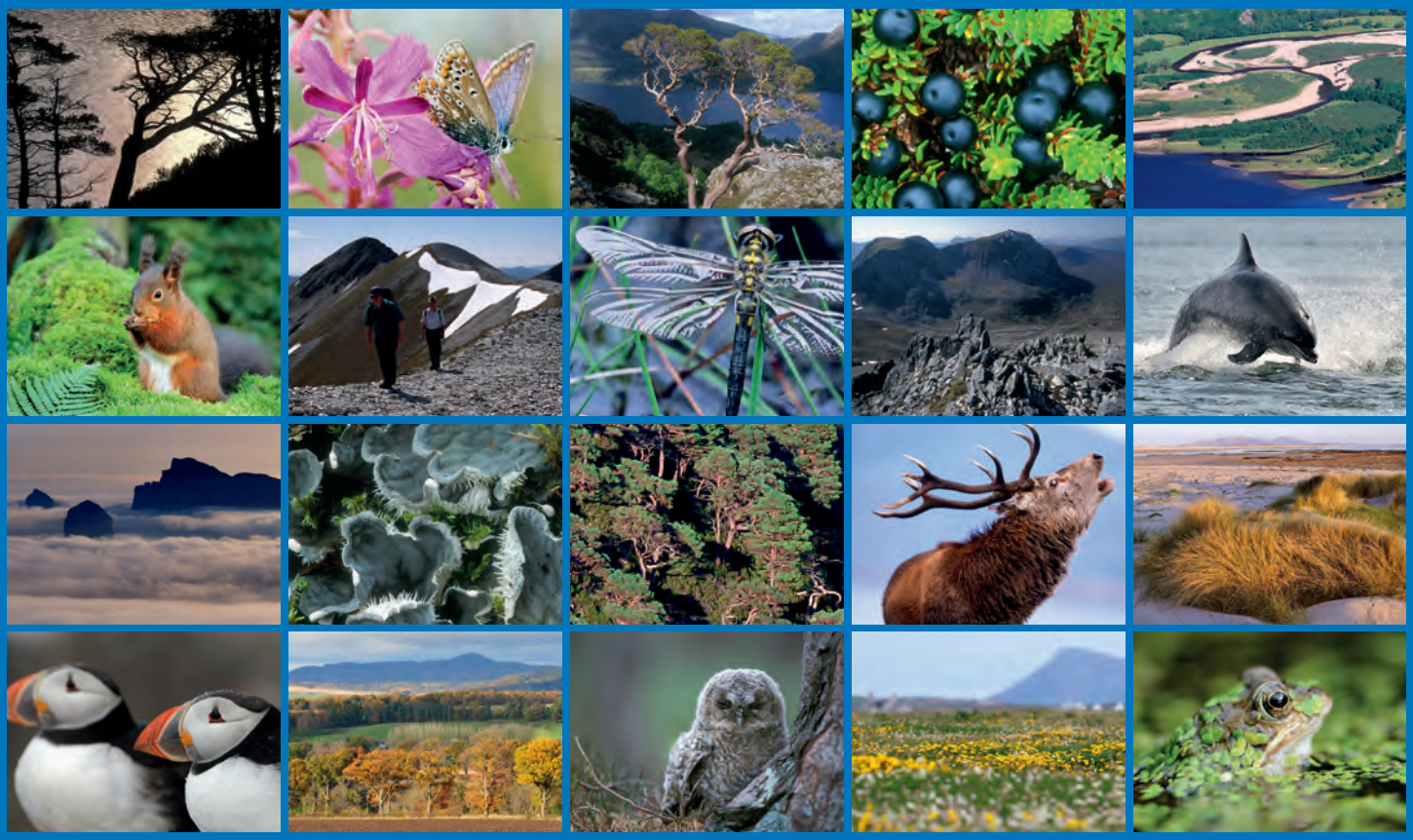
Scottish Natural Heritage
Research Report No. 1181

A woodland profile survey and assessment of herbivore impacts within the Ardnamurchan Deer Management Group part of the Sunart Special Area of Conservation (SAC) and 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 Ardnamurchan Deer Management Group part of the Sunart Special Area of Conservation (SAC) and Site of Special Scientific Interest (SSSI)

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Project No: 117136
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Keywords

Sunart SAC; oak woodland; Lochaber; herbivore impact assessment; Ardnamurchan DMG.

Background

The upland oak woodland habitat within the Sunart SSSI has been identified as being 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 and other aspects of the woodland structure.

Main findings

The diameter of all species of tree within 51 sample plots chosen at random throughout the woodland within the protected area was measured in May and August 2018. The numbers of browsed and un-browsed seedlings and saplings, both small and large, were counted in the same plots. A total of 2,693 seedlings and 1,343 saplings were found in 1.83 ha of woodland. The diameters of 824 live trees and 98 dead trees were measured in a slightly larger area of 2.07 ha of woodland. The main findings are as follows:

- Seedlings of birch were the second most abundant (628 per ha) after rowan (756 per ha) and they both had the lowest levels of browsing (43% and 53%). Downy birch trees are showing adequate regeneration to replace the mature trees in 31 of the 51 plots that were surveyed.
- Sessile oak dominates the woodland canopy and there are 49 and 47 mature and over-mature trees per ha, respectively. The density of sessile oak seedlings were low at 10 per ha. The densities of oak saplings are even lower at 6 per ha and only seven young reproductive trees were found in all of the plots surveyed (2.07 ha). There was inadequate regeneration to replace the population of mature and over-mature trees in 47 of the 51 plots surveyed.

- The population structure of sessile oak, rowan, hazel, holly, ash and alder are poor and at present unable to replace the extant mature and over-mature trees. This means that this part of the Sunart SAC is not satisfying one of its conservation objectives to maintain the 'viability of typical species as components of the habitat'.
- Shading by mature and over-mature trees is not thought to be significant in preventing in seedlings from growing through to saplings or young reproductive trees in all but possibly 13 of the 51 plots.
- There was no evidence that water-logging or dense vegetation or any other factors were seen to be limiting the establishment of seedlings.
- The high levels of browsing on seedlings and small saplings are considered to be primary reason for the poor recruitment of saplings from the cohorts of seedlings.
- Although sheep and goat are locally significant large herbivores, deer (roe and red) are considered to be the main large herbivore within the Sunart SAC/SSSI responsible for the browsing on the seedlings and saplings.
- Rhododendron bushes were present in just over a third (36%) of the plots and in six of the plots that could be accessed safely the density of rhododendron bushes is sufficiently high to prevent or restrict the establishment of native tree seedlings and saplings.

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Acknowledgements

I would like to thank all the landowners for giving permission to access their land in order to carry out the survey covered in this report. I want also to thank all the members of the survey team (Tom Edwards and Fraser Milne) for their efforts in completing the survey, and to Graeme Taylor of Scottish Natural Heritage in the helpful management of the contract.

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 biological features:

- Bryophyte assemblage
- Caledonian Igneous
- Chequered skipper (*Carterocephalus palaemon*)
- Dragonfly assemblage
- Eelgrass beds
- Egg wrack (*Ascophyllum nodosum* ecad *mackaii*)
- Lichen assemblage
- Moine
- Moths
- Otter (*Lutra lutra*)
- Rocky shore
- Saltmarsh
- Tertiary Igneous
- Upland assemblage
- Upland oak woodland
- Vascular plant assemblage

The whole of the SSSI covers 5,540.16 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 for each of the qualifying habitats:

- 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 Site Management Statement lists the following actions that need to take place in order that the SSSI woodland features 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 of 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. 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 exclosures are having the desired effect in allowing tree regeneration and recruitment, and its consequent effect on the structure of the woodland habitat.

2. METHODS

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 give 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

2.1 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 51 were within the area covered by the Ardnamurchan 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.

2.2 Field survey

2.2.1 Woodland profile

Most of the survey was carried out between the 7th and 13th May, but the survey of six plots had to be delayed until the 7th August due to the presence of a pair of breeding birds that are on Schedule 1 of the Wildlife & Countryside Act (1981 as amended).

The surveyors navigated their way to the sample plot locations using maps and hand-held GPS receivers (typically Garmin GS12s). Two sample plots had to be discarded due to problems of access (dense rhododendron, rocks and steep ground) making it impossible to reach the given grid references, and 14 plots 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. Forty 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. Eleven plots were between 10 and 20 metres of the grid reference supplied and three plots were between 20 and 42 metres from the grid reference.

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

The Forestry Commission guidance on monitoring even-aged stands of trees suggests that at densities of more than 300 stems per ha, a 11.2 m diameter plot is used, i.e. 100 m^2 (Kerr *et al.*, 2002). Where the densities are between 150 and 300 stems per hectare, a 16 m diameter plot is used, i.e. 200 m^2. In addition, where there was a high density of seedlings and/or saplings, i.e. more than 100 per 25.2 m diameter plot, a smaller plot size of 11.2 m or 16 m diameter centred on the same post were used.

It was necessary to reduce the area used for counting the number of seedlings and saplings at 20 plots (S34, S45, S54, S60, S78, S79, S86, S91, S96, S104, S110, S112, S114, S119, S127, S131, S141, S145, S146 and S198). The result was that the total area of the plots used for counting seedlings and saplings amounted to 1.83 ha.

The plot size was reduced for counting and measuring trees at 14 plots: S45, S54, S60, S78, S79, S86, S91, S96, S104, S112, S114, S127, S131 and S145. 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. This meant that the total area of the 51 plots used to count trees in different life-classes and to measure their diameters amounted to 2.07 ha.

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

2.2.2 Herbivore impacts

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

As four plots did not have any seedlings or saplings, the levels of browsing on (basal shoots, epicormic shoots, preferentially browsed species, sward and fraying/ bark stripping) was assessed as well using the criteria in Armstrong *et al*. (2014). The indicators and thresholds for the different levels of browsing are given in Annex 3.

If the indicator was absent 'NP' was recorded. Where there were too few epicormic shoots, basal shoots, seedlings, saplings or preferentially browsed species 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.

2.2.3 Quality control

Before the assessment was started Dr Headley spent at least one day with each of the other field surveyors (Tom Edwards 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.

2.3 Data analysis

2.3.1 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 (2.07 ha for trees and 1.83 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.

2.3.2 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.

The levels of grazing on the sward and the levels of fraying/bark stripping were not used in the calculations as they are less relevant to an understanding of the impact on the overall woodland structure. An overall browsing impact was calculated from each of the individual indicators by ranking the values and taking the median score. To calculate the median value, the number of indicators falling in each impact category was calculated and the central one was taken when these values are ranked in ascending order. For example, if there were five

indicators available the value of the 3rd indicator when placed in rank order was taken as the impact category for the sample plot as a whole. When there was an even number of indicators available the mid-point between the two indicators either side of the mid-point was used. In some cases this fell between two categories, such as Moderate and Low. In this instance an impact of Moderate/Low was taken.

2.3.3 Statistical analysis

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

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

3. RESULTS

3.1 Overall number of trees, seedlings and saplings

A total of 824 live trees and 98 dead trees were counted and measured within the 51 plots that were located within the Ardnamurchan DMG part of the Sunart SSSI. This gives a density of 399 live trees per ha (excluding seedlings and saplings) and 47 dead stems per ha (Table 1). A total of 2,693 seedlings and 1,343 saplings were counted. There were, therefore, 1,475 seedlings per ha and 737 saplings per ha in this set of samples (Table 1). Seedlings were present in 44 of the 51 sample plots, whilst small and large saplings were found in 34 and 24 sample plots, respectively. At least one tree was present in all but two of the 51 sample plots (S25 and S79).

3.2 Species composition

Overall, downy birch (*Betula pubescens*) and rowan (*Sorbus aucuparia*) are the most abundant species within this part of the Sunart SSSI (Figure 3). The total density of live individuals, including seedlings and saplings, of these species was 1,514 and 811 plants per ha, respectively (Table 1). Although sessile oak (*Quercus petraea*) is the next most abundant species at 121 plants per ha, it only makes up 5% of all seedlings, saplings and live trees that were counted. Hazel (*Corylus avellana*), holly (*Ilex aquifolium*) and alder (*Alnus glutinosa*) are the next most abundant species, and at 38, 46 and 31 live stems per ha, they only each make up between 1.2 and 1.7% of the composition of the woodland, respectively (Table 1). Ash (*Fraxinus excelsior*), Scots pine, grey willow (*Salix. cinerea*), wych elm (*Ulmus glabra*) and the non-native Sitka spruce (*Picea sitchensis*), fir (*Abies* sp.) and European larch (*Larix decidua*), are very minor components of the woodland and their combined numbers amount to only 3.3% of all live plants (Figure 3).

3.3 Woodland structure (life-classes)

Across the area surveyed as a whole there are far more seedlings than saplings and trees (Figure 4 and Table 1). The combined densities of pole stage and young reproductive trees was 150.4 stems per ha, which is only a little short of the density of mature trees (Figure 4). The densities of small and large saplings are higher than the mature or over-mature life-classes (Figure 4). The densities of senescent and “phoenix” life-classes are low, which suggests that not too many trees are dying of old age at present.

When the life-classes of individual species of tree are examined there are marked differences in the densities in each life-class (Table 1). The seedling stage is dominated mostly by rowan and downy birch seedlings (Figure 5). The small and large sapling life-classes are dominated by downy birch with rowan making only a small contribution to the population of saplings (Figure 5). Small saplings of sessile oak were present at low densities, but the large saplings of sessile oak were very rare with only two being found across the 1.83 ha of ground surveyed within the 51 plots (Table 1). Small and large saplings of alder were more abundant than those of sessile oak (Table 1).

Oak seedlings were relatively rare and were found in only nine of the 51 sample plots surveyed. The plots with oak seedlings are scattered throughout the survey area covered in this report (Figure 6). Sessile oak saplings were at even lower densities than the seedlings and small saplings were found in only four plots and large saplings in two plots (Figures 7 and 8). Only seven young reproductive sessile oak trees were found in all the plots that were surveyed. This compares with a total of 49 dead oak trees that were found in the same plots. In contrast to the sessile oak population, the population of downy birch is successfully reproducing with a higher density of seedlings and saplings than mature trees (Table 1). The densities of birch seedlings exceed those of the median density of mature birch trees (140 per ha) in 18 of the sample plots. There is considerable spatial variation in the recruitment of birch

seedlings and saplings (Figures 7, 8 and 9). There is probably sufficient recruitment of large saplings and young birch trees in over half of the plots to maintain the population of downy birch in the long term. This is because the combined densities of saplings, pole stage and young reproductive trees exceed those of mature live birch trees in 31 of 51 sample plots.

The recruitment of rowan saplings and young trees is moderate with the combined densities of small and large saplings and young reproductive trees exceeding the density of mature rowan trees in 16 of the sample plots. However, the densities of mature rowan trees were low with an average density of only 3.4 mature trees and 1 over-mature tree per ha (Table 1). Despite the very high densities of seedlings in some plots only 3.6% of these get to the small sapling stage and the densities of large rowan saplings is less than half that of the small rowan saplings.

Although there are good numbers of holly seedlings, very few saplings were found and only one pole stage and no young reproductive trees were found (Table 1). There is, therefore, an insufficient level of recruitment of young holly trees to replace the few mature holly trees found in this survey.

Hazel has a similarly low number of saplings and young reproductive trees compared to the densities of mature trees (Table 1).

Overall, alder has a higher density of saplings and young reproductive trees than mature or over-mature trees (Table 1). It appears that there is adequate recruitment of juvenile and young alder trees in three of the four plots where alder was present.

The other species of tree native to these woods are ash, wych elm and grey willow. Scots pine is native to the area but the large mature Scots pine tree in the area around Dùn Ghallain between Camasina and Laga Bay were all of similar size and close to a forestry plantation. These trees are almost certainly planted.

Figures 10 to 14 show the densities of each of the different life-classes of tree in each plot across the Ardnamurchan DMG part of the Sunart SSSI. Pole stage trees are at high densities in a few plots and largely absent from most other plots whilst young reproductive trees are found in most plots throughout the study area (Figure 11). Over-mature and especially “phoenix” trees were found in the patch of woodland to the north of Glenborrodale (Figures 12 and 13). Dead trees were found in most plots, except those in the woodland to the north of Glenborrodale (Figure 14).

3.4 Size/age distribution

The sessile oak trees within this part of the Sunart SSSI are composed mostly of small and medium sized trees (Table 3 and Figure 15). The densities of seedlings, small saplings and large saplings are much lower than those of all size classes of tree, except for the very large trees (Figure 15). There is no obvious pattern to the spatial distribution of live sessile oak trees across the area covered in this report (Figure 16). The median diameter of all the live oak trees was 28 cm and the inter-quartile range was from 21 to 36 cms. Assuming radial growth rates in the region of 1 to 2 mm per annum, then most of the sessile oak trees were established between 52 and 180 years ago (Büyüksair *et al.*, 2018; Härdtle *et al*., 2013).

The downy birch population has more seedlings than saplings, which are themselves more abundant than live trees in any size class (Figure 17). Not surprisingly there are very few large (dbh 40 to 55 cm) and no very large (dbh > 55cm) downy birch trees (Figure 17). Downy birch trees were most abundant in the centre of the survey area and were largely absent from the wood to the west of Ben Hiant (Figure 18). The median diameter of all live birch trees was 11 cm and the inter-quartile range was between 8 and 17 cms.

The rowan and holly populations are dominated by seedlings (Figures 19 and 20). The apparent survival rate of both the rowan and holly seedlings to the large sapling stage is 2%. The low survival of these species through to the large sapling stage is the main reason for the low frequency of trees of these species within the Sunart SSSI's upland oak woodland habitat (Table 1). Most small trees of holly and rowan were found growing out of relatively inaccessible rock outcrops within the sample plots.

Hazel and alder can also be important constituents of upland oak woodland habitat. The cohort of hazel saplings were at lower densities than the small or medium sized trees (Figure 21). Many of the large sapling sized stems of hazel and alder were part of multiple stemmed stools of an older tree. These species of tree naturally coppice, and therefore, stem densities can give an exaggerated impression of the abundance of a species. Therefore, the apparently high levels of recruitment of small and large saplings of alder are not necessarily of all new individuals, but some are of new vegetative off-shoots from existing trees (Figure 22).

