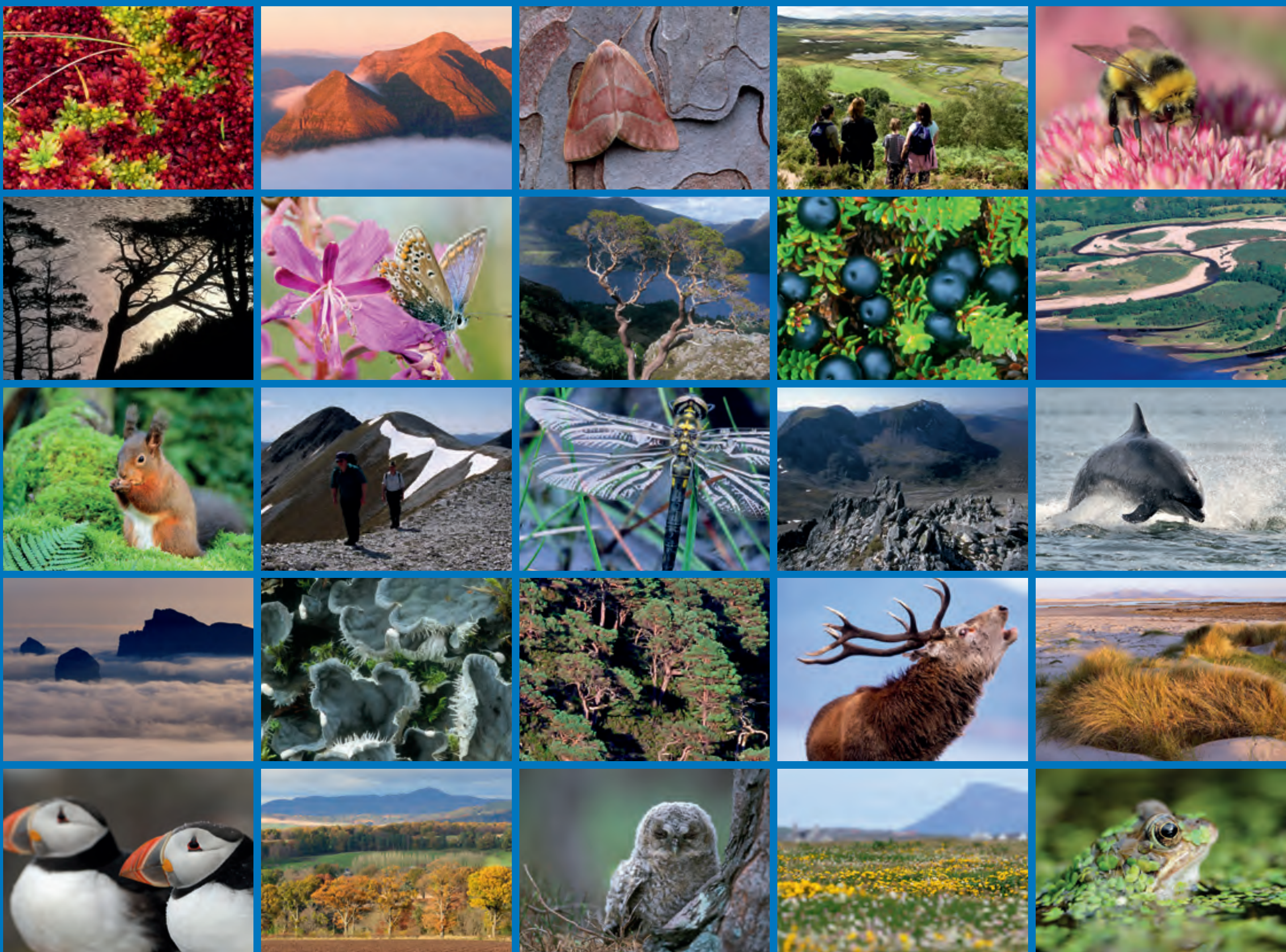
Scottish Natural Heritage
Research Report No. 1183

