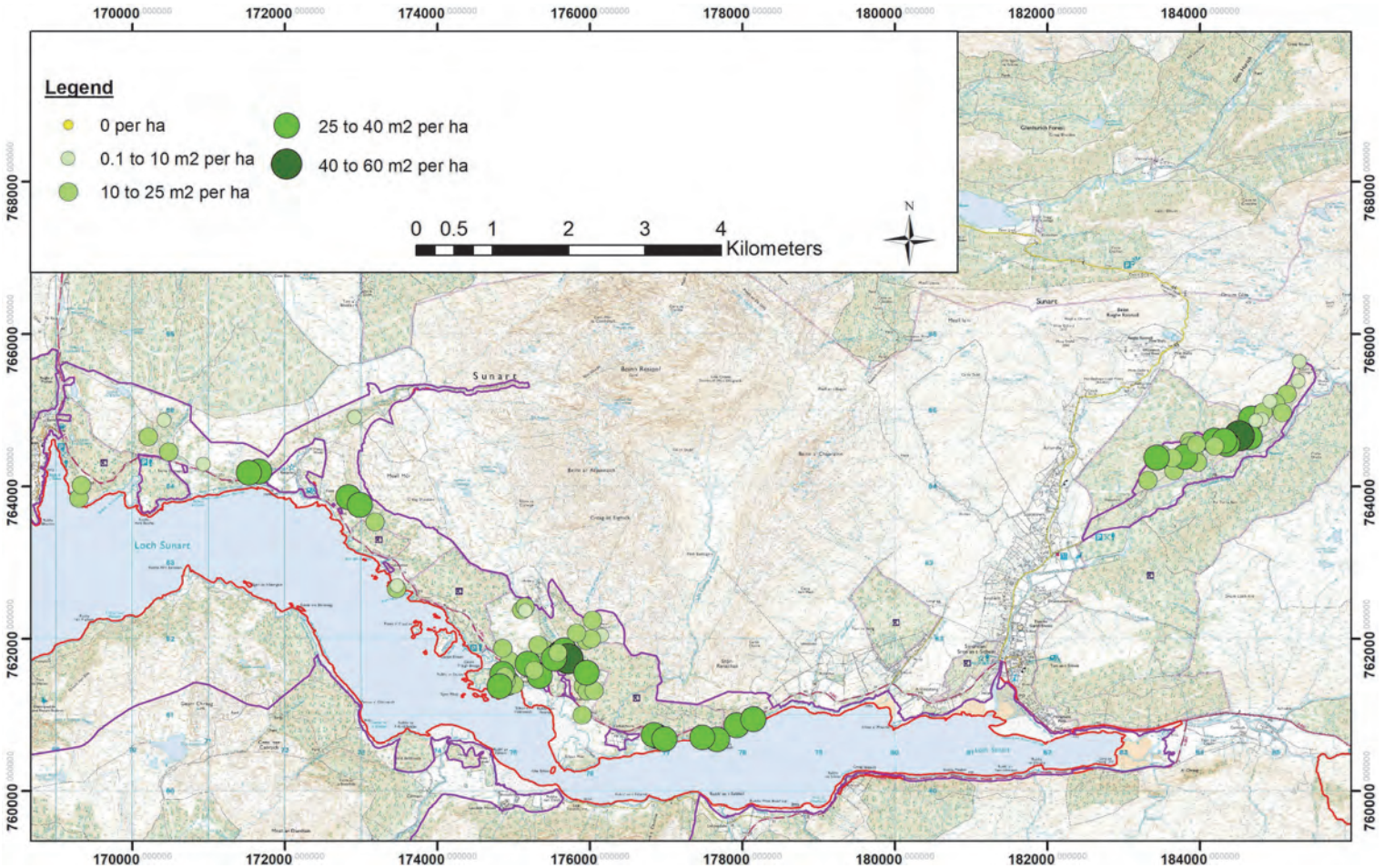

Figure 22. The basal area (m^2 per ha) of all live trees in the plots surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG.