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 basal area averaged across all live trees and plots surveyed was 17.5 m^2 per ha (Table 4). This represents just under 0.2% of the ground area that is occupied by the trunks of trees. At 18 m^2 per ha the median basal area is the same as the mean basal (Table 5). As one would expect most of the basal area is in the mature and over-mature life-classes of tree (Figure 23).

Sessile oak accounts for 50% of the total basal area of live trees measured, with downy birch contributing another 25% to the total live basal area (Table 4). Scots pine makes a significant contribution (14%) to the total basal area due to a small number of large trees in a few plots in the area around Dùn Ghallain. Alder and European larch are similar in that a relatively few large stemmed trees make a greater contribution to the total basal area than the number of stems present (Tables 3 and 5). Together, all the other species of tree (ash, hazel, rowan, holly, wych elm and grey willow) account for less than 6% of the basal area of all live trees (Table 4).

3.6 Non-native species

The larch trees in plot S22 at Rubha Shainphort near Camasinas are not native and are planted, whilst the single trees in plots S66 and S147 may or may not have been deliberately planted. Only one seedling of this species was found in plot S22 as these mature trees. Seedlings of Sitka spruce were found in four plots and young reproductive trees were found in one other plot. These plots do not have any mature Sitka spruce trees immediately close by. There are, however, a number of Sitka spruce plantations immediately adjacent to or close to the Sunart SAC/SSSI.

One unidentified fir (*Abies* sp.) seedling was found in one plot (S43).

Rhododendron bushes were recorded in 16 plots, including two where they prevented access (S164 and S188), and they made it difficult to survey the area around Camasinas. The density of rhododendron bushes is almost certainly preventing tree regeneration in this area and this was evident in plots S9, S110, S115, S164 and S207 plots. This is not necessarily the worst affected area, as another area with a severe infestation of rhododendron is around Glenborrodale, especially in and around plots S34, S43, S92, S96, S104, S125, S127, S188 and S198. Plots S91, S119 and S140 also have rhododendron, but the plants have not become especially tall and dense. Recent clearance of the rhododendron in plot S34 has allowed significant regeneration of downy birch, but no sessile oak seedlings were present

despite the presence of trees of this species in and around the plot. The densities of rhododendron are considered to be sufficient to be preventing or reducing the establishment of seedlings and/or saplings of native species of tree in six of the sample plots surveyed, plus the two which could not be accessed due to the impenetrable nature of the thicket of rhododendron bushes.

3.7 Herbivore impacts

Browsing levels on seedlings, small saplings and large saplings across all the species were 51%, 70% and 32%, respectively (Table 6). Levels of browsing on seedlings of downy birch were significantly lower than those on all other species other than Sitka spruce (Table 6). Browsing levels on seedlings of alder, ash, European larch, hazel and sessile oak were very high at over 90% (Table 6). The lower browsing on rowan and downy birch seedlings may in part be due to the small size of these far more numerous seedlings resulting in them being hidden below the field layer during the summer months in their first year of growth.

The browsing levels on small saplings of alder, rowan and sessile oak were higher than that on downy birch (Table 6). There were too few small saplings of holly, hazel, willows and ash to make any valid comparisons. The fact that none of the large saplings of rowan, alder, holly, sessile oak and willows had more than 50% of their shoots browsed may reflect the fact that most of the branches were above the browsing level of any large herbivores.

When the browsing levels are analysed across individual plots the inter-quartile range for browsing on seedlings was between 19 and 93% with the median browsing level being 77% (Table 7). The browsing levels on all seedlings were high throughout the survey area, except for the Glenborrodale Nature Reserve (Figure 24). Browsing levels on small saplings were also high throughout most of the survey area with only a few plots close to the road at Glenborrodale, Laga and Port nan Gall with no browsing of the small saplings (Figure 25). There are too few plots with large saplings to discern any spatial pattern in the levels of browsing of large saplings (Figure 26).

There are high levels of browsing within the deer fence around the woodland to the west of Ben Hiant. Stags were seen within the woodland and a group of red deer were seen to cross through a gap in the fence at the time of the survey.

Browsing levels on epicormic shoots could not be assessed in 30 sample plots because they were absent and the levels of grazing on the sward could only be assessed in 26 plots (Table 8). The absence of suitable species to assess grazing on the sward was one reason for not being able to assess this latter indicator. The browsing/grazing impacts were generally High on the seedlings and saplings, and epicormic and basal shoots of trees (Table 8). Fraying and bark stripping on seedlings and saplings was very rarely observed and therefore the median impact for this indicator is Low (Table 8).

Overall herbivore impacts were High in most of the area surveyed except within the Glenborrodale nature reserve (Figure 27). Overall herbivore impacts within the Glenborrodale Nature Reserve are almost certainly Low due to the presence of a deer fence. The plots also close to the village of Glenborrodale have Low overall herbivore impacts probably due to their proximity to the road and houses.

3.8 Herbivores

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.

Evidence for the presence of deer, especially red deer, was found in most plots. The evidence included dung and hoof prints, but one dead stag was found in a power-line wayleave at Camasinas. As mentioned above stags and hinds were seen within the exclosure Uamha na Creadha and they were seen running through a gap in the fence. The area immediately around this exclosure is used for hill grazing by sheep. It is probably this same hill grazing that use the small fragments of wood above Camas nan Geall.

A small group (5 to 10 individuals) of goats browse in the area around Camasinas and these were apparently released into this area in the last 5 to 10 years.

3.9 Potential for tree regeneration

All areas of the Sunart SSSI that were surveyed have the potential to support trees and there is no obvious reason why seedlings or saplings should not establish in any of these areas. There are plenty of seed sources for the regeneration of downy birch and sessile oak. Although mature trees of rowan, hazel, holly and alder are much rarer there is no reason why their seedlings and saplings should not establish as there are plenty of seedlings of rowan and holly despite the mature trees of these species being present at low densities (3.4 and 1.5 trees per ha).

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 large sapling generation is virtually absent and there were relatively few small saplings present (Figure 15). The density of oak seedlings was also very low and much 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 and Figure 17). Holly, rowan, hazel and alder are other typical species of upland oak woodland habitat. The holly and rowan populations are not viable as the vast majority of seedlings do not survive through to the small or large sapling stages (Figures 20 and 19). Similarly the hazel population is not currently able to recruit new individuals due to the lack of large saplings.

The Sunart SSSI was been designated for its upland oak woodland and this habitat supports a number of other features within this protected area, including the internationally important assemblages of lichens and bryophytes. Therefore, any reduction in the cover of oak or any of the other trees that support the mosses, liverworts and lichens that grow on the trunks and larger branches (epiphytes) will be detrimental to this important feature. Birch tends not to support so many of these epiphytic organisms. The levels of recruitment of new sessile oak trees are worryingly low with far fewer seedlings and saplings than mature trees. Any self-sustaining population of plants or animals has to produce more offspring than adults as most young individuals die before they get to a reproductive age (Begon *et al*., 2006). When the number of individuals in different cohorts is plotted the resultant graph, for trees at least, is normally an inverted J-shaped curve (Gao *et al*., 2017; Edwards & Mason, 2006). In the case of the sessile oak it is currently an unsustainable population as there are very few seedlings as well as the fact very few of these seedlings are currently getting through to the pole stage or young reproductive trees (Table 1 and Figure 6). Therefore, the Conservation Objectives are not currently being met within at least for this part of the Sunart SAC.

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 and 7 are satisfied. In terms of the cover of non-native species in the tree canopy layer, the European larch and Sitka spruce trees are the only main non-native species present, but their combined basal area, a surrogate for cover, amounts to only 0.533 m^2 per ha, which is only 3% of the total basal area of all live trees (Table 4). Therefore, target 8 is satisfied. However, the presence of rhododendron in about a third of the plots and in six of the 53 plots it was present as a dense thicket. Therefore, rhododendron probably makes up over 10% of the cover of the shrub layer within the woodland habitat and consequently the Sunart SSSI would fail the condition assessment on this criterion.

A total of 11 fallen lying trees with diameters greater than 20 cm were found in the 2.1 ha surveyed, whilst there were 32 standing dead trees per ha. Therefore, both criteria in target 5 were satisfied.

Target 1 is only satisfied in that large saplings (3 to 5 metres tall) were present in 47% 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 16 of the 53 sample plots assigned to this part of the Sunart SAC/SSSI. The densities of this invasive non-native shrub were observed to be significant in affecting the regeneration of the native trees and shrubs in about 16% of the woodland. The densities of rhododendron bushes were so high as to cause significant problems in preventing access to the woodland around Camasinas. The woodland around Glenborrodale also has extensive areas of rhododendron some of which forms dense thickets. This means that the 5^{th} and 7^{th} of the conservation objectives listed in the introduction are not being met.

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

There are two problems with the oak population: 1) there appears to be few seedlings establishing and 2) very few of the seedlings are surviving to the large sapling stage. The seedlings of oak are currently at densities that are probably too low to replace the mature and over-mature trees in all but three of the 51 sample plots.

The lack of seedlings and small saplings surviving through to large sapling and young trees not only applies to sessile oak, but also to the populations of rowan, holly, hazel, ash and wych elm.

The lack of oak seedlings in the plots surveyed is unlikely to be due to a lack of seed production as the canopy is dominated by sessile oak in 24 of the 51 plots. A low density of sessile oak seedlings could be attributed to predation of the acorns by voles, squirrels and various species of bird (Shaw, 1968). However, conversely a lack of regeneration of oaks has sometimes been linked to a lack of red squirrels or jays caching seeds which subsequently germinate before being re-found by these animals.

The poor establishment of saplings and young reproductive trees from seedlings could be attributed to: 1) browsing by large herbivores, 2) insufficient light and/or 3) disease. There was no evidence that plant pathogens had resulted in the death of any of the seedlings and saplings of any species.

Excessive shading can prevent seedlings and saplings of the more light demanding species from establishing, as shown for birch (Jarvis, 1964). The basal area of trees can be used as a proxy for the amount of light likely to reach the floor of conifer plantations and to allow for the natural regeneration of trees (Hale 2004). Sessile oak seedlings and saplings are moderately shade tolerant and can apparently tolerate shading levels as low as 50% of ambient light (Jarvis, 1964; Annighöfer *et al*., 2015; Březina & Dobrovolný, 2011). Out of the 51 plots surveyed only 13 plots had basal areas greater than 25 m^2 ha^{-1}. The highest density of oak seedlings found in this survey (200 per ha) was in plot S141 which had a basal area of 33.1 m^2 ha^{-1}. Therefore, the lack of establishment of sessile oak saplings and possibly the other species of tree cannot be realistically attributed to significant amounts of shading by older trees. This, however, does not exclude the fact that rhododendron thickets are almost certainly preventing tree regeneration across about 11% of the woodland.

Given the lack of evidence for shading and disease for preventing the regeneration of sessile oak within the woodland habitat at Sunart SSSI it only leaves browsing as the most likely factor. Apart from birch, rowan and Sitka spruce, the browsing of the leading shoots of all seedlings was very high at 85% or more. Browsing of the small saplings is also very high at 70%. Browsing is, therefore, considered to be the main, and almost certainly the only reason for the lack of regeneration of trees within the woodland habitat within this part of the Sunart SAC/SSSI. Birch has a greater degree of resilience to browsing due to it storing a greater proportion of its carbohydrate reserves belowground, whilst Sitka spruce is less palatable to browsers and is consequently less likely to be browsed by large herbivores (Forestry Commission).

Although sheep and goats are probably important large herbivores in around Ben Hiant and Camasinas, respectively, the majority of the upland oak woodland covered within this survey is not affected by these animals. This only leaves red and roe deer as the most important large herbivore that regularly browse on tree seedlings and saplings. The evidence for the impact of sheep and/or deer in preventing the regeneration of broad-leaved trees in upland woodland is long-standing and widespread (Shaw, 1968; Pigott, 1983; Beaumont *et al*., 1995; Rao, 2017).

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 sessile oak 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 sessile oak population within the Sunart SSSI that lies within the Ardnamurchan DMG is poor, due to a low number of saplings, pole stage and young reproductive trees.
- Far more young 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 and/or predation of the acorns produced 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 goats and sheep 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.

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ANNEX 1: TABLES

Table 1. The number of trees (per ha) in each life-class for each species of tree surveyed across the Ardnamurchan Deer Management Group (DMG) part of the Sunart SSSI.

Species of tree	Life-class										
	Seed-lings	Small saplings	Large saplings	Pole stage	Young reproductive	Mature	Over-mature	Senescent	"Phoenix"	**Total Live**	Dead
downy birch	628.4	301.9	362.1	66.8	59.1	70.2	16.9	2.4	6.3	**1,514.2**	9.2
rowan	756.1	27.4	12.1	1.0	8.2	3.4	1.0	0.0	0.0	**809.1**	0.5
sessile oak	10.4	4.9	1.1	0.0	3.4	49.4	47.0	1.9	2.4	**120.5**	23.7
holly	42.7	1.1	0.5	0.0	0.5	1.5	0.0	0.0	0.0	**46.3**	0.0
hazel	26.8	1.1	0.0	0.0	0.5	8.2	0.5	0.5	0.5	**38.1**	0.0
alder	2.7	7.7	7.1	0.0	6.3	4.4	2.4	0.0	0.0	**30.6**	0.0
ash	4.9	1.1	0.0	0.0	0.0	3.9	3.4	0.0	0.0	**13.3**	0.0
Scots pine	0.0	0.0	0.0	0.0	1.0	10.7	0.0	0.0	0.0	**11.6**	2.4
European larch	0.5	0.0	0.0	0.0	0.0	8.7	0.0	0.0	0.0	**9.3**	2.4
grey willow	0.0	0.0	6.6	0.0	0.0	1.0	0.0	0.0	0.0	**7.5**	0.0
Sitka spruce	2.2	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	**6.1**	0.0
wych elm	0.0	0.0	0.0	0.0	0.5	1.0	0.0	0.5	0.0	**1.9**	0.5
unassigned willow	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.1**	0.0
unassigned fir	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.5**	0.0
unknown species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	8.7
All species	**1,475.4**	**346.3**	**391.2**	**66.8**	**84.7**	**161.7**	**71.2**	**5.3**	**9.2**	**2,611.8**	**47.4**

Table 2. Summary statistics for the density (per ha) of seedlings, small saplings, large saplings and all live trees collected from each of the 51 sample plots surveyed.

Species	Life-class	Statistic						
		Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
Density of all plants of all species (per ha)	Seedlings	2,641	4,779	0	80	820	3,680	30,100
	Small saplings	694	1,497	0	0	80	500	8,400
	Large saplings	926	3,280	0	0	0	250	21,000
	Pole stage	195	570	0	0	0	0	2,842
	Young reprod'	81	159	0	0	20	65	3,000
	Mature	164	169	0	40	120	265	802
	Over-mature	76	86	0	0	40	120	406
	Senescent	2	9	0	0	0	0	40
	"Phoenix"	14	47	0	0	0	0	298
	All live trees	532	651	0	200	340	606	3,248
	All dead trees	46	81	0	0	0	60	341
sessile oak	Seedlings	12	36	0	0	0	0	203
	Small saplings	4	15	0	0	0	0	100
	Large saplings	0.8	3.9	0	0	0	0	20
	All live trees	89	127	0	0	40	120	582
downy birch	Seedlings	1,390	4,506	0	0	199	1,060	30,451
	Small saplings	659	1,528	0	0	0	391	8,526
	Large saplings	893	3,274	0	0	0	211	21,315
	All live trees	369	643	0	20	140	300	3,045
rowan	Seedlings	1,056	1,588	0	0	200	1,634	5,521
	Small saplings	27	80	0	0	0	0	441
	Large saplings	29	185	0	0	0	0	1,320
	All trees	14	38	0	0	0	0	203
holly	Seedlings	135	828	0	0	0	0	5,887
	Small saplings	2	14	0	0	0	0	102
	Large saplings	0.4	2.8	0	0	0	0	20
	All live trees	2	7	0	0	0	0	40
alder	Seedlings	2	12	0	0	0	0	80
	Small saplings	6	39	0	0	0	0	281
	Large saplings	5	29	0	0	0	0	201
	All live trees	11	47	0	0	0	0	281
hazel	Seedlings	51	166	0	0	0	0	1,015
	Small saplings	0.8	3.9	0	0	0	0	20
	All live trees	9	23	0	0	0	0	100
grey willow	Small saplings	2	14	0	0	0	0	100
	Large saplings	5	31	0	0	0	0	221
	All live trees	4	28	0	0	0	0	203
ash	Seedlings	12	60	0	0	0	0	406
	Small saplings	0.8	4	0	0	0	0	20
	All live trees	14	72	0	0	0	0	508
wych elm	All live trees	2	9	0	0	0	0	60
Scots pine	All live trees	13	41	0	0	0	0	203
Sitka spruce	Seedlings	3	15	0	0	0	0	102
	All live trees	3	22	0	0	0	0	160
larch	Seedlings	0.4	2.8	0	0	0	0	20
	All live trees	7	45	0	0	0	0	321
fir	Seedlings	0.4	2.8	0	0	0	0	60

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	194.2	17.9	2.4	0.0	5.8	1.9	1.5
sessile oak	41.6	39.2	13.6	3.4	15.5	6.8	1.5
alder	7.7	1.9	0.5	0.0	0.0	0.0	0.0
hazel	3.9	0.5	0.0	0.0	0.0	0.0	0.0
Scots pine	1.5	1.9	3.9	4.4	1.9	0.0	0.5
rowan	11.6	0.5	0.0	0.0	0.5	0.0	0.0
European larch	3.9	3.9	0.5	0.0	1.9	0.0	0.5
ash	3.4	3.4	0.5	0.0	0.0	0.0	0.0
grey willow	1.0	0.0	0.0	0.0	0.0	0.0	0.0
holly	1.5	0.5	0.0	0.0	0.0	0.0	0.0
wych elm	1.5	0.5	0.0	0.0	0.0	0.5	0.0
Sitka spruce	3.9	0.0	0.0	0.0	0.0	0.0	0.0
unknown species	0.0	0.0	0.0	0.0	6.3	1.5	1.0
All species	275.5	70.2	21.3	7.7	32.0	10.7	4.8

Table 4. The basal area (m^2 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	0.000	0.038	3.232	5.218	0.085	0.147	0.704	**8.719**
downy birch	0.463	0.407	2.418	0.884	0.124	0.162	0.194	**4.458**
Scots pine	0.000	0.017	2.381	0.000	0.000	0.000	0.224	**2.398**
alder	0.000	0.057	0.305	0.168	0.000	0.000	0.000	**0.531**
European larch	0.000	0.000	0.508	0.000	0.000	0.000	0.029	**0.508**
ash	0.000	0.000	0.159	0.231	0.000	0.000	0.000	**0.390**
hazel	0.000	0.001	0.195	0.002	0.029	0.005	0.000	**0.233**
rowan	0.000	0.055	0.071	0.026	0.000	0.000	0.009	**0.152**
holly	0.000	0.001	0.073	0.000	0.000	0.000	0.000	**0.073**
wych elm	0.000	0.005	0.049	0.000	0.001	0.000	0.006	**0.056**
Sitka spruce	0.000	0.025	0.000	0.000	0.000	0.000	0.000	**0.025**
grey willow	0.000	0.000	0.006	0.000	0.000	0.000	0.000	**0.006**
unknown species	0.000	0.000	0.000	0.000	0.000	0.000	0.192	**0.000**
All species	**0.463**	**0.608**	**9.397**	**6.529**	**0.238**	**0.314**	**1.358**	**17.550**

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 that is within the Ardnamurchan DMG.