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



RESEARCH REPORT

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RESEARCH REPORT

Summary

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

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Keywords

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

Background

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

Main findings

The diameter of all species of tree within 77 sample plots chosen at random throughout the woodland habitat was measured in April and May 2018. A total area of 3.38 ha of woodland was surveyed for trees, with a slightly smaller area of 3.30ha surveyed for seedlings and saplings. The numbers of browsed and un-browsed seedlings and saplings, both small and large, were counted in the same plots. A total of 1,290 live trees and 80 dead trees were measured and a total of 2,577 seedlings and 1,143 saplings were counted. The main findings are as follows:

- The woodland has an overall density of 382 live tree per ha. Seedling densities are on average 781 per ha, but there is a high degree of spatial variation in density with the inter-quartile range being 80 to 580 seedlings per ha. Densities of all small and large saplings are lower at 240 and 106 stems per ha, respectively.
- Downy birch dominates the woodland as it makes up 69% of all the live trees and based on the basal area of the tree trunks it accounts for approximately half of the canopy cover. Sessile oak is the second most abundant species of tree making up only 11% of the live trees, but based on basal area it makes up approximately a third of the canopy cover. Hazel, ash, rowan and alder are also relatively frequent within this part of the Sunart SSSI.
- The population of downy birch is moderately healthy with its seedlings at higher densities (198/ha) than the small saplings (121/ha), but the mature trees (120/ha) are at higher

densities than the large saplings (68/ha). Regeneration of seedlings and recruitment of saplings was, however, spatially very variable as there were no birch seedlings in just over half of the sample plots.

- Although seedlings of sessile oak were present they are at lower densities (10/ha) than the mature (15/ha) and over-mature (24/ha) life-classes of sessile oak. Only one large sessile oak sapling was found in all the plots surveyed. All the oak seedlings were heavily browsed and 55% of the small saplings were browsed. The sessile oak population is currently not regenerating due primarily to the high levels of browsing, but there appear to be low levels of seedling establishment.
- The high levels of browsing on seedlings and small saplings of rowan, holly, hazel and ash are preventing the recruitment of the next generation of these trees as well as sessile oak.
- Shading by trees is probably only a factor in inhibiting saplings from developing into young reproductive trees within only about 8% of the woodland.
- The internationally important assemblage of species of lichen, moss and liverwort that grow on the trunks and branches of the large oak trees is, therefore, in potential danger of being depleted in the long term due to the inevitable death and loss of the older larger sessile oak trees.
- The upland oak woodland/Western acidic oak woodland habitat is therefore not satisfying one of the Conservation Objectives for the Sunart SAC, which is to have 'viability of typical species as components of the habitat'.
- Browsing by deer is the only plausible causal factor for the current poor levels of recruitment of young trees of sessile oak, hazel, rowan, holly and ash.

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Acknowledgements

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Nomenclature

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

1. INTRODUCTION

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

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

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

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

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

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

In the last assessment of the condition of the upland oak woodland habitat in November 2009, it was assessed to be in ‘unfavourable no change’ condition. The condition assessment identified over-grazing and the presence of invasive non-native species (*Rhododendron ponticum*) as the main pressures on the habitat. The woodland habitat is also considered to be ‘at risk’ from the impacts of large herbivores, in particular deer. The Site Management Statement for the SSSI lists the following actions that need to take place in order that the 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 also states that:

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

1.1 Aims

The key aim of this survey is to implement a fit for purpose baseline survey on the existing woodland profile in terms of life-class, including seedlings and saplings, and the relative nature and extent of current herbivore impacts on the populations of trees within the SSSI. This will provide the data necessary to assess the long-term viability and future of the woodland habitat and, if there is a poor age-structure to the population of trees, to identify the likely causal factors that may be resulting in any lack of regeneration in the population of trees. The survey will also identify the presence of rhododendron and whether deer exclosures are having the desired effect in allowing tree regeneration and structure of the woodland habitat. This report concentrates on only those parts of the Sunart SSSI and Sunart SAC that are within the Morvern Deer Management Group (DMG) that is on the south shore of Loch Sunart.