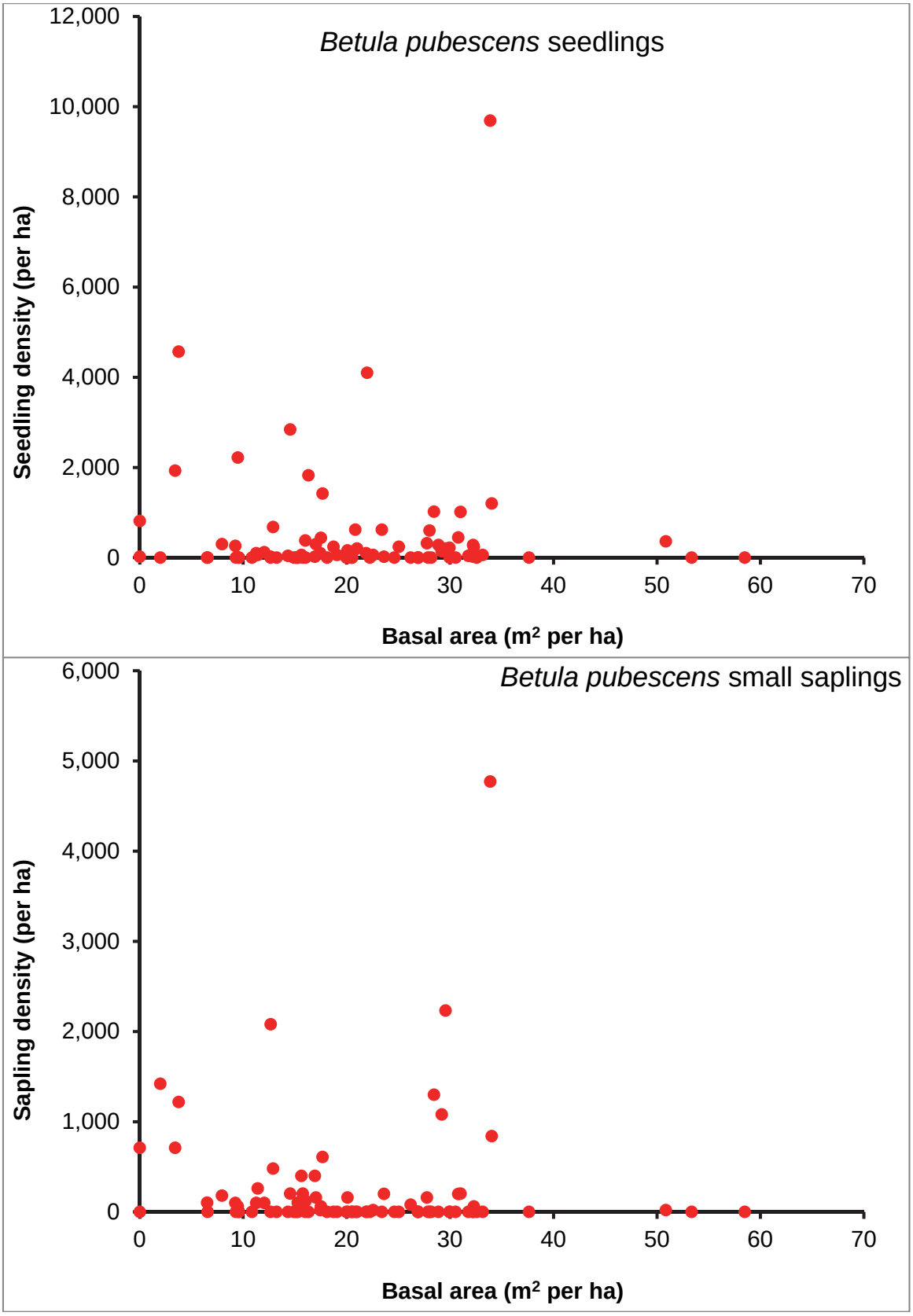

Figure 23. The relationship between the density of downy birch (Betula pubescens) seedlings or small saplings and the basal area of trees within the same plot.