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**
birch	651	496	43	175	376	68	434	227	34	**2,359**	**47**
rowan	647	733	53	12	38	76	22	0	0	**1,452**	**53**
holly	12	66	85	1	1	50	1	0	0	**81**	**83**
hazel	3	46	94	1	1	50	0	0	NA	**51**	**92**
alder	0	5	100	0	14	100	13	0	0	**32**	**59**
sessile oak	1	18	95	1	8	89	2	0	0	**30**	**87**
all willows	0	0	NA	0	2	100	12	0	0	**14**	**14**
ash	0	9	100	1	1	50	0	0	NA	**11**	**91**
Sitka spruce	3	1	25	0	0	NA	0	0	NA	**4**	**25**
European larch	0	1	100	0	0	NA	0	0	NA	**1**	**100**
All species	**1,317**	**1,376**	**51**	**191**	**441**	**70**	**484**	**227**	**32**	**4,036**	**51**

Table 6. The summary statistics calculated for the levels of browsing on seedlings, small saplings and large saplings in each of the 51 sample plots surveyed.

Life-class	Statistic						
	Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
Seedlings	65	24	0	19	77	93	100
Small saplings	74	36	0	45	90	100	100
Large saplings	4	22	0	0	0	0	100

Table 7. The number of sample plots with different levels of herbivore impact for each of six indicators in the vegetation within the part of the Sunart SSSI covered by the Ardnamurchan DMG. Cells highlighted in yellow indicate the median impact level for that indicator.

Browsing impact indicator		Herbivore Impact Class							Not applicable
	Increasing	Very High	Very High/High	High	High/Moderate	Moderate	Moderate/Low	Low	
Basal shoots	0	0	0	21	6	3	0	10	11
Epicormic shoots	0	0	0	18	0	0	0	3	30
Seedlings and saplings	0	2	0	28	1	1	0	10	9
Preferentially grazed spp.	1	0	0	18	6	4	0	10	13
Sward	0	0	0	7	0	5	0	14	25
Bark Stripping	0	0	0	0	0	0	0	51	0
Overall Impact	**1**	**0**	**1**	**29**	**6**	**3**	**0**	**10**	**2**

ANNEX 2: FIGURES

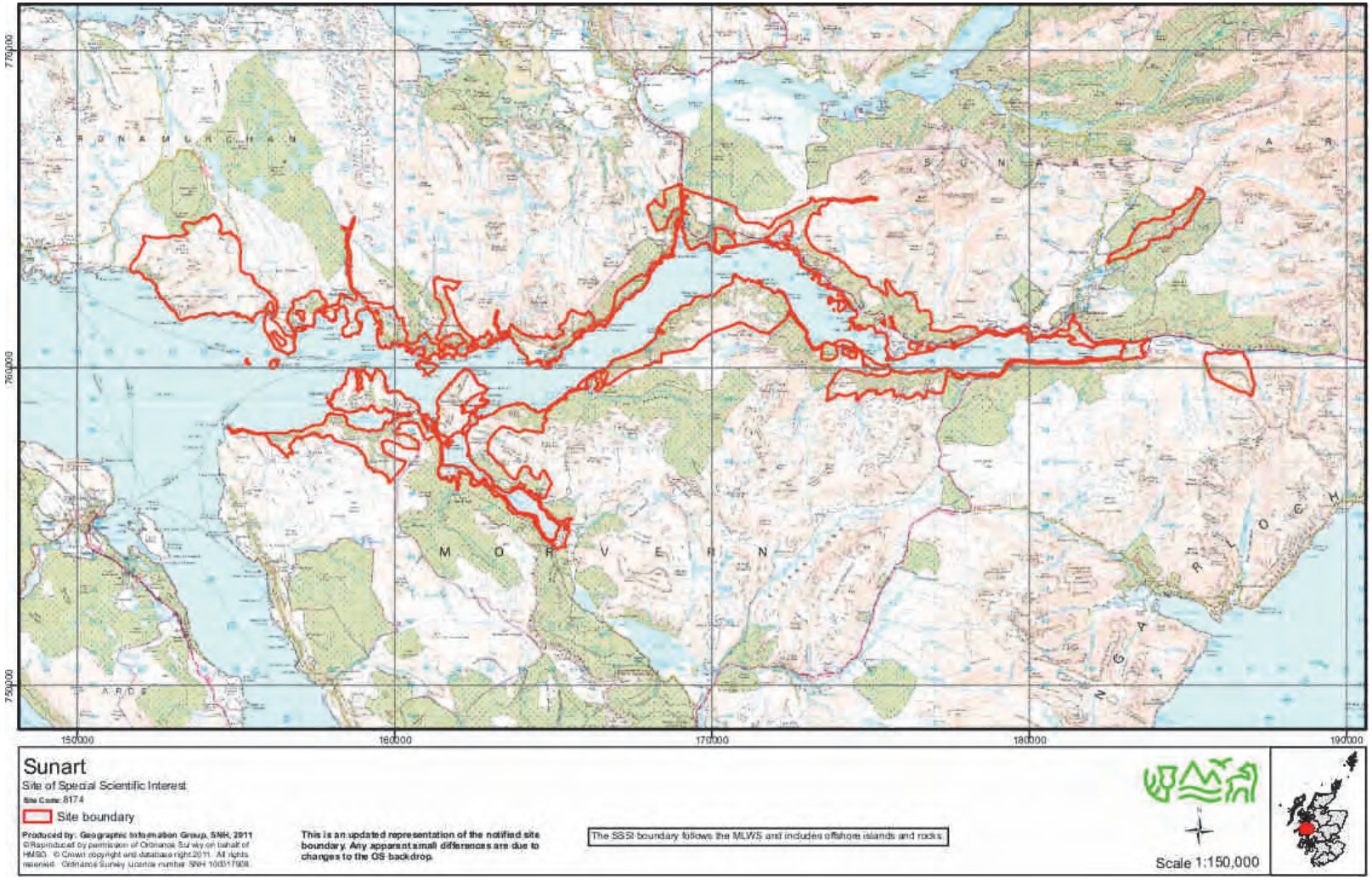

Figure 1. Map showing the location and boundary of the Sunart SSSI.

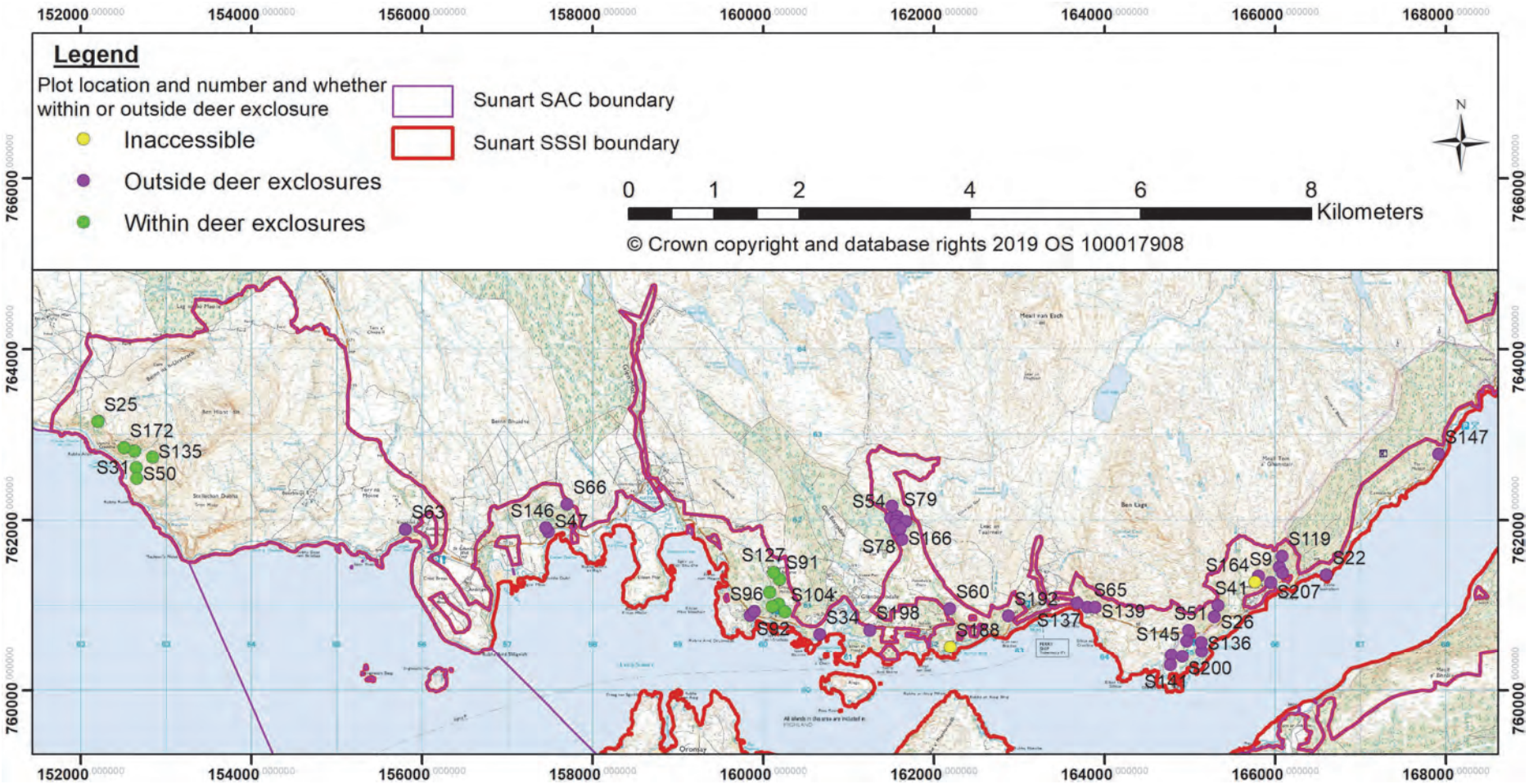

Figure 2. Map showing the location of the 53 sample plots within the Ardnamurchan Deer Management Group (DMG) part of the Sunart SSSI taken to describe the structure and assess the herbivore impacts on the upland oak woodland habitat.

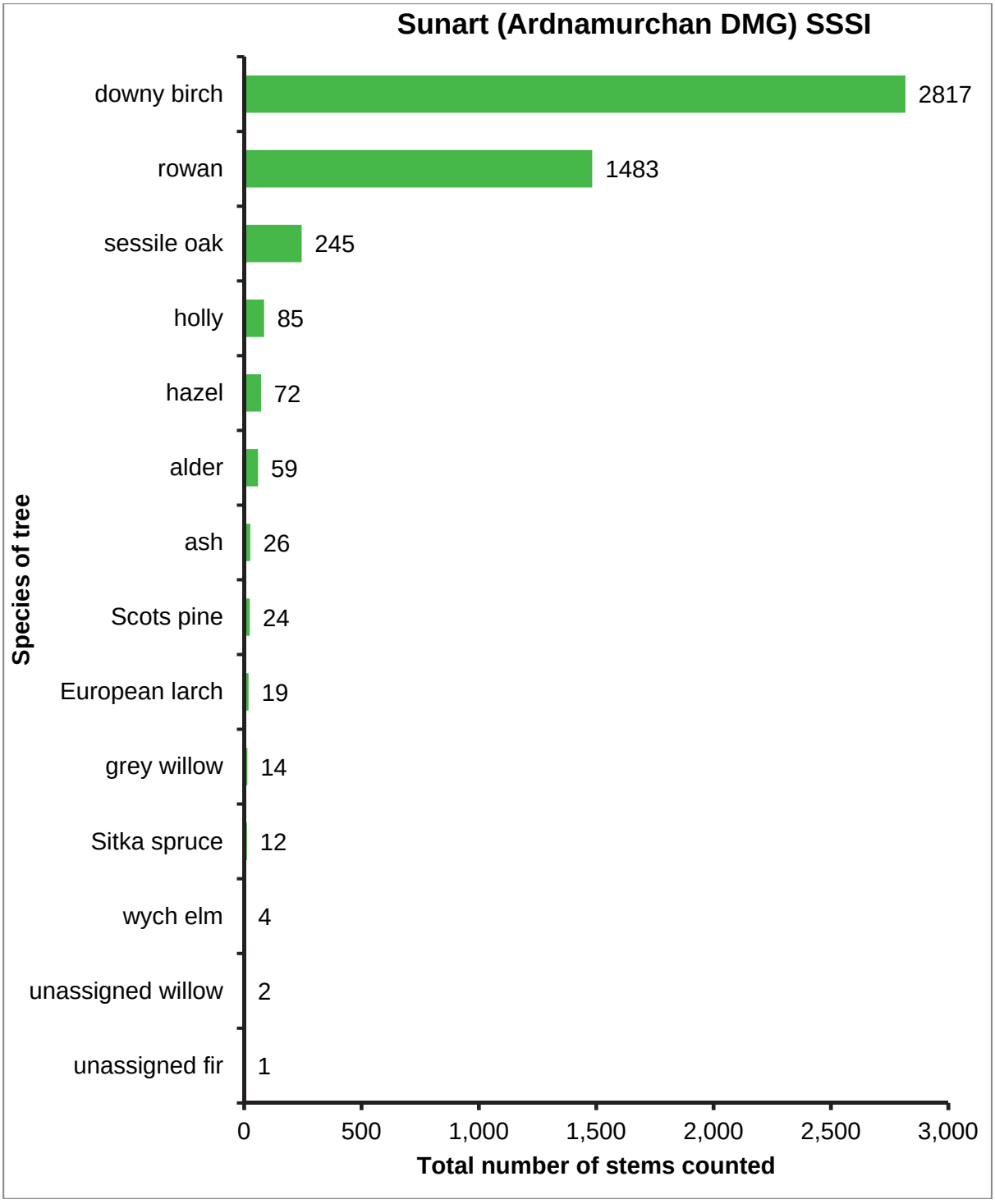

Figure 3. The total number of seedlings, saplings and live trees measured and counted for each species of tree surveyed across the Sunart SSSI that were also within the Ardnamurchan DMG.

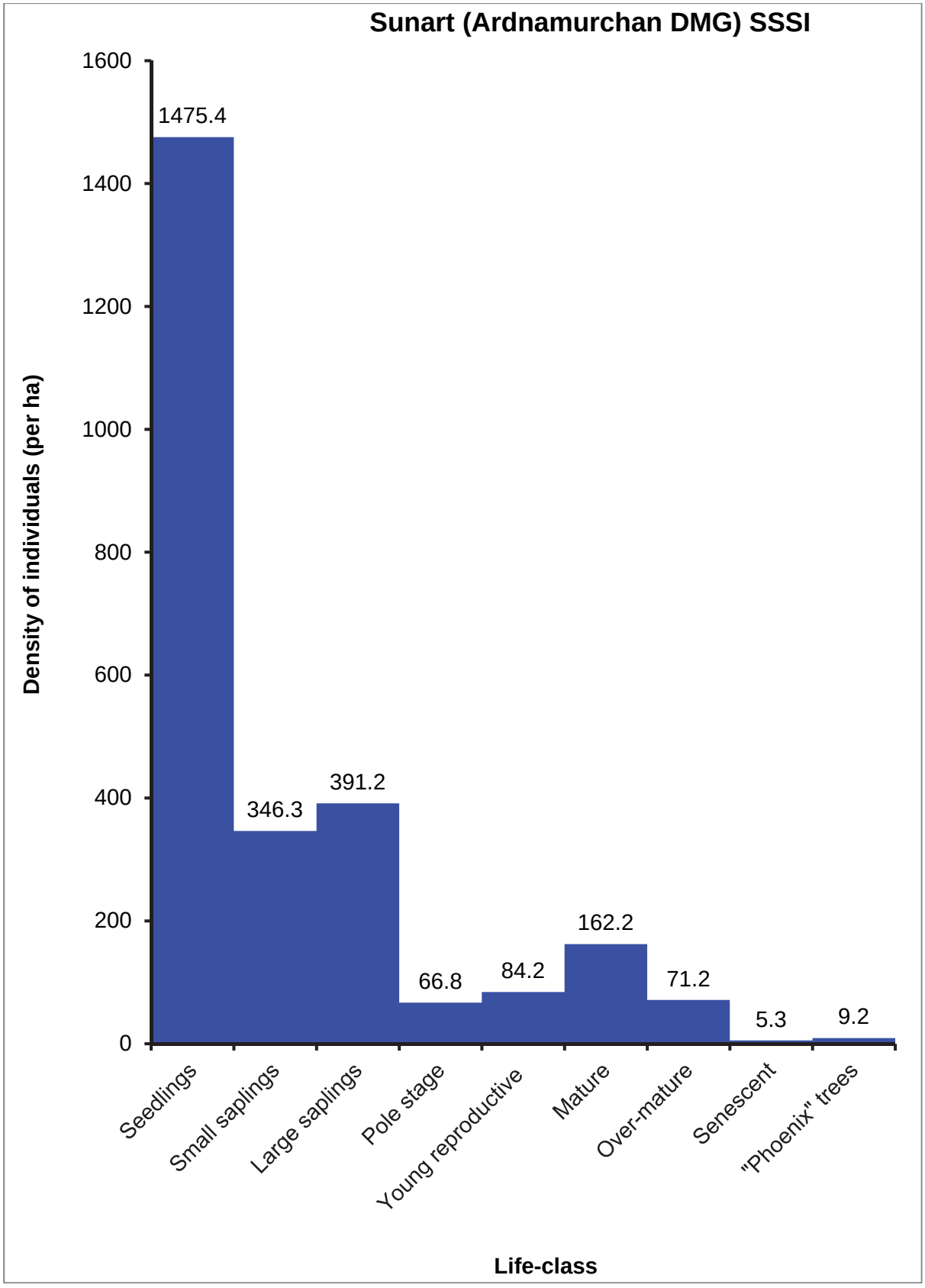

Figure 4. The density of individuals (seedlings, saplings and live trees) of all species of tree in each life-class surveyed within the Sunart SSSI that were also within the Ardnamurchan DMG.