2. METHODS

2.1 Woodland profile

For any healthy self-sustaining population of organisms there must be more individuals in the younger generations than the older generations, otherwise the population will die out. Although there may be spatial variation in the distribution of older and younger trees within a woodland, for a woodland to sustain itself there must be more younger trees, especially seedlings and saplings, than older trees. The direct measurement of the age of trees is both time consuming and potentially damaging to trees as it requires the removal of a core of the tree in order to count the number of annual growth rings. Trees can also be placed into different life-classes by their size, shape and proportion of dead branches (Clifford *et al.*, 2004). The life-classes do not relate directly to the age of the trees, but gives a descriptive indication of the stage in the trees life-history and these life-classes can be summarised as follows:

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

2.2 Sampling strategy

Approximately 0.6% of the upland oak woodland habitat was sampled across the whole of the Sunart SSSI by taking a total of 212 plots, of which 79 were within the area covered by the Morvern DMG, although two of these had to be excluded, as they were too steep and inaccessible to access safely. The sample plots were taken at random within areas known to have oak woodland habitat present within the SSSI and the location of these plots is shown in Figure 2. This map shows which plots are within deer exclosures, but some of these fences are no longer effective in keeping red deer out of the ground enclosed.

2.3 Field survey

2.3.1 Woodland profile

The survey was carried out between the 16th April and 9th May. The surveyors navigated their way to the sample plot locations using maps and hand-held GPS receivers (typically Garmin GS12s). Two sample plots (S35 and S174) had to be discarded because they were totally inaccessible on the cliffs below Creag Dhubh between Laudale House and Liddesdale at the east side of the Morvern DMG (Figure 2). In addition, a number had to be moved a certain distance so that they were accessed safely. In every instance the grid reference at the centre of the plot was recorded. The centre of the plot was marked with a wooden post with a numbered tag. Fifty five 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 another 11 plots were more than 20 metres from the grid reference. Several of the plots had to be moved a significant distance from the given grid reference to make it possible to ensure that at least one tree, seedling or sapling was present within the plot or to ensure the plot could be accessed safely.

At 63 of the 77 plots surveyed all trees, seedlings and saplings were recorded within a 25.2 metre diameter plot centred on the central post. The diameter of each tree (diameters more than 5 cm) was measured 1.3 metres above the ground (dbh) to the nearest centimetre with either a forestry tape or a tailor's tape measure. The Forestry Commission NFI Survey Manual for measuring tree diameters was followed (FC NFI 15.0). Where a tree had multiple stems at 1.3 m above the ground each one was measured separately and assigned to the tree. The species of tree and its life-class was also noted using the classes described by Clifford *et al*. (2004) (see Annex 3 for details of life-classes).

The Forestry Commission guidance on monitoring even-aged stands of trees suggests that at densities of more than 300 stems per ha, a 11.2 m diameter plot is used, i.e. 100 m^2 (Kerr *et al.*, 2002). Where the densities are between 150 and 300 stems per hectare, a 16 m diameter plot is used, i.e. 200 m^2. The plot size was also reduced for counting and measuring trees at 12 of these plots (S3, S11, S13, S42, S59, S77, S89, S132, S183, S197, S205 and S213). 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 gave a total of 3.38ha being surveyed for trees.

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 14 plots (S3, S11, S13, S42, S48, S59, S77, S89, S132, S151, S183, S197, S205 and S213). A total of 3.30ha was surveyed for seedlings and saplings.