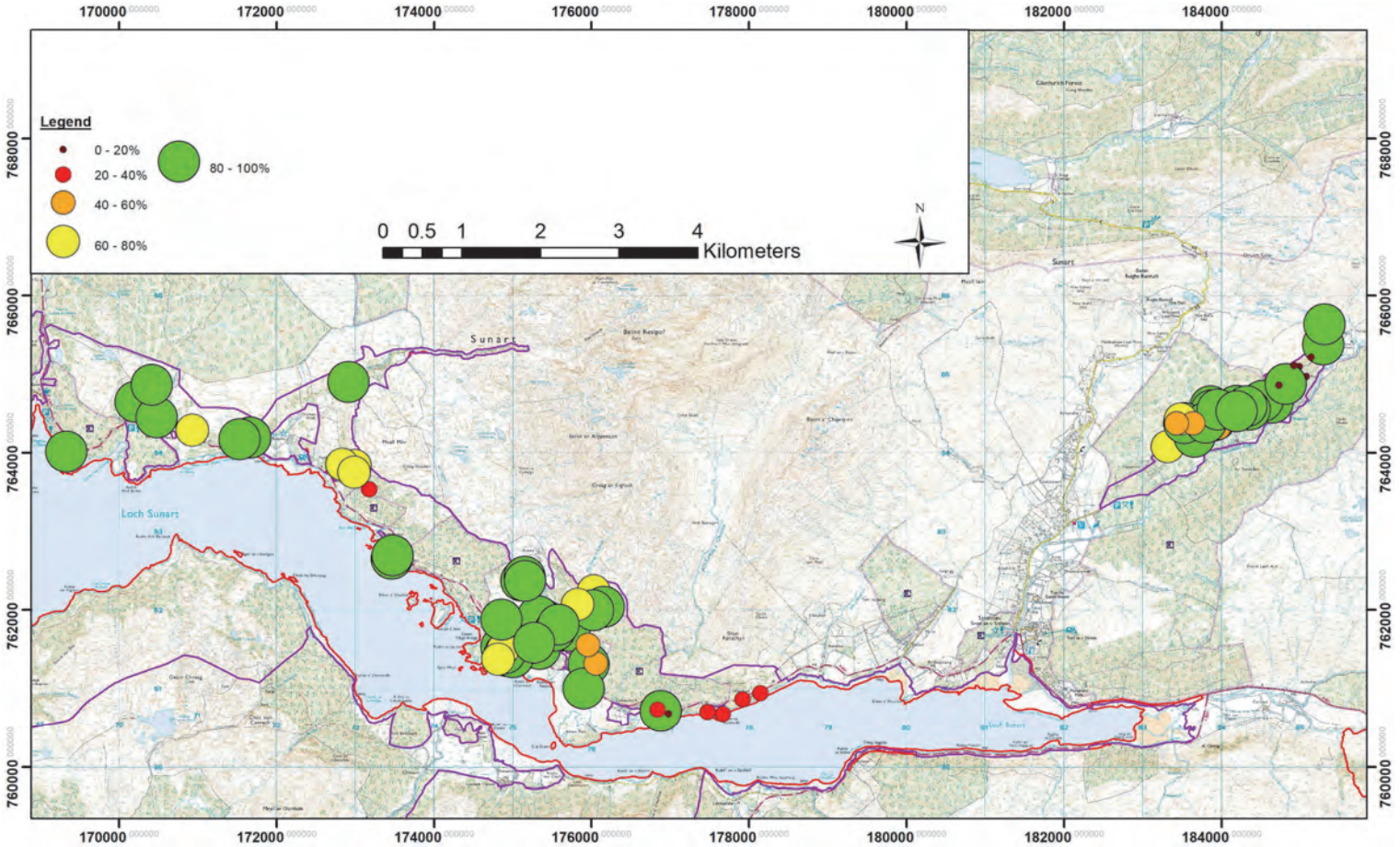

Figure 24. The levels of browsing on seedlings in the plots surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