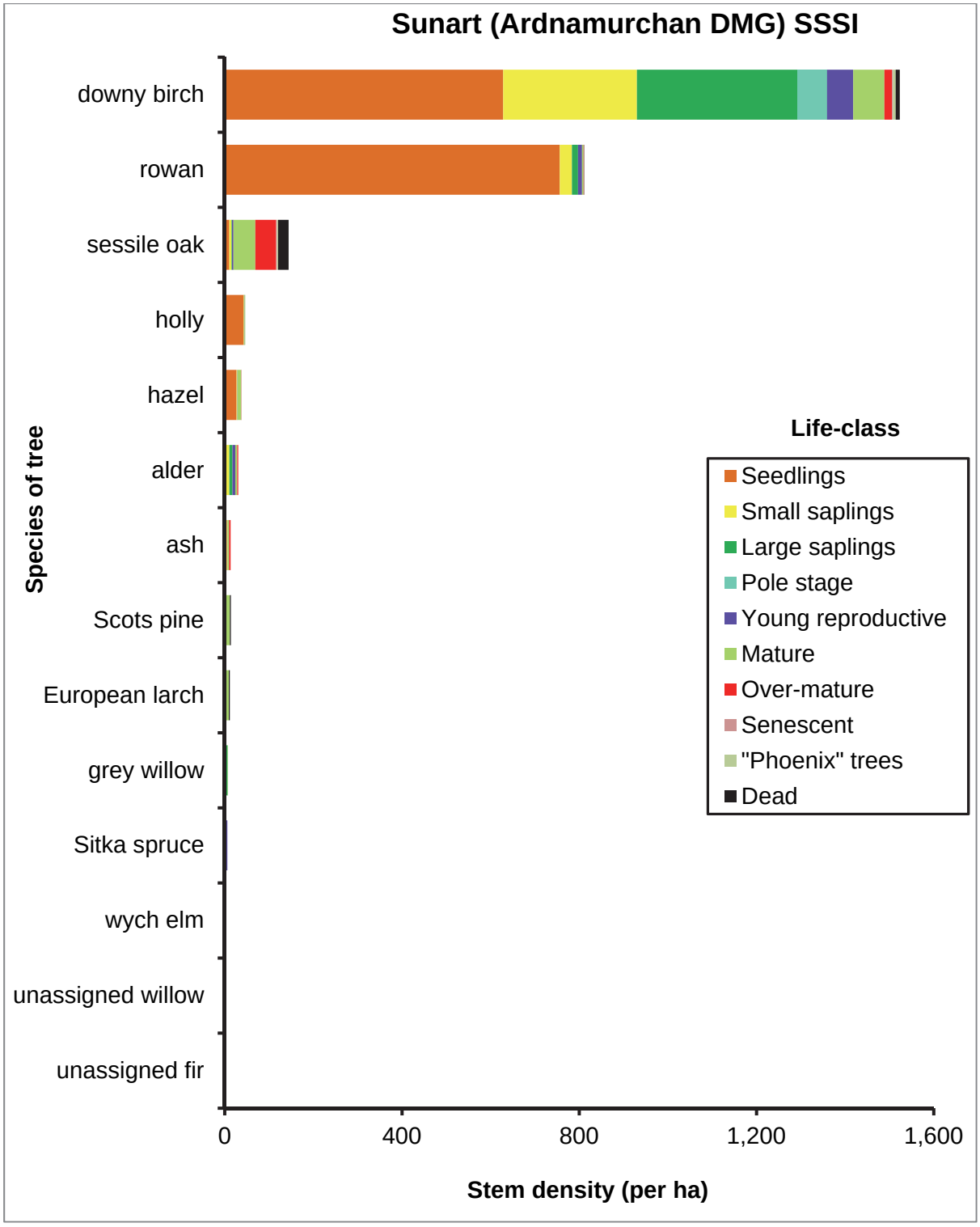

Figure 5. The density of individuals (per ha) in each life-class for each species of tree surveyed across the Sunart SSSI that were also within the Ardnamurchan DMG.

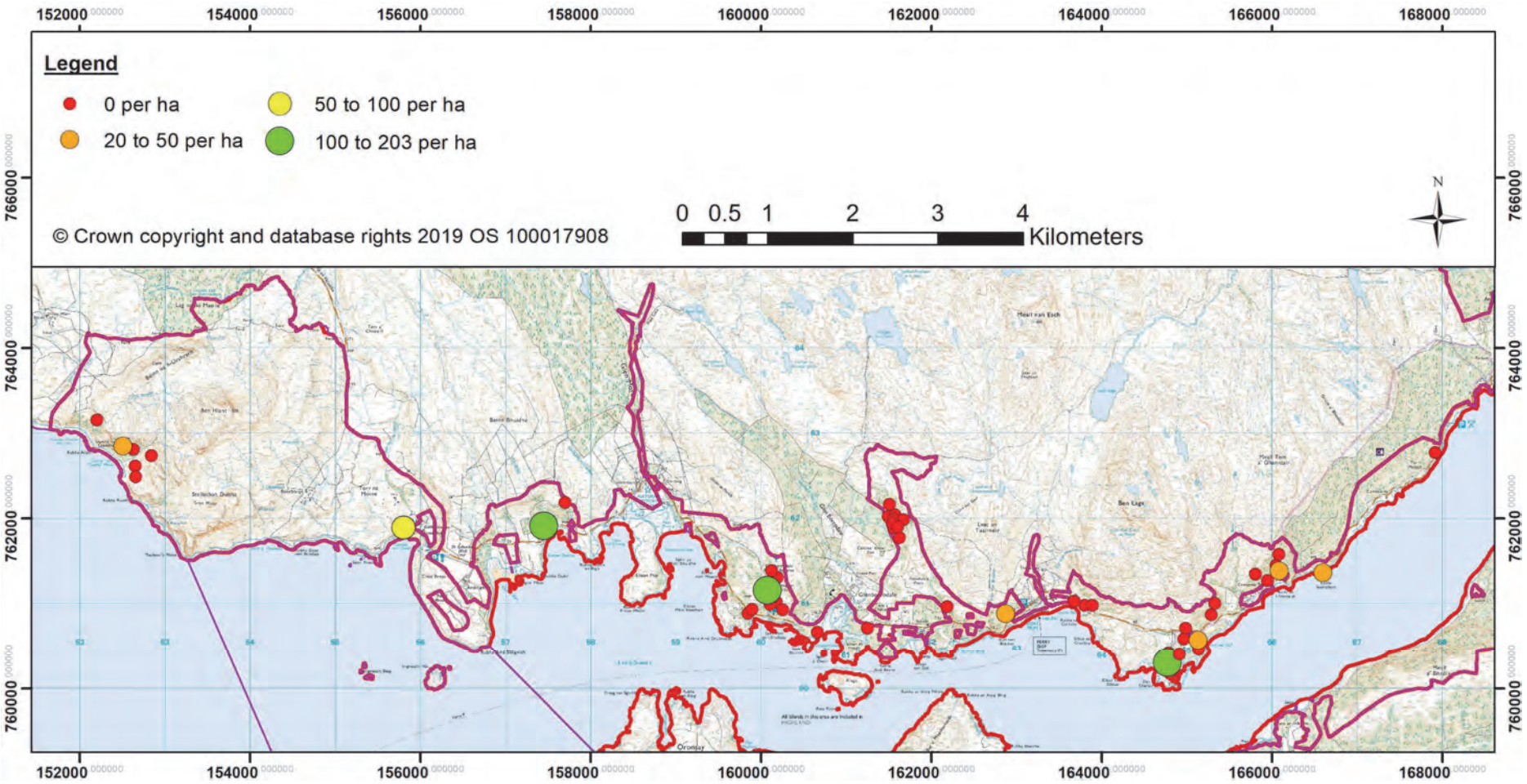

Figure 6. The density of sessile oak seedlings in the individual plots surveyed across the Ardnamurchan DMG part of the Sunart SSSI.

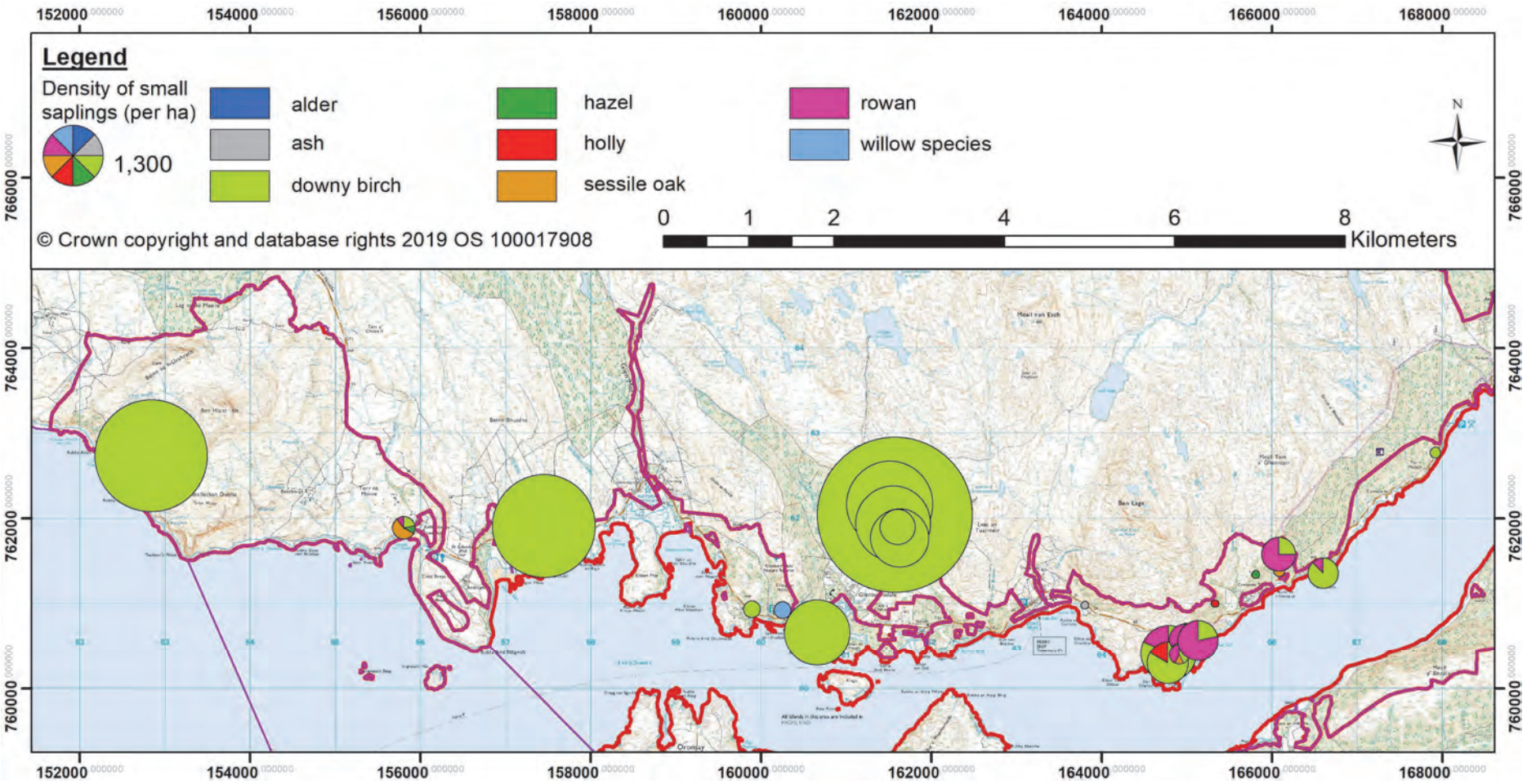

Figure 7. The density of small saplings (per ha) of all species in the plots surveyed across the Sunart SSSI that were also within the Ardnamurchan DMG.

The area of the pies is proportional to the total density of the small saplings.

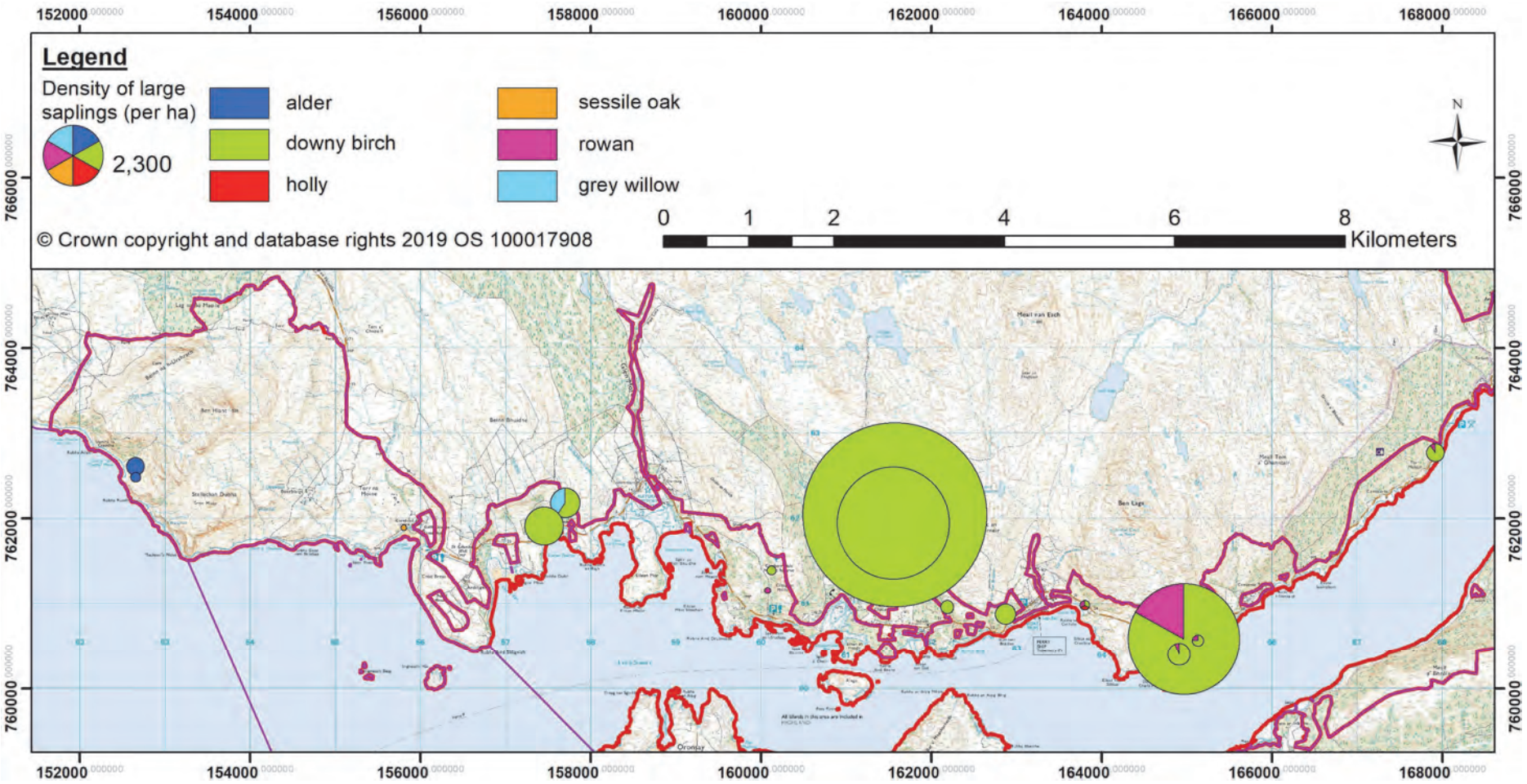

Figure 8. The density of large saplings (per ha) of each species of tree in the plots surveyed across the Sunart SSSI that were also within the Ardnamurchan DMG.

The area of the circle is proportional to the cumulative density (per ha) of each species.