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

2.3.2 Herbivore impacts

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

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

If the indicator was absent 'NP' was recorded. Where there were too few epicormic shoots, basal shoots, seedlings or saplings then a 'U' was recorded to indicate it is uninformative. If the indicator was considered to be inappropriate a 'NA' was recorded. For instance, early in the season where purple moor-grass (*Molinia caerulea*) had not started to grow, but dominated the sward it was not possible to assess the levels of grazing on the sward.

2.3.3 Quality control

Before the assessment was started Dr Headley spent at least one day with each of the other field surveyors (Tom Edwards, Gus Routledge 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. Twenty large saplings were included in the calculation of basal areas and the density of small trees as they had dbh values of 5 or more cm, but were included in the calculation of large sapling densities.

2.4 Data analysis

2.4.1 Calculation of age-structure

The numbers of individual trees in each life-class were totalled for each species and then divided by the total area of the plots surveyed (3.38 ha for trees and 3.30 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

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. Standing dead trees were not included in this calculation as they cast little shade.

2.4.2 Calculation of browsing impacts

The calculation of levels of browsing on seedlings and saplings was a simple calculation of the proportions where there were absolute numbers.

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

2.4.3 Statistical analysis

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

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

3. RESULTS

3.1 Overall number and densities of trees, seedlings and saplings

A total of 1,290 live trees were counted and measured across the 3.38 ha of ground within the 77 plots surveyed. This gives an overall density of 382 live trees per ha. Seven plots (S33, S37, S74, S83, S144, S168 and S170) had no live trees within them. One or more tree seedlings were found in the remaining 66 of the 77 sample plots, but small and large saplings were only found in 50 and 32 plots, respectively. Within the 3.3 ha surveyed for seedlings and saplings a total of 2,577 seedlings and 1,143 saplings were counted. This gave an overall density of 781 seedlings per ha, 240 small saplings per ha and 106 large saplings per ha (Table 1).

A total of 39 standing dead trees were measured as well as 36 fallen dead trees and 5 dead tree stumps. The overall density of dead trees was 24 stems per ha (Table 1).

3.2 Species composition

Downy birch (*Betula pubescens*) and rowan (*Sorbus aucuparia*) were the most abundant species within this part of the Sunart SSSI (Figure 3 and Table 1). This includes all seedlings and saplings. However, when only the 1,290 live trees are analysed 69% were of downy birch, 11% were of sessile oak (*Quercus petraea*) and 9% of hazel (*Corylus avellana*). The other species making up the tree canopy in this survey were:

- 4.0% alder (*Alnus glutinosa*);
- 2.9% rowan;
- 1.6% grey willow (*Salix cinerea*);
- 1.2% holly (*Ilex aquifolium*);
- 1.0% ash (*Fraxinus excelsior*);
- 0.5% wych elm (*Ulmus glabra*);
- 0.1% Sitka spruce (*Picea sitchensis*); and
- 0.1% sycamore (*Acer psuedoplatanus*).

Two senescent trees could not be identified to a particular species of tree.

Hawthorn, eared sallow, silver birch and unidentified willows were also present, but only as seedlings and/or saplings (Table 1).

3.3 Woodland structure

For all the trees surveyed there are far more seedlings than saplings and trees (Figure 4 and Table 1). All life-classes of tree are represented, but the young reproductive life-class is at a very low density compared to the other life-classes (Figure 4). Even if the densities of the pole stage and young reproductive life-classes are combined (135.2 per ha), the number of trees per ha is less than that of the mature trees (Figure 4). The densities of senescent and “phoenix” life-classes are probably at the densities one should expect for a self-sustaining woodland.

The seedling stage is dominated mostly by rowan, with downy birch seedlings also being abundant (Figure 5 and Table 1). The small and large sapling life-classes are dominated by downy birch and to a lesser extent by hazel (Table 1). Small saplings of sessile oak were present at low densities (6.1 per ha), but only one large sapling of sessile oak was found in all the plots surveyed in this part of the Sunart SSSI giving a density of 0.3 large saplings per ha (Table 1 and Figure 5). Despite rowan having the highest densities of seedlings the densities of small saplings were third highest and the densities of large saplings were much lower still at just over 1% of the seedling density (Table 1).