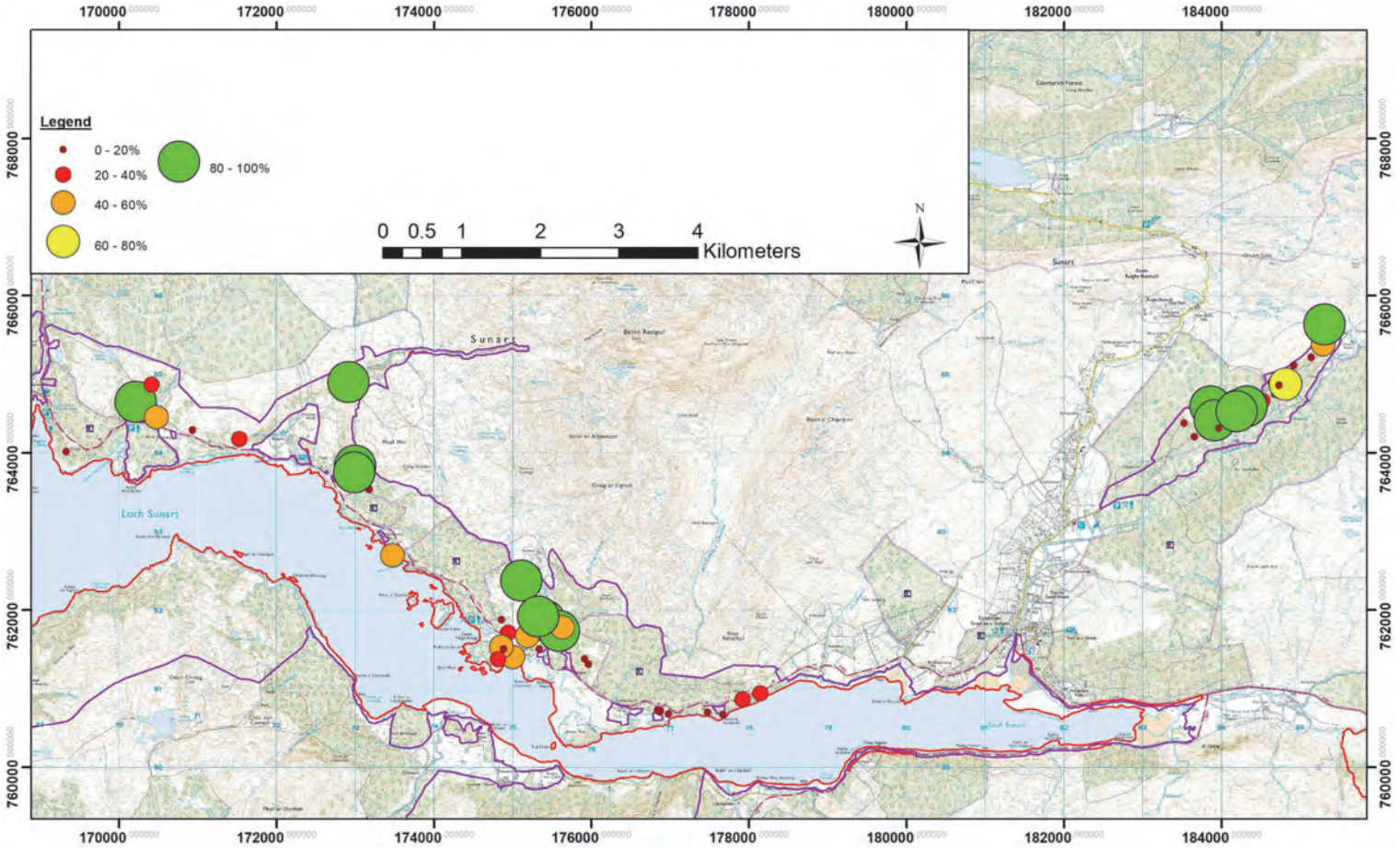

Figure 25. The levels of browsing on small saplings in the plots surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