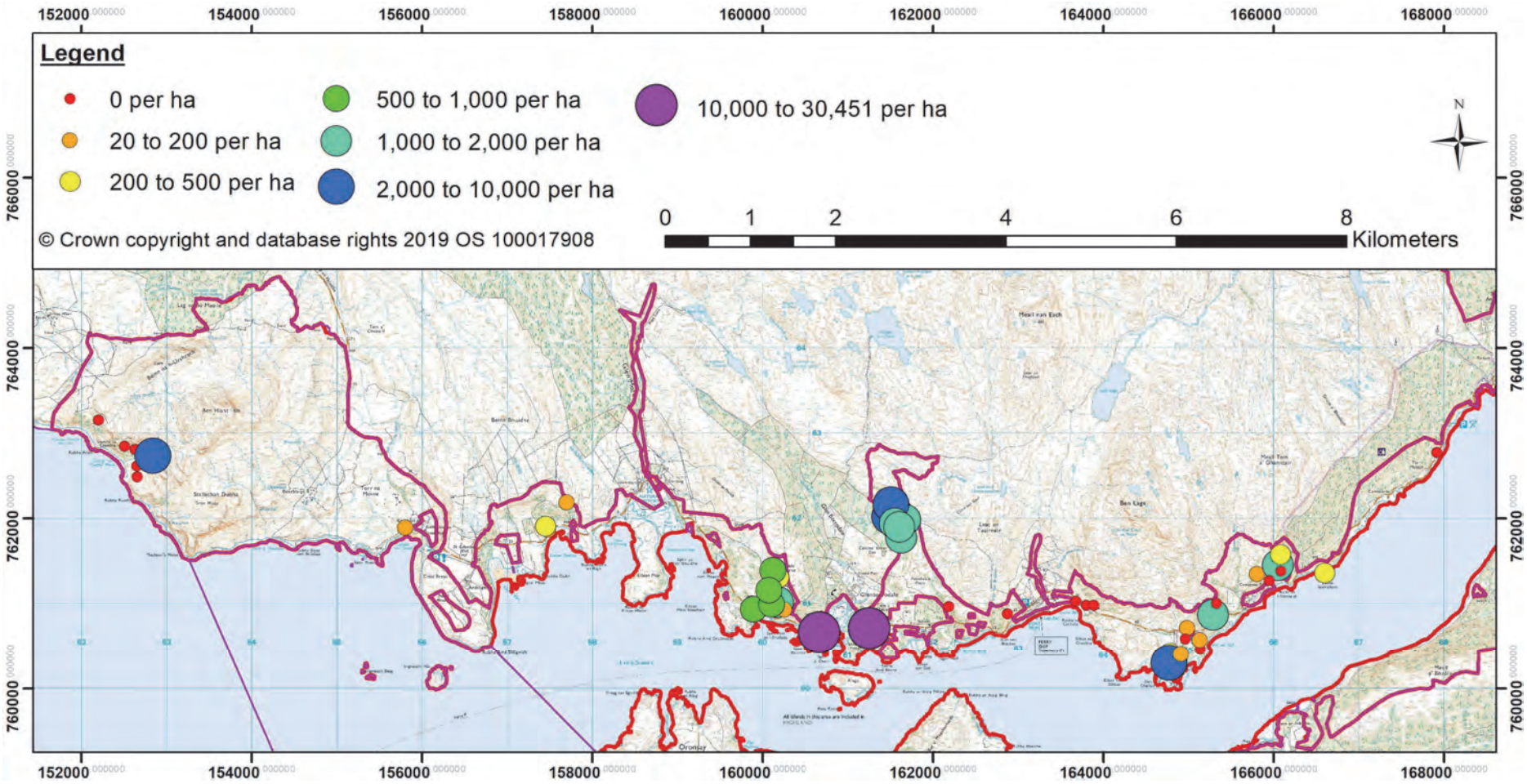

Figure 9. The density of downy birch seedlings in the individual plots surveyed across the Ardnamurchan DMG part of the Sunart SSSI.

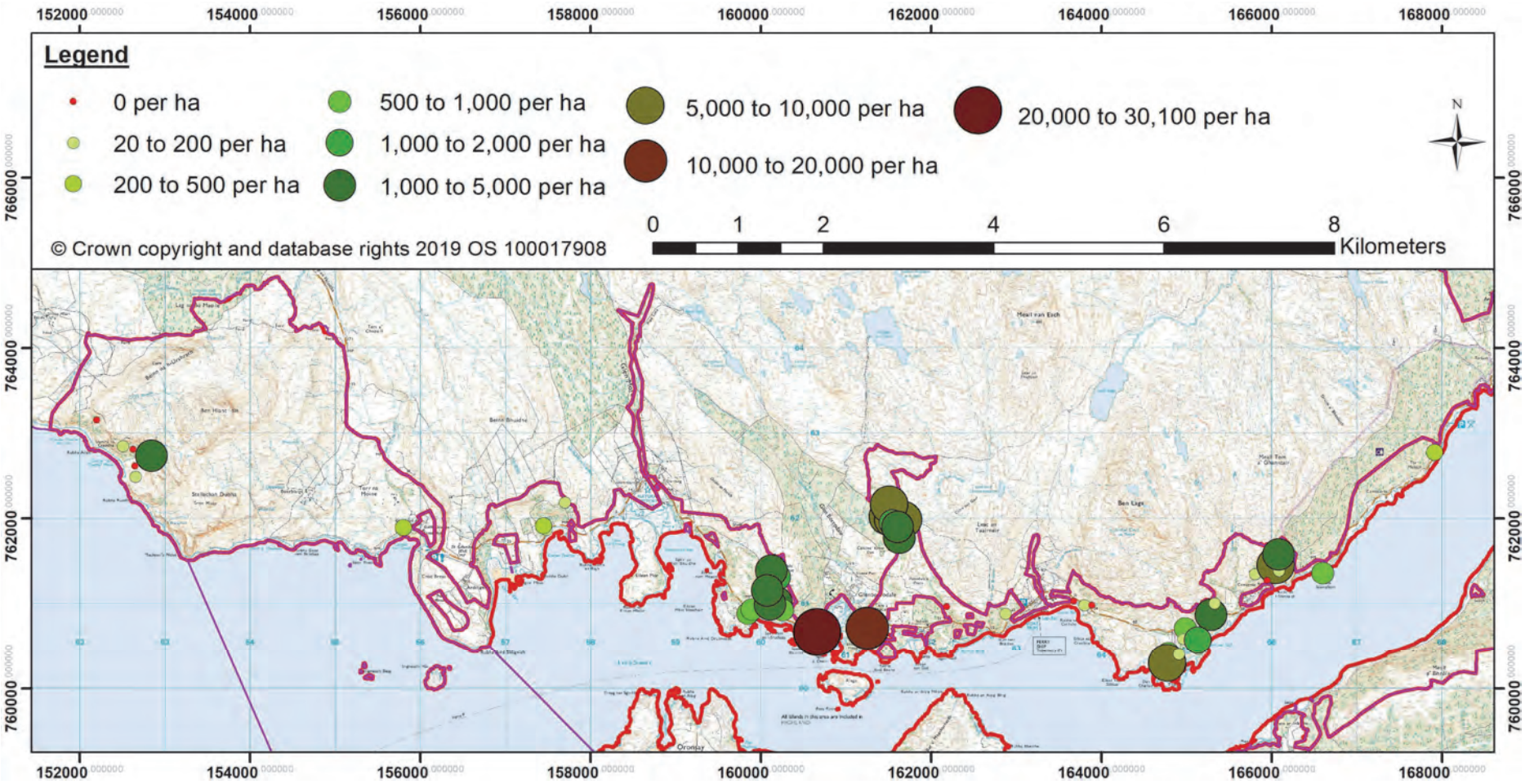

Figure 10. The density of all seedlings (per ha) in each of the plots surveyed across the Sunart SSSI that were also within the Ardnamurchan DMG.

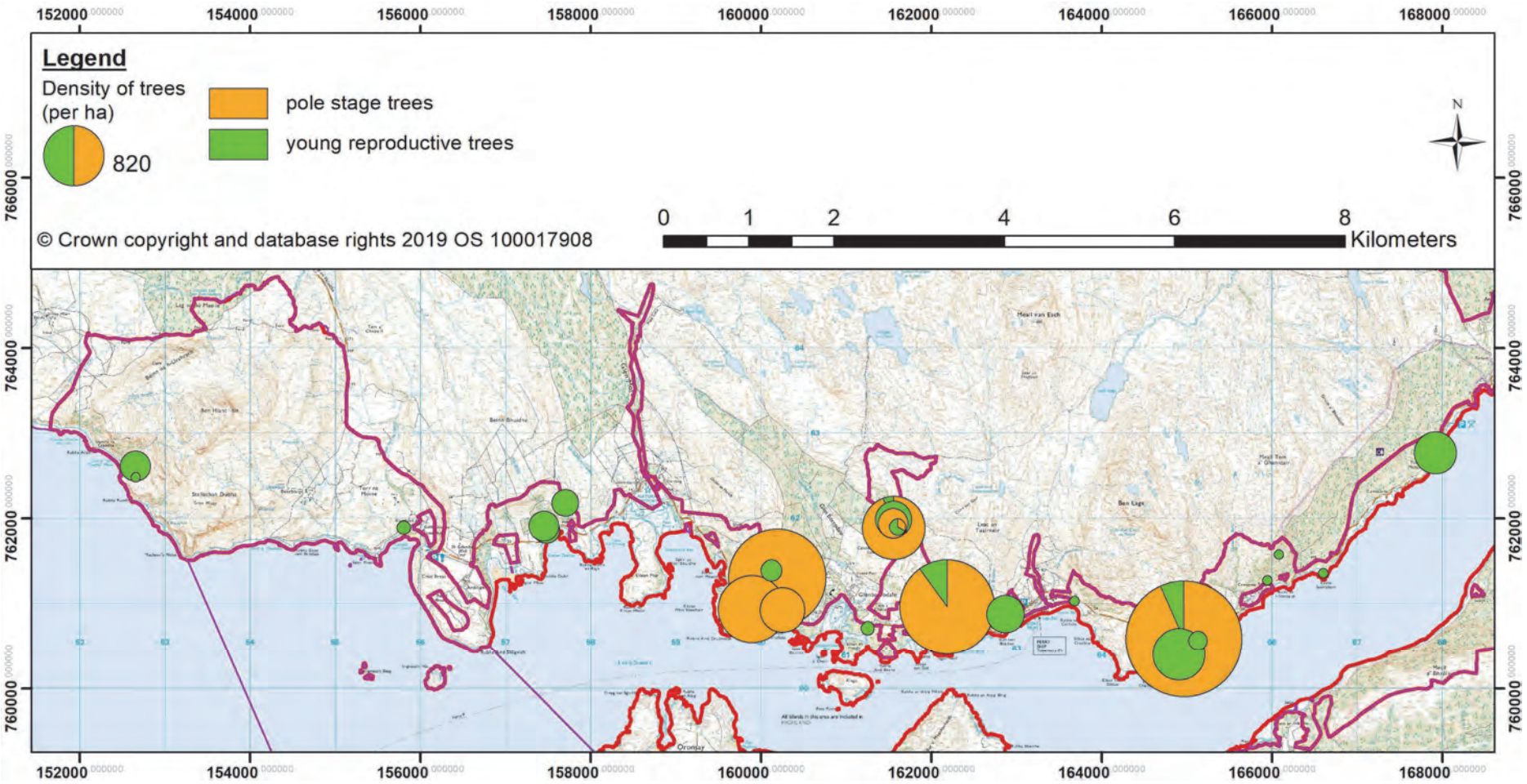

Figure 11. The density of pole stage and young reproductive trees (per ha) in the plots surveyed across the Sunart SSSI that were also within the Ardnamurchan DMG.

The area of the circles is proportional to the cumulative density (per ha) of the two life-classes.

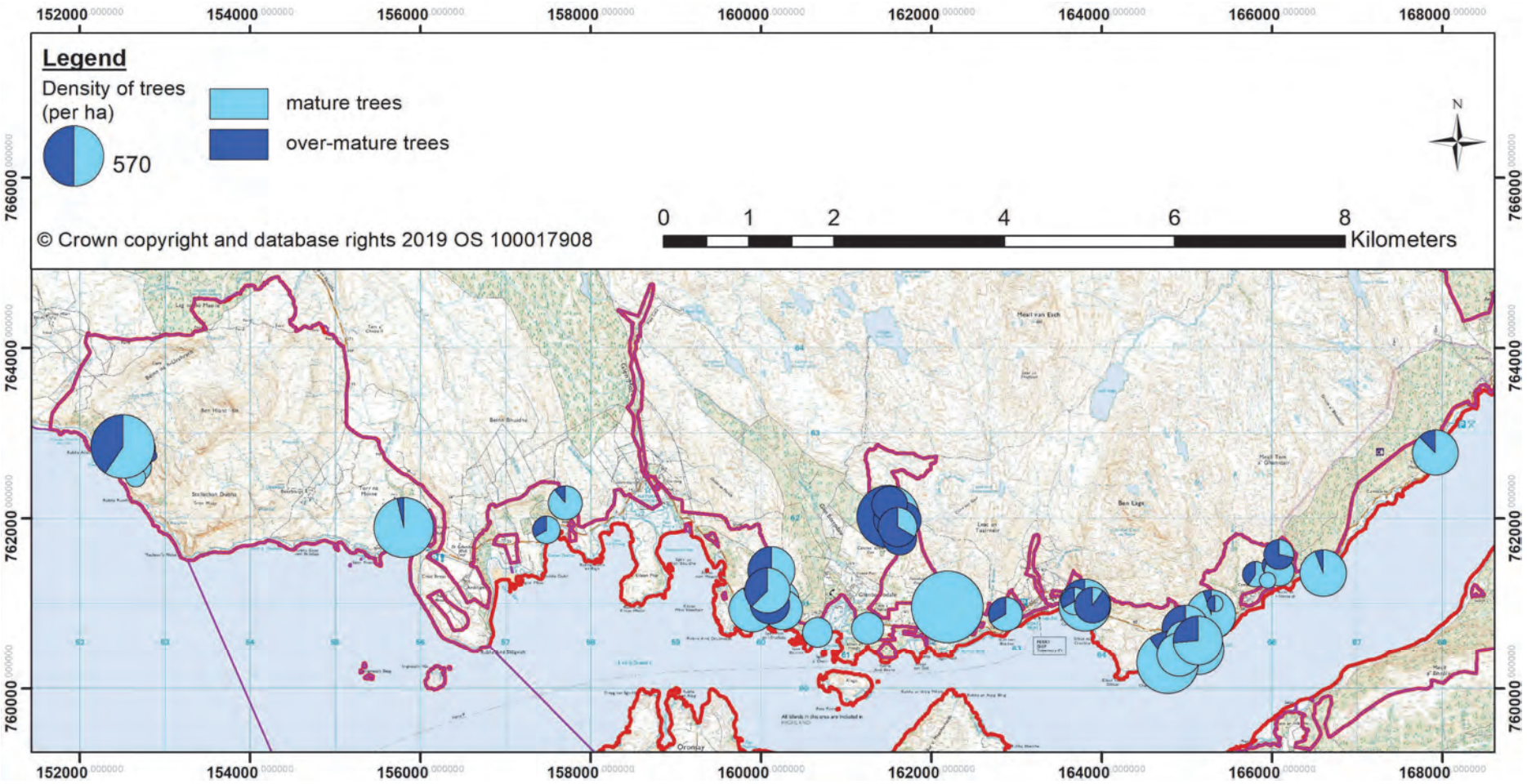

Figure 12. The density of mature and over-mature trees (per ha) in the plots surveyed across the Sunart SSSI that were also within the Ardnamurchan DMG.

The area of the circles is proportional to the cumulative density (per ha) of the two life-classes.

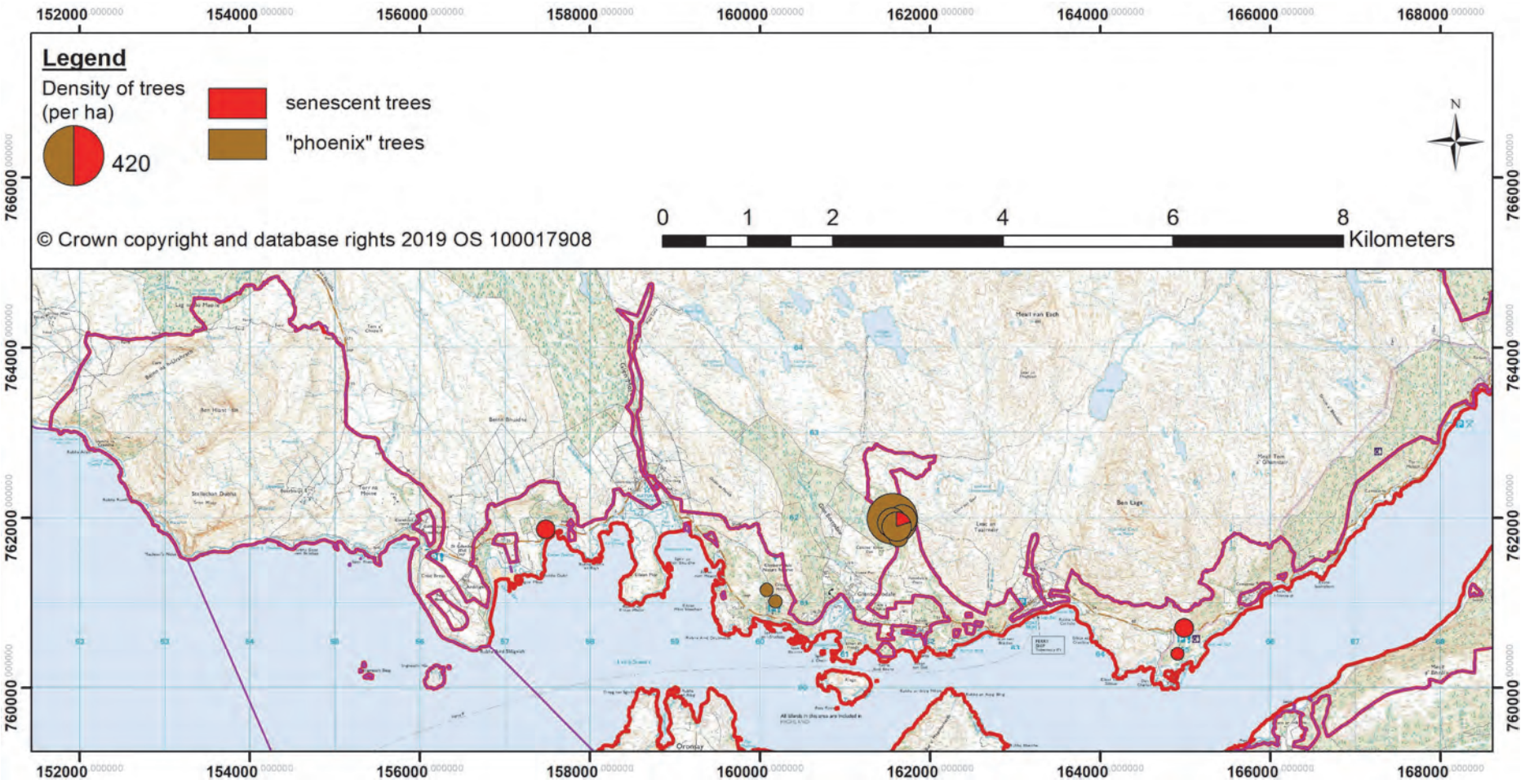

Figure 13. The density of senescent and "phoenix" stage trees (per ha) in the plots surveyed across the Sunart SSSI that were also within the Ardnamurchan DMG.

The area of the circles is proportional to the cumulative density (per ha) of the two life-classes.