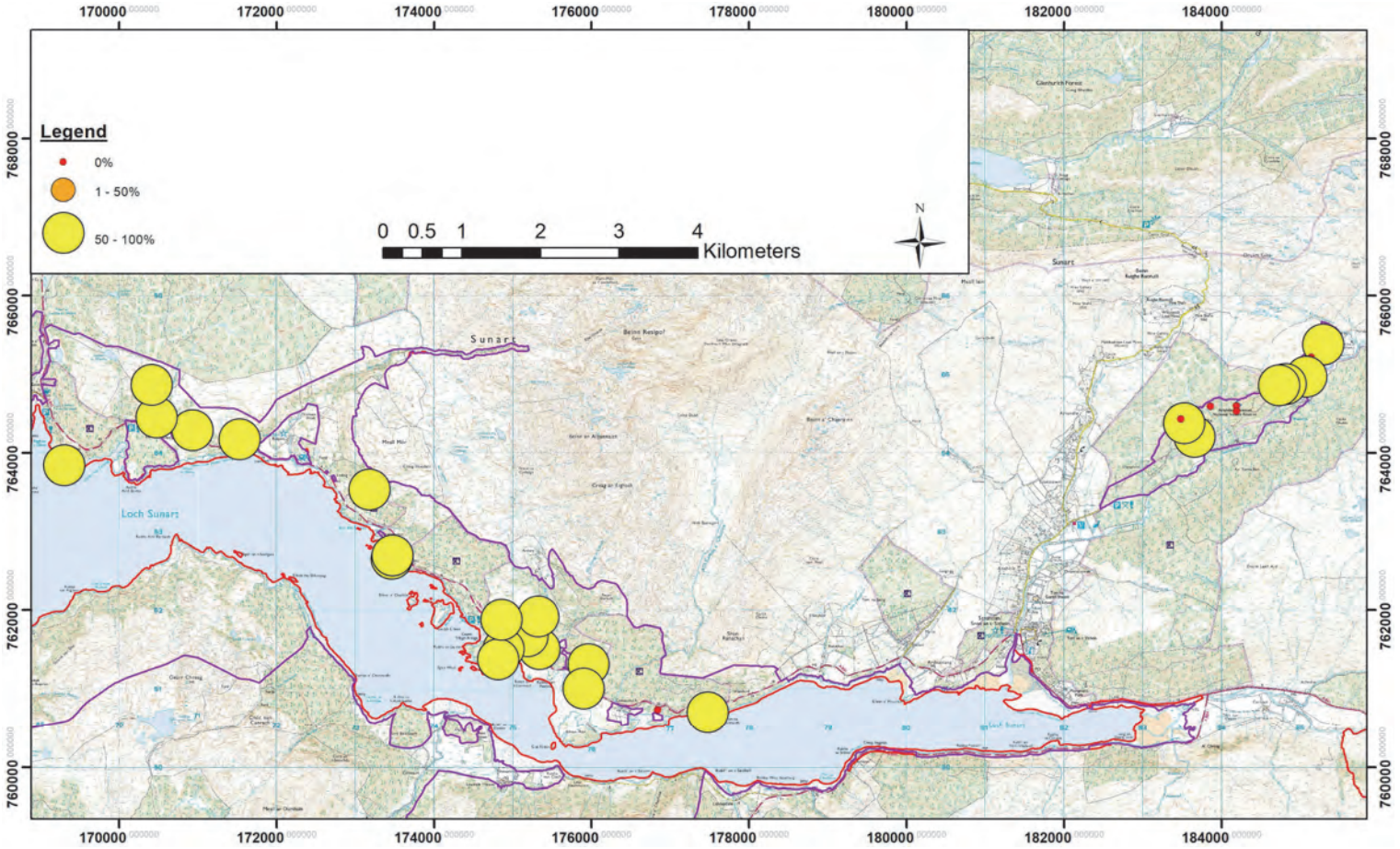

Figure 25. The levels of browsing on large saplings in the plots surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

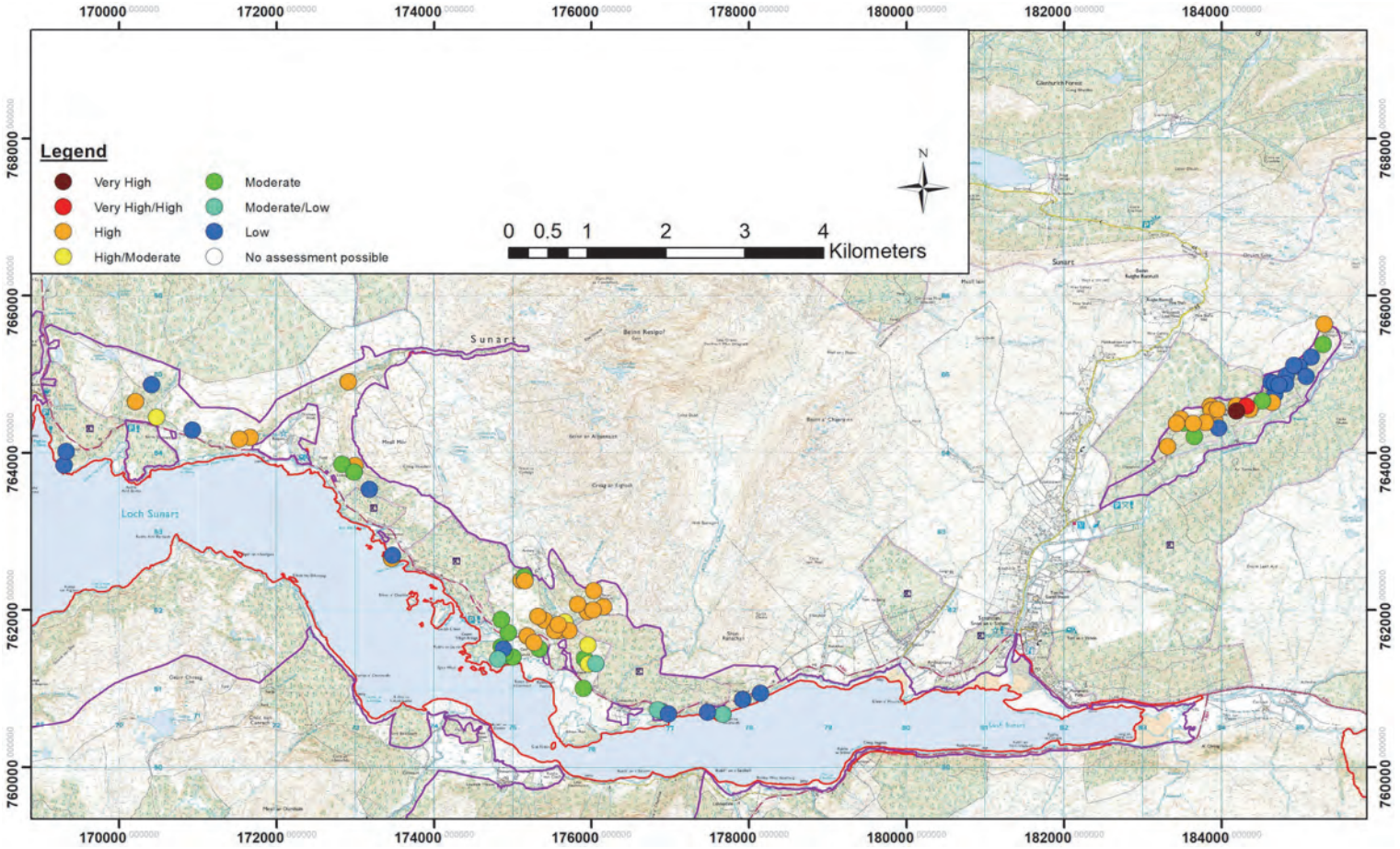

Figure 26. The overall herbivore impacts in the plots surveyed within the Sunart SSSI that lie within the East Loch Shiel DMG. © Crown copyright and database right 2018. Ordnance Survey 100017908.

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 **usually over 5m** height, with spreading canopy; **Canopy 20-50% dead** 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 **usually over 5m** height, with spreading canopy much ravaged by wind & pathogens; **Canopy 50-99% dead** 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; 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. 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		

NOTES: 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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