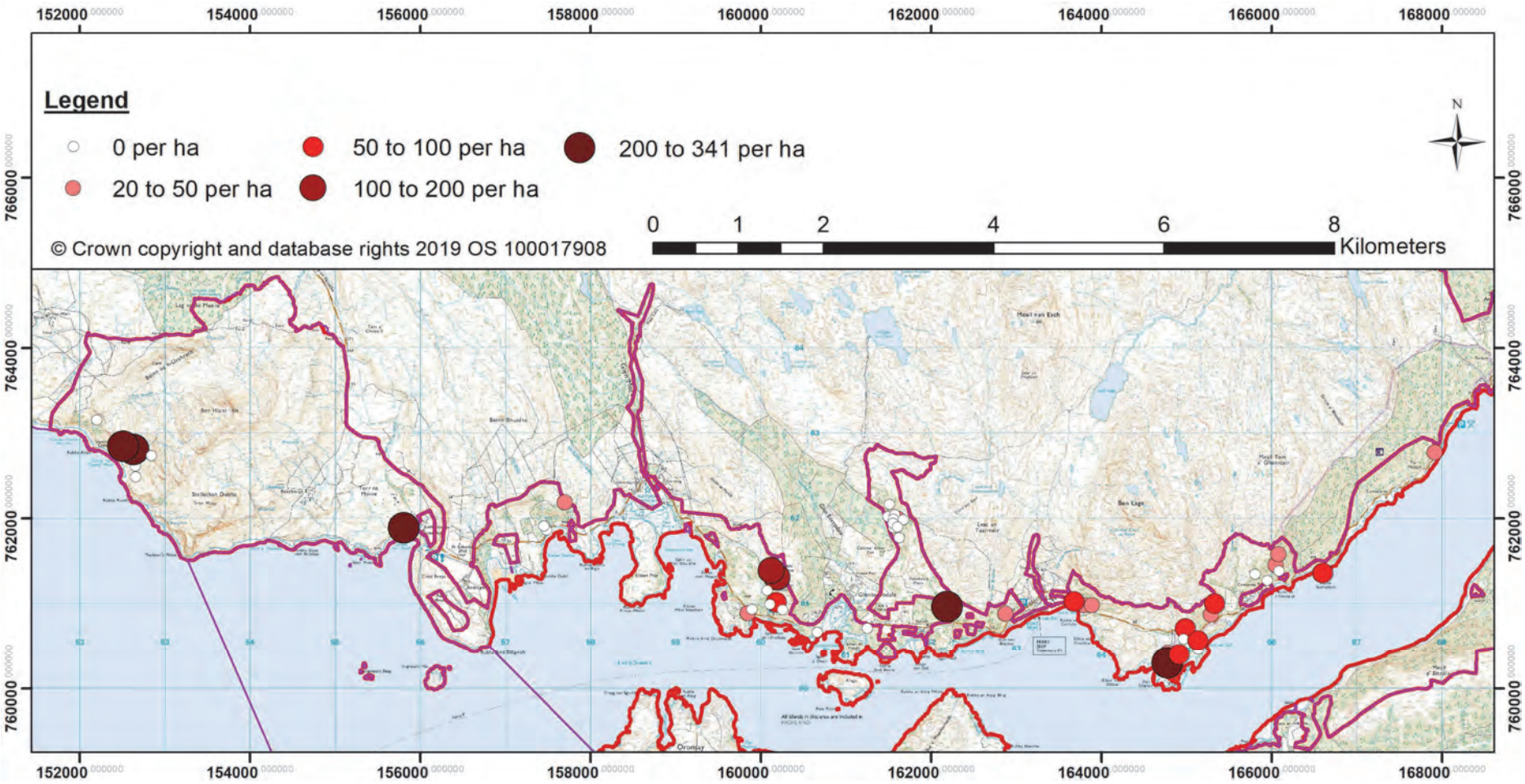

Figure 14. The density (per ha) of dead trees in the different plots surveyed across the part of the Sunart SSSI that were also within the Ardnamurchan DMG.

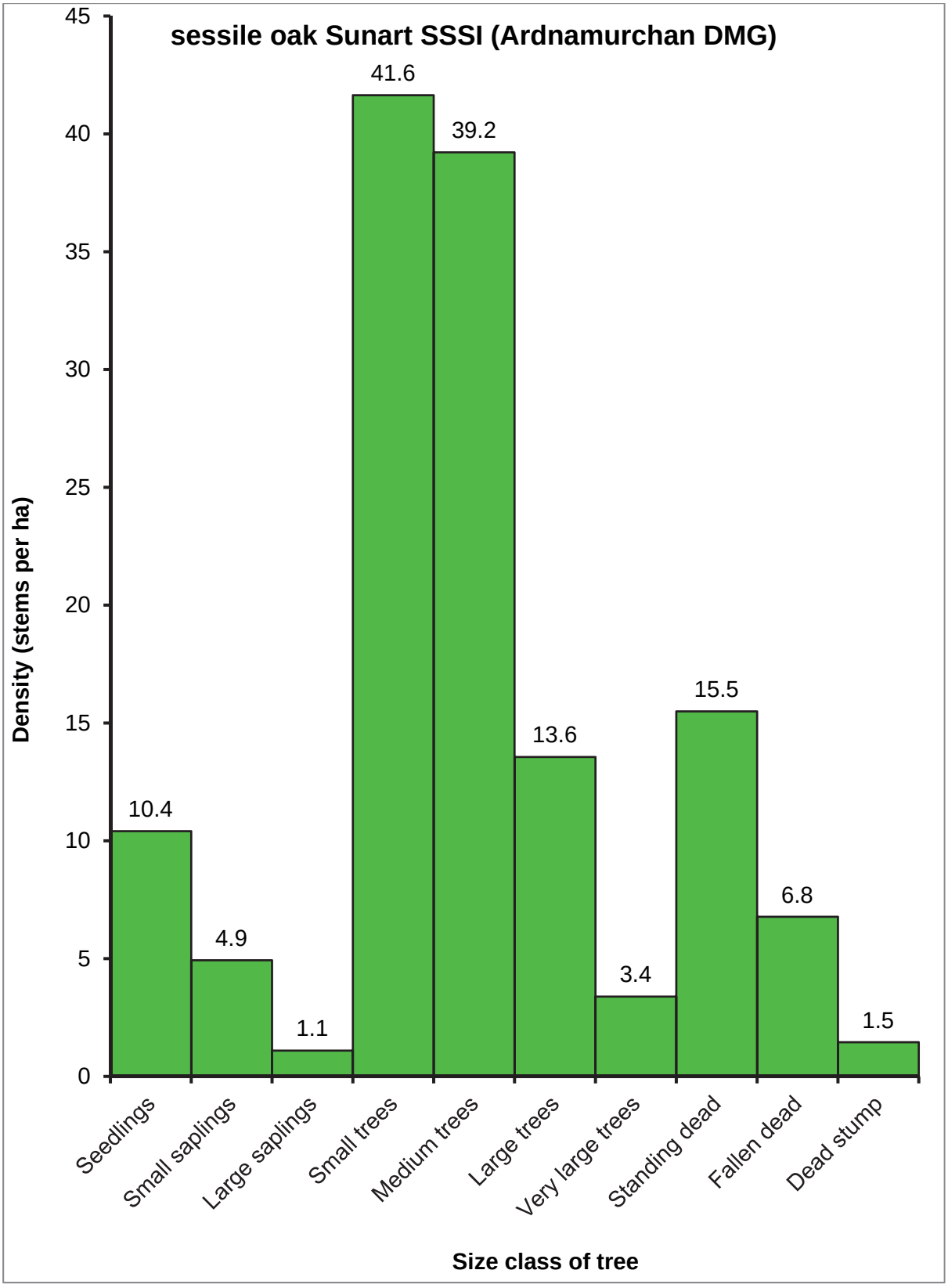

Figure 15. The size distribution of the sessile oak population within the Sunart SSSI that is also within the Ardnamurchan DMG.

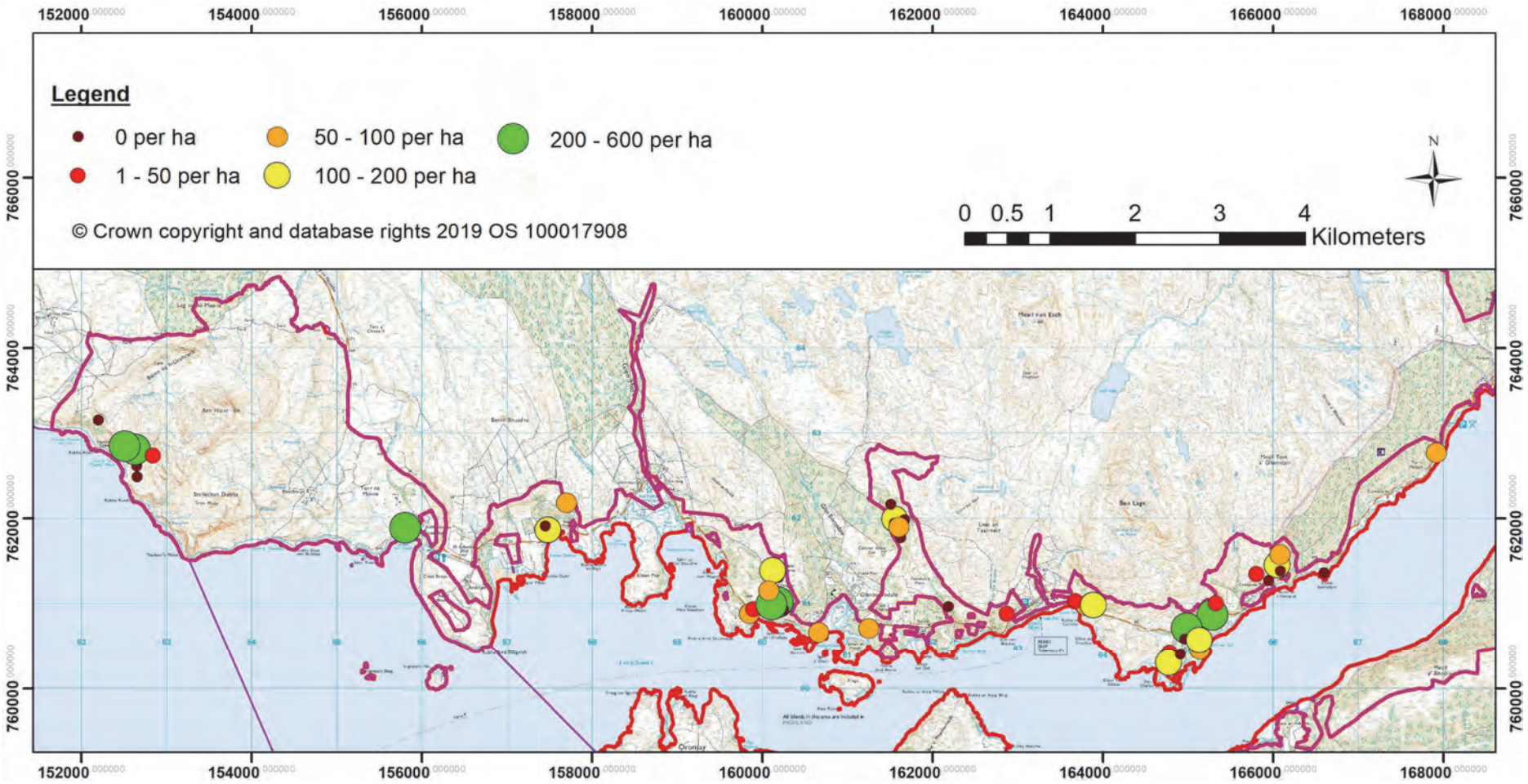

Figure 16. The density of live sessile oak trees in the individual plots surveyed across the Ardnamurchan DMG part of the Sunart SSSI.

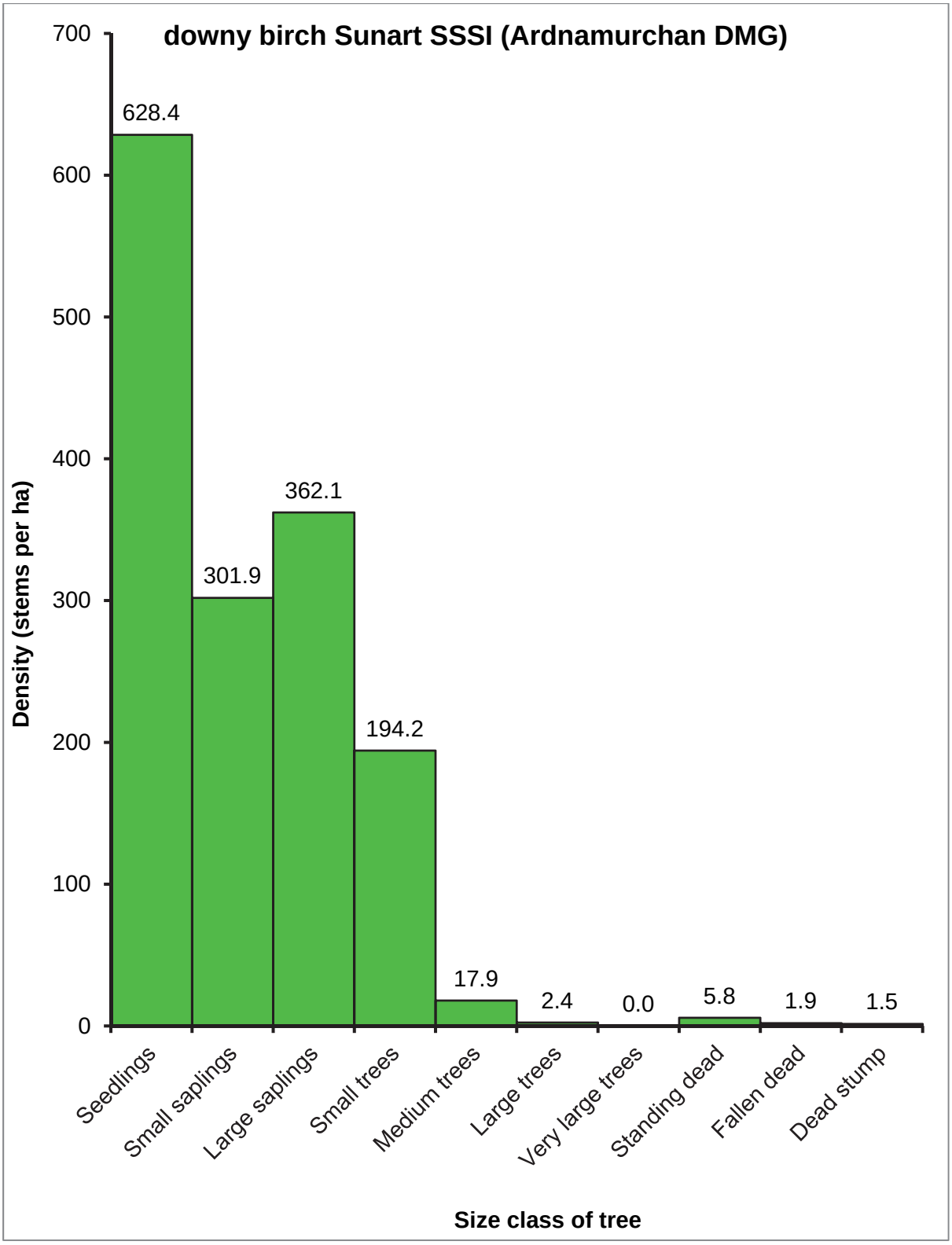

Figure 17.The size distribution of the downy birch population within the Sunart SSSI that is also within the Ardnamurchan DMG.

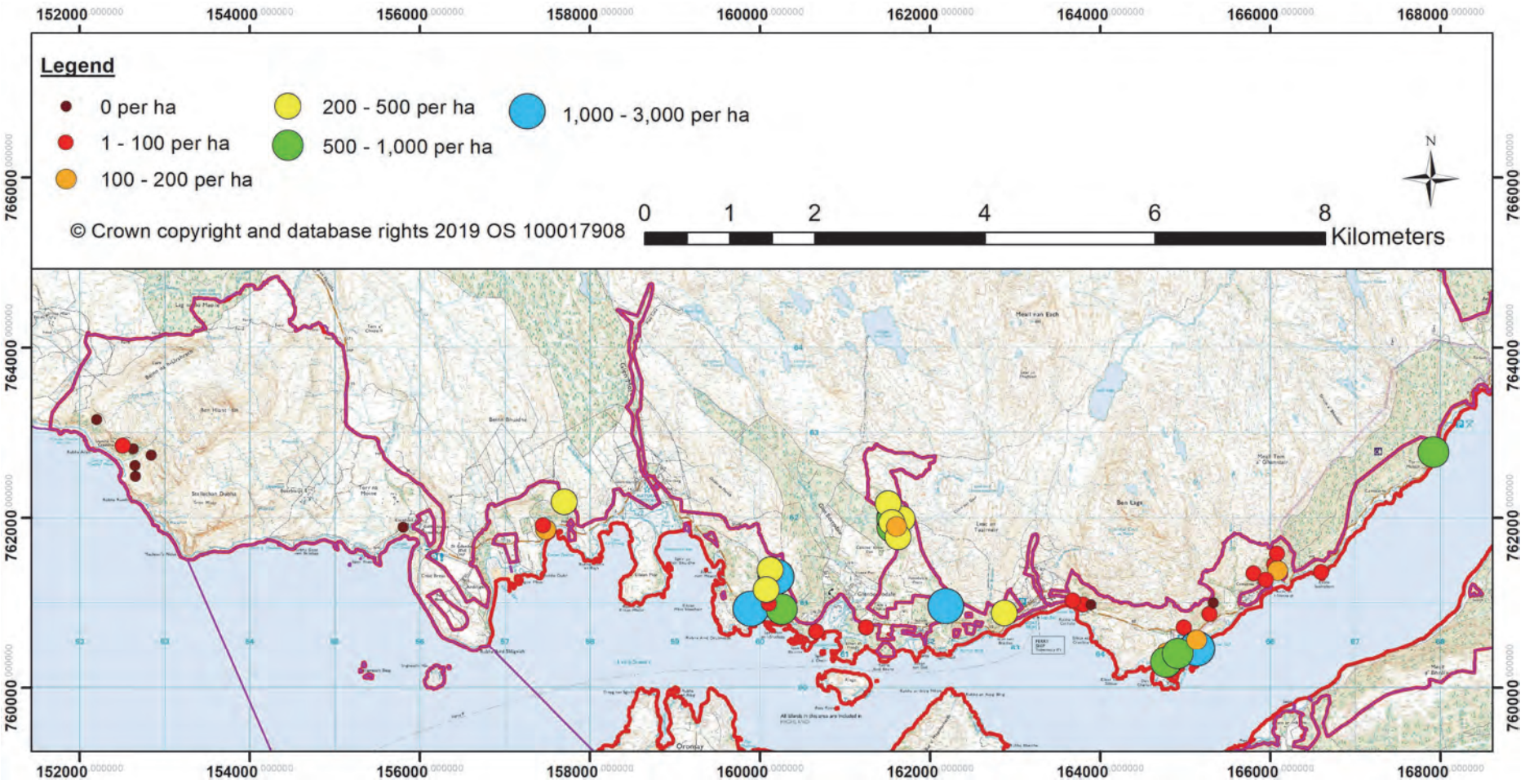

Figure 18. The density of live downy birch trees (per ha) in the different plots surveyed across the part of the Sunart SSSI that are also within the Ardnamurchan DMG.

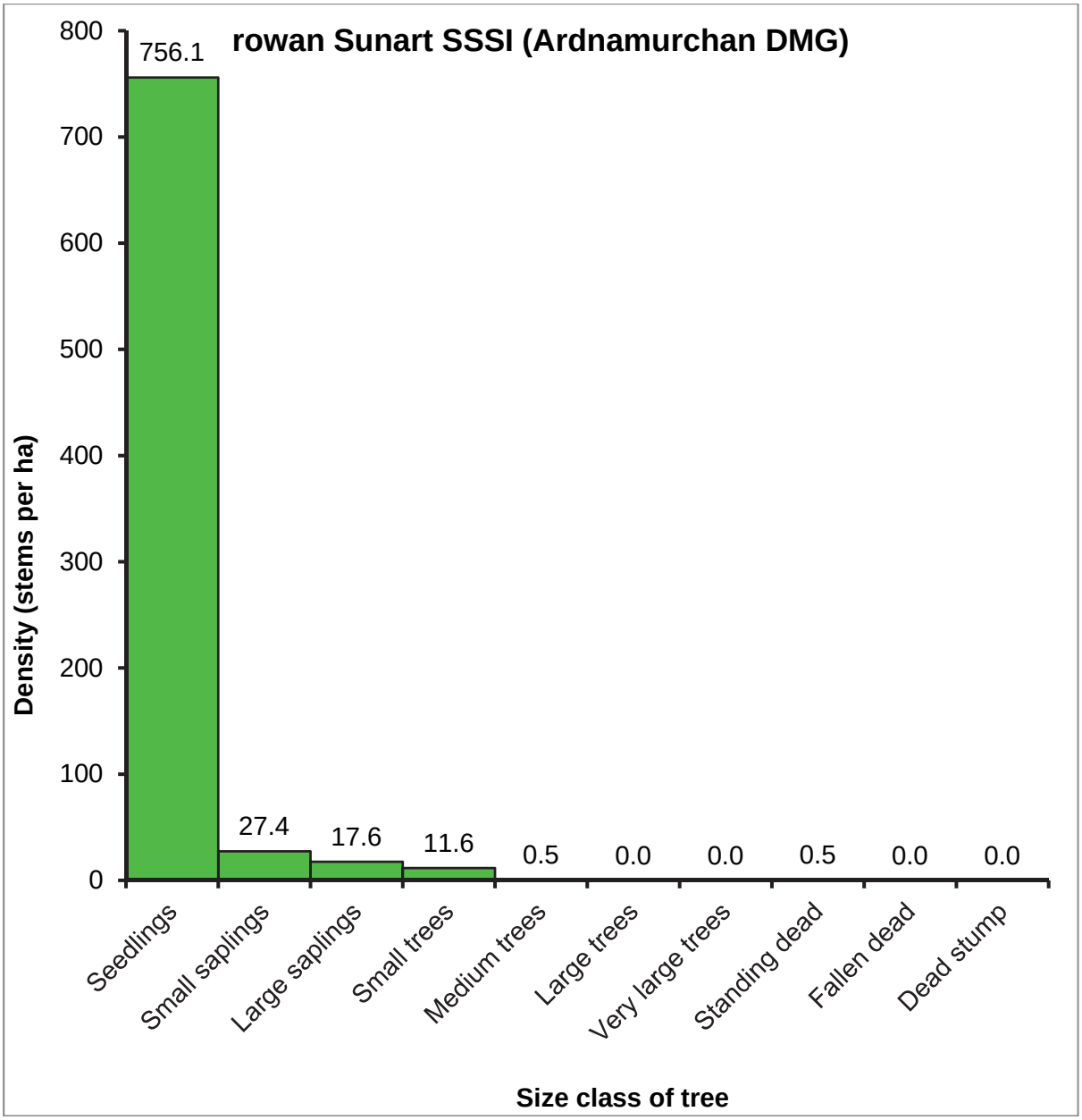

Figure 19. The size distribution of the rowan population within the Sunart SSSI that is also within the Ardnamurchan DMG.

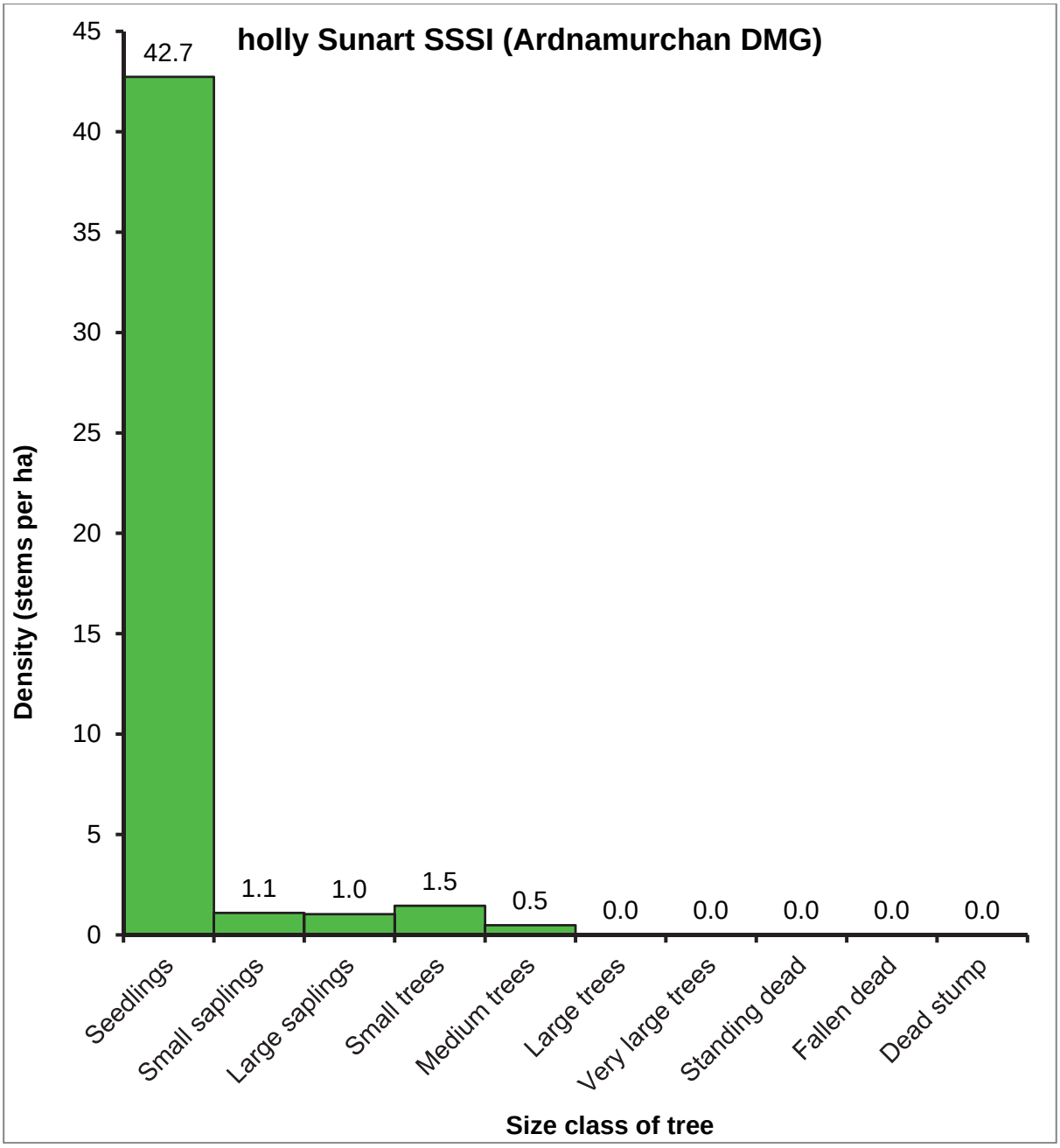

Figure 20. The size distribution of the holly population within the Sunart SSSI that is also within the Ardnamurchan DMG.

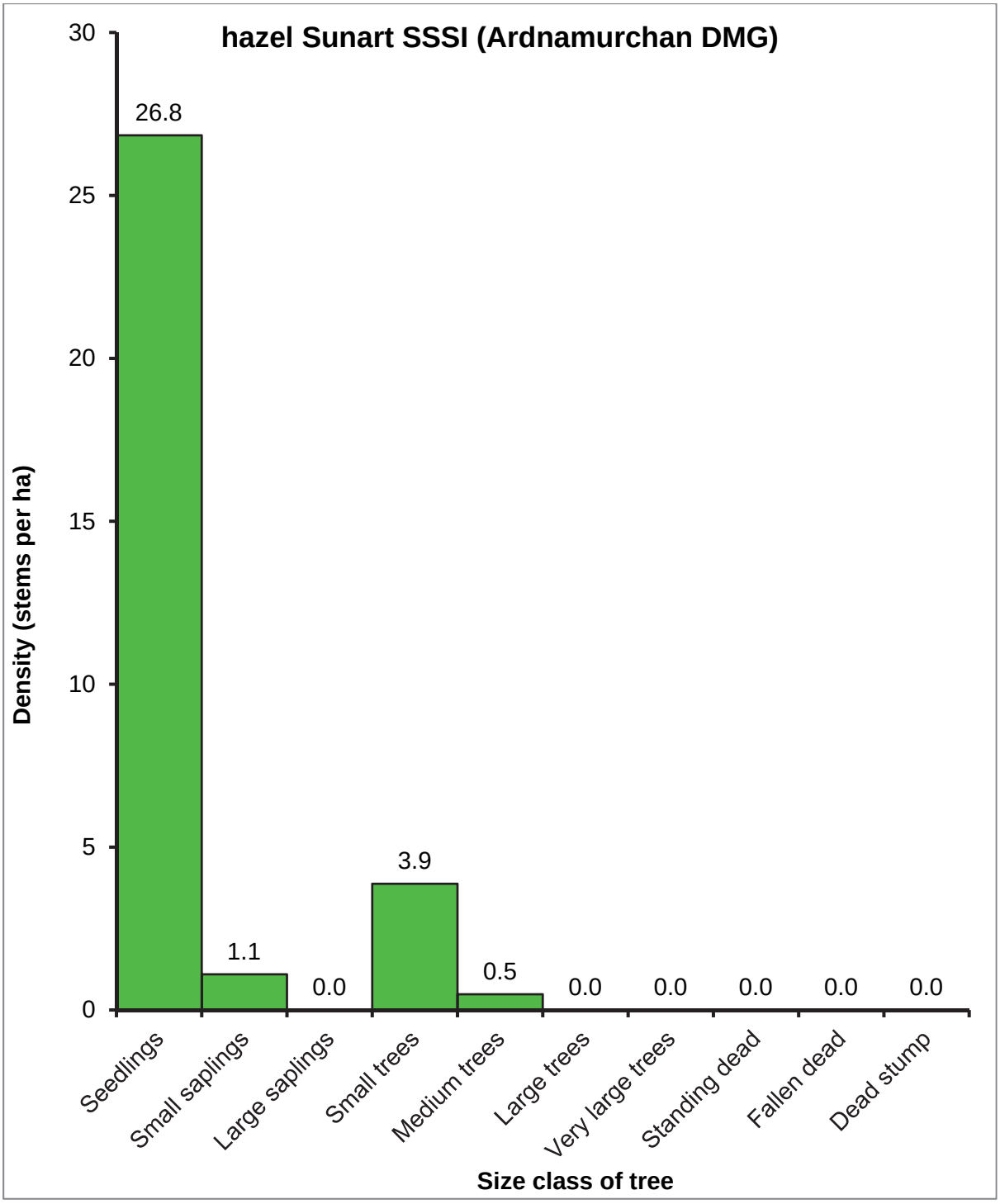

Figure 21. The size distribution of the hazel population within the Sunart SSSI that is also within the Ardnamurchan DMG.

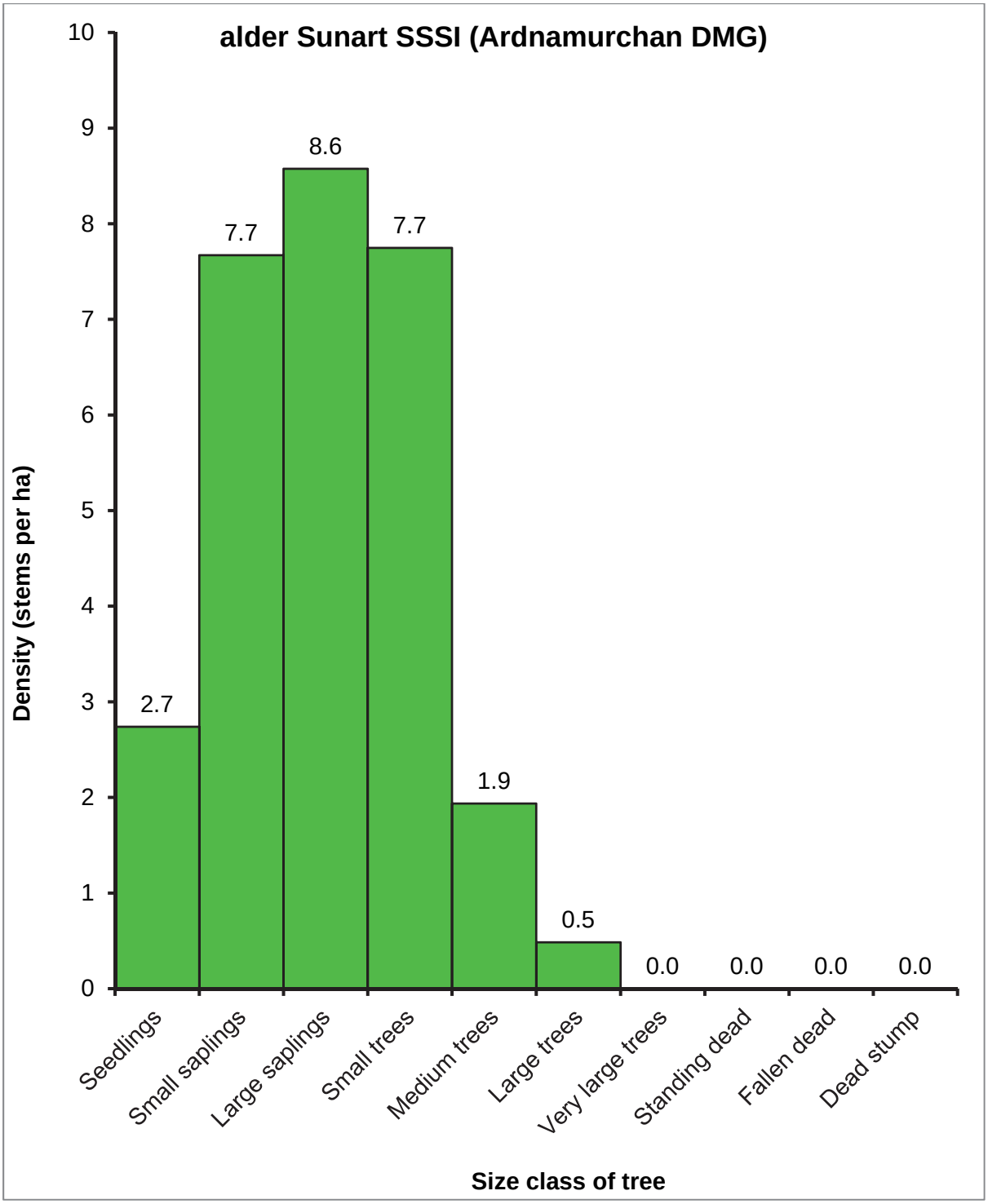

Figure 22. The size distribution of the alder population within the Sunart SSSI that is also within the Ardnamurchan DMG.

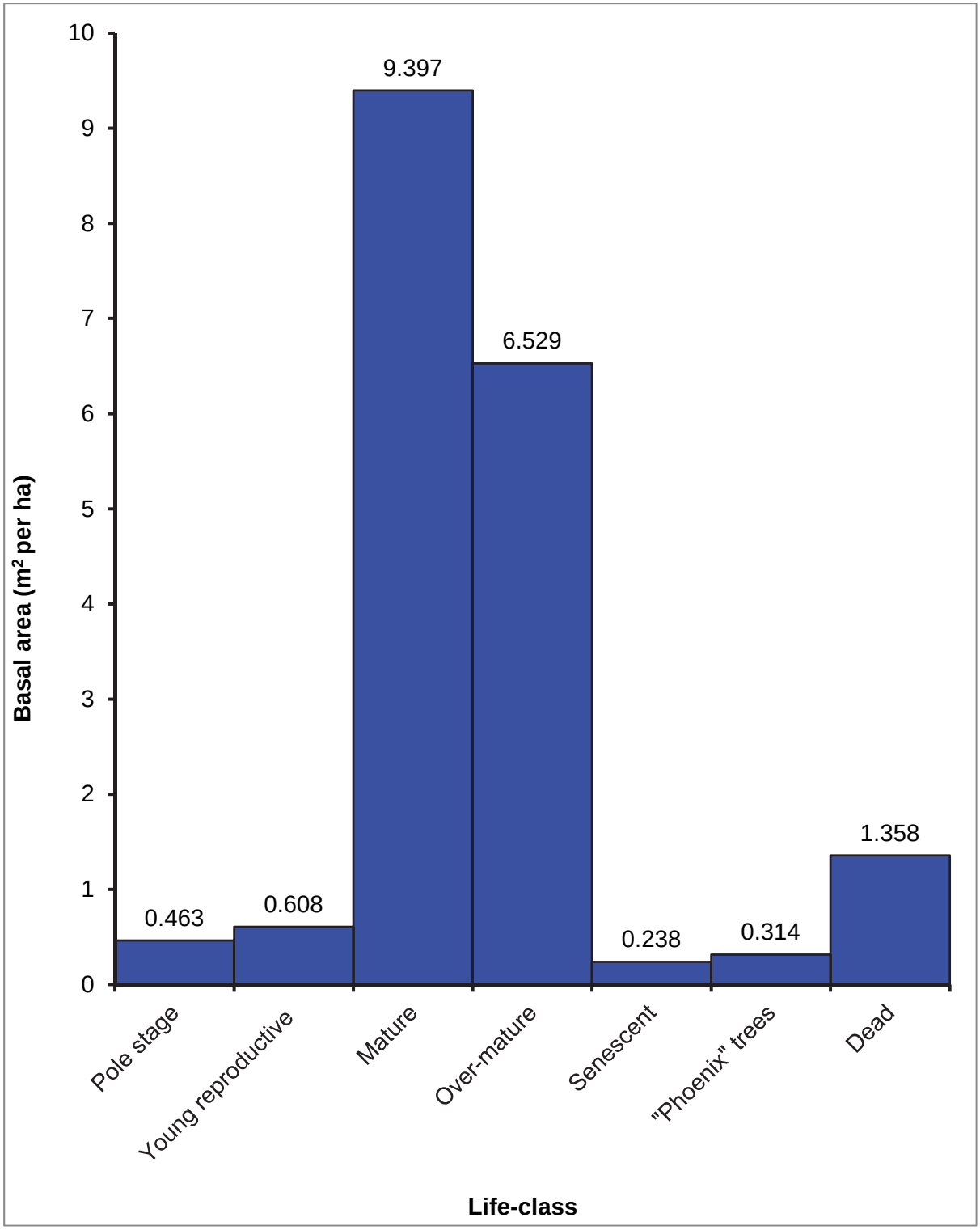

Figure 23. Basal area (m2 per ha) of trees in different life-classes within the Sunart SSSI and that were within the Ardnamurchan DMG.

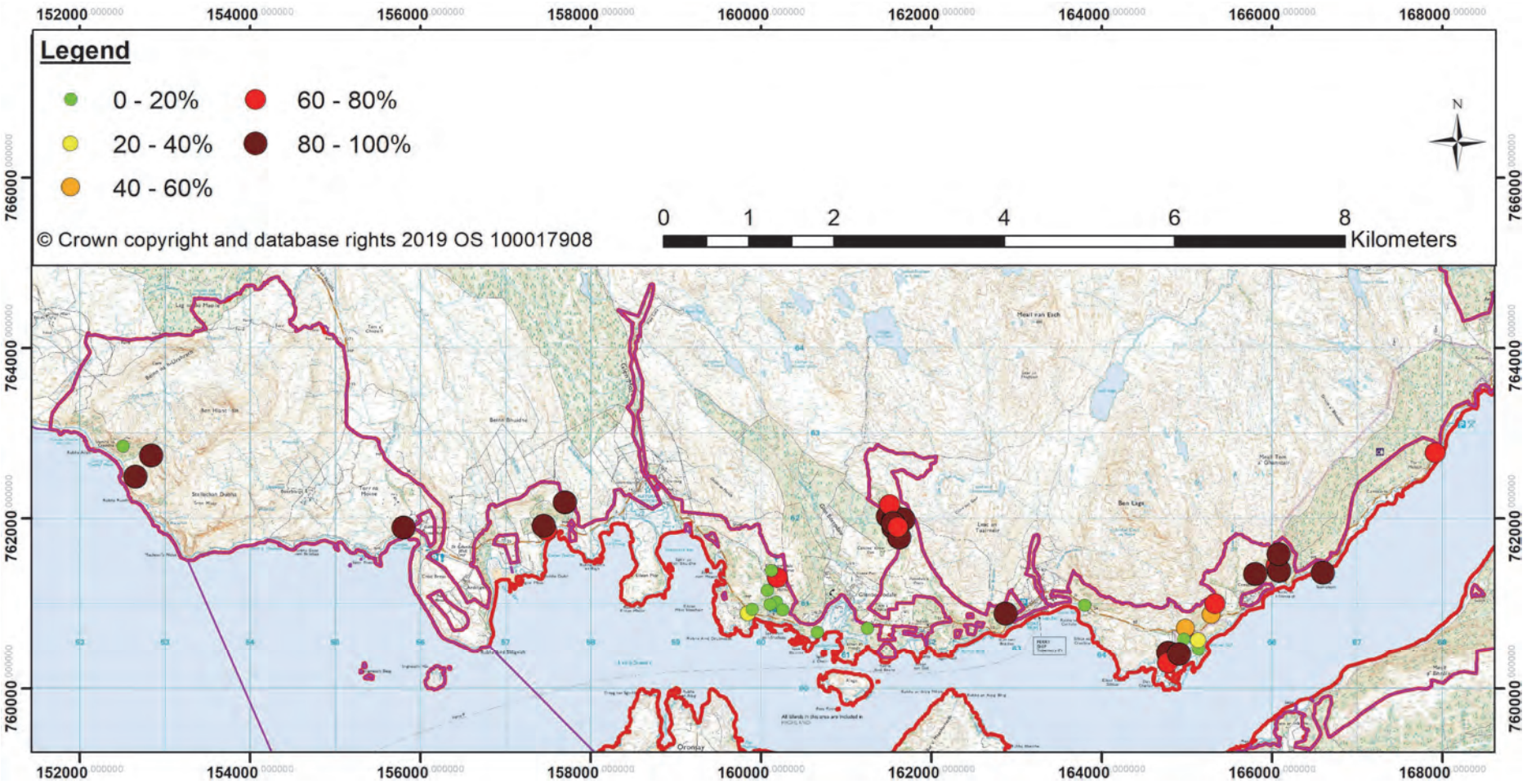

Figure 24. The levels of browsing on all seedlings across the part of the Sunart SSSI that is also within the Ardnamurchan DMG.

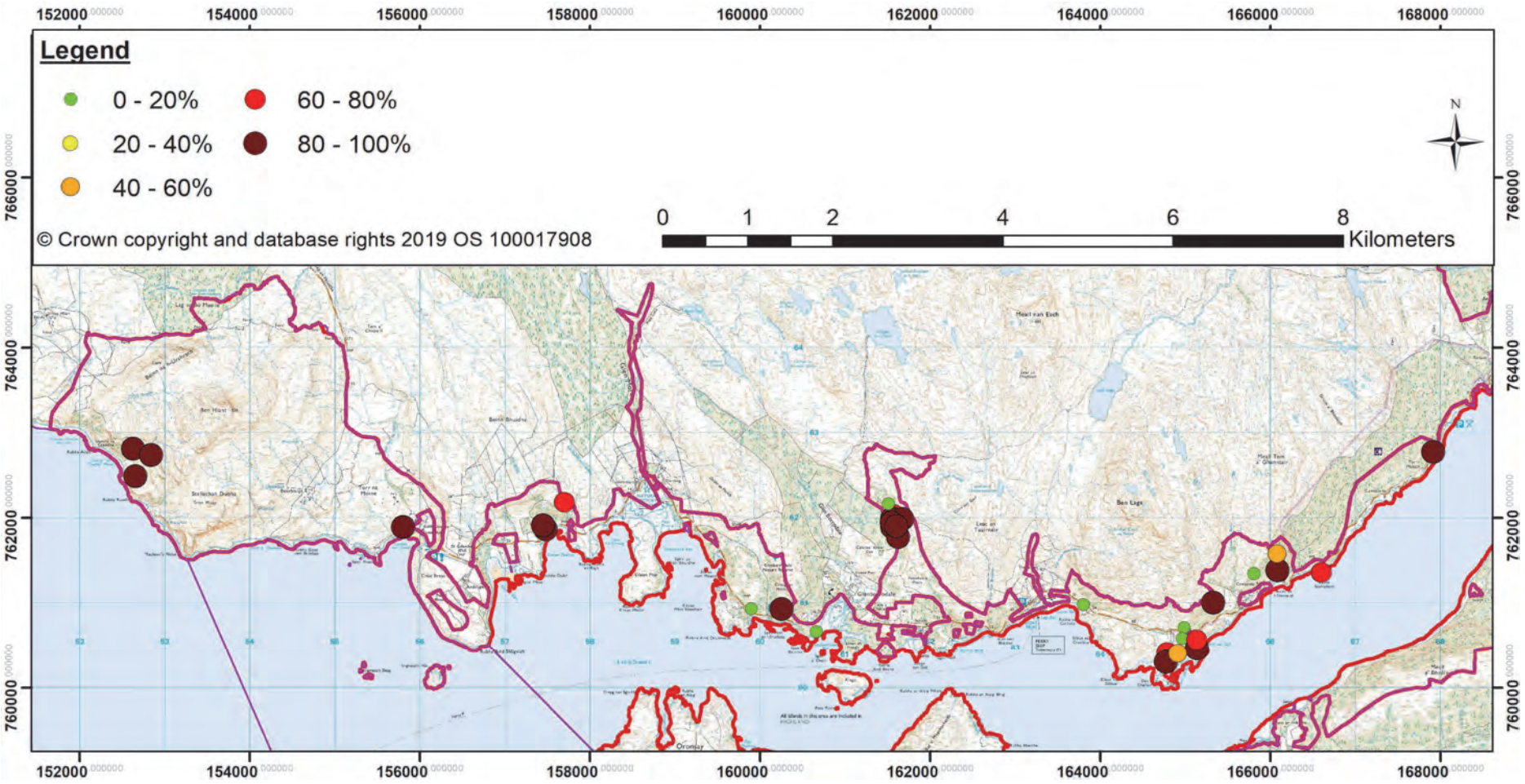

Figure 25. The levels of browsing on all small saplings across the part of the Sunart SSSI that is also within the Ardnamurchan DMG.

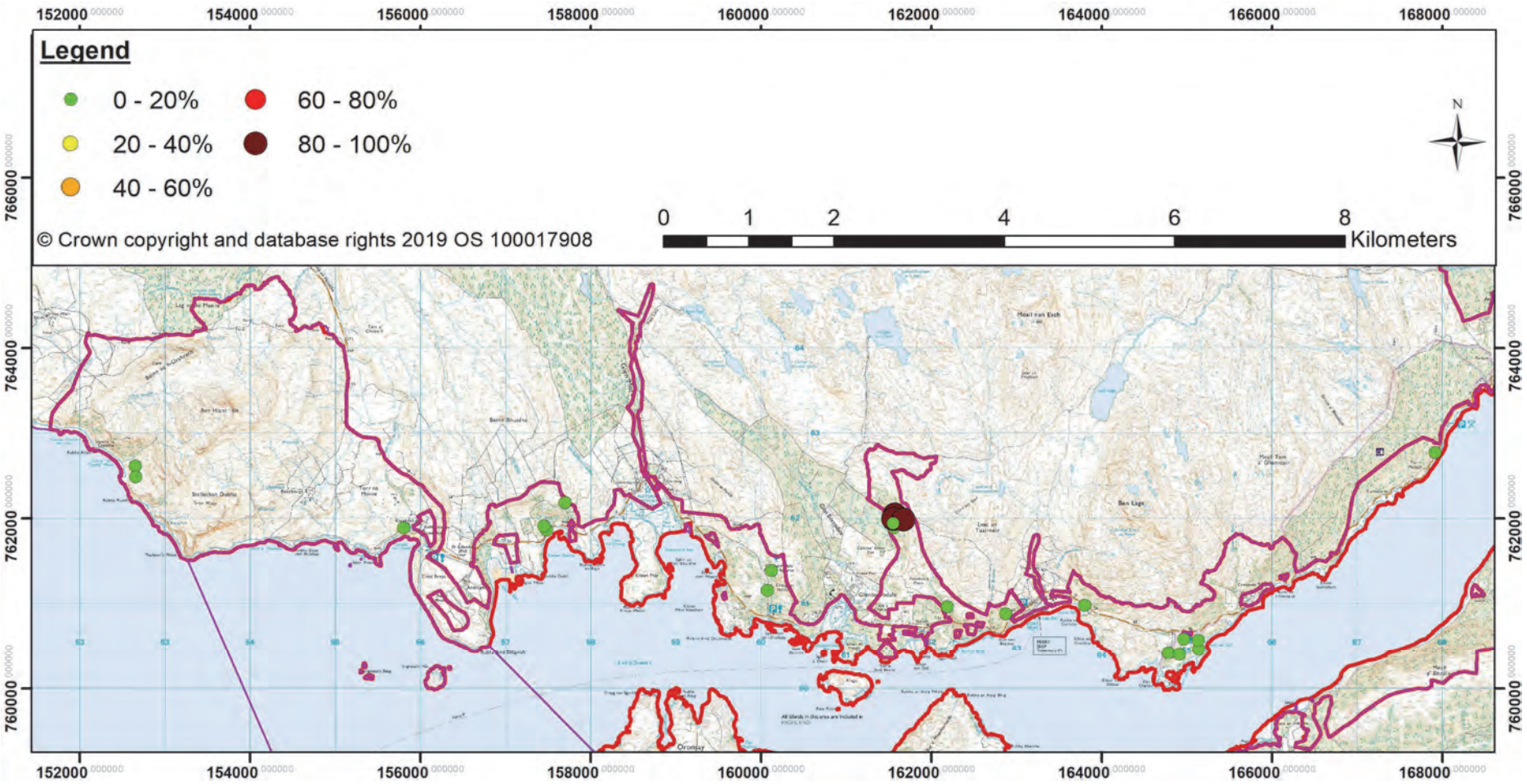

Figure 26. The levels of browsing on all large saplings across the part of the Sunart SSSI that is also within the Ardnamurchan DMG.

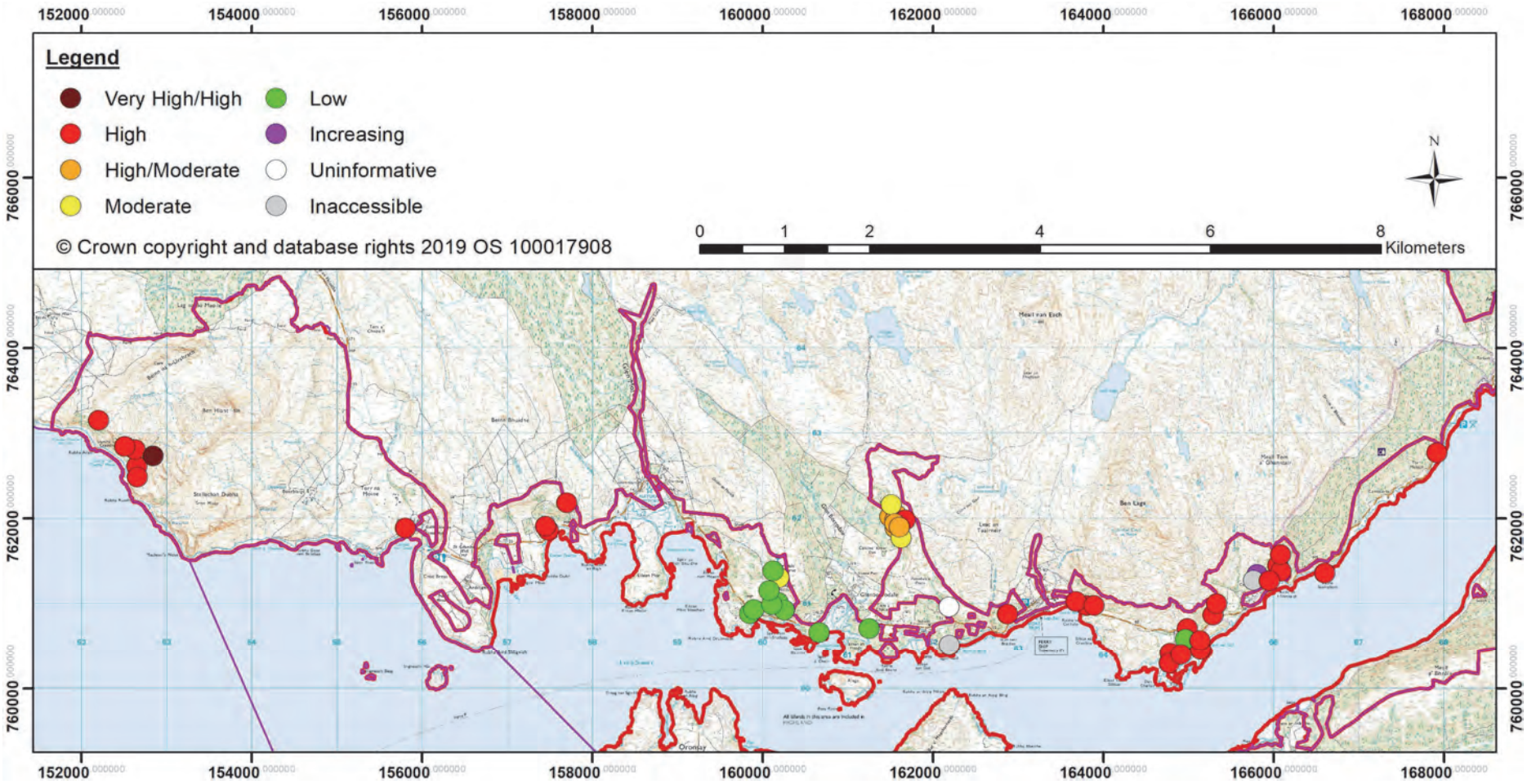

Figure 27. The overall herbivore impacts in the plots surveyed across the part of the Sunart SSSI that is also within the Morven DMG.

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

Table 8. 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 9. 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 10. 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 11. 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 12. 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 13. 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 14. 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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