Downy birch and hazel are by far the most abundant pole stage trees, but nearly all of the pole stage hazel trees are as a result of natural coppicing of large stools of this species (Table 1). The only species with trees in the young reproductive life-class were downy birch, rowan, ash and alder (Table 1).

Downy birch is the most abundant species of mature tree with a stem density eight times that of sessile oak which is the next most abundant species in the mature life-class (Figure 5 and Table 1). Alder, hazel, rowan and grey willow also make significant contributions to the number of trees in the mature life-class (Table 1). Over-mature trees of sessile oak and downy birch were at similar stem densities and well above all other species in the same life-class (Table 1). Most of the trees in the senescent and "phoenix" life-classes are mostly downy birch, sessile oak and to a lesser extent holly and alder (Table 1).

Nine of the 11 sample plots without any seedlings were in the western half of the SNH Glencripesdale property (Figure 6). Seven plots had seedling densities exceeding 2,000 per ha and six of these were in the deer exclosure around Dorlin in the Drimnin property (Figure 6). The plots with high seedling densities around Dorlin are composed mostly of high densities of rowan seedlings. Plot S42 in SNH Glencripesdale had a very high density of ash seedlings (Figure 7). Birch seedlings were found in 55% of the plots and these were scattered throughout the survey area, but they were probably most abundant in the Dorlin exclosure (Figure 7). Oak seedlings were much rarer and three of the six plots that they were found in were close to Rahoy (Figure 7). Seedlings of hazel were found in fourteen plots, and most were in three distinct areas: in five plots at the northern part of Glencripesdale; in three plots around Rahoy; and in four plots around Dorlin (Figure 7). Eight of the 19 plots with holly seedlings were in the area around Rahoy and in several plots close to Druimbuidhe within the Dorlin exclosure (Figure 7).

Small saplings were found in 65% of the sample plots and those plots with the highest densities were found:

a) at the western end of the Dorlin exclosure,
b) around Rahoy and
c) at the northern part of SNH Glencripesdale (Figure 8).

Plots with low densities or no small saplings at all were mostly found between the eastern end of the Dorlin exclosure/northern part of the Rahoy Estate through to the central part of SNH Glencripesdale (Figure 8). Most of the plots with high small sapling densities were within the Dorlin area and one of the plots was close to Rahoy. Most small saplings were of downy birch, although a very small number of plots had higher numbers of ash, hazel or grey willow (Figure 9). Many of the plots with small saplings of hazel were at the northern end of Glencripesdale and around Rahoy (Figure 9). Small saplings of rowan were only present in 22% of the 77 plots surveyed and they were most abundant around Druimbuidhe and in some parts of Glencripesdale (Figure 9).

Large saplings were present in 32 (42%) of the 77 sample plots and the inter-quartile range of densities were from 0 to 40 stems per ha (Table 2). The four plots with densities greater than 1,000 large saplings per ha were scattered across the survey area, but large saplings are largely absent from around Rahoy, the area immediately to the south of Druimbuidhe, the area around Coire Buidhe in the northern part of the Rahoy Estate, and throughout the western half of SNH Glencripesdale (Figure 10). Most of the large saplings are of downy birch and hazel, including those with high densities (Figure 11). Most of the large saplings of rowan were found within Glencripesdale (Figure 11).

Pole stage trees were found in 49% of the sample plots. Although trees in the pole stage life-class were present in most parts of the area surveyed they were generally at their highest densities within the Glencripesdale property (Figure 12). Young reproductive trees were mostly found around Dorlin and at the eastern end of the Glencripesdale property (Figure 12).There were few pole stage or young reproductive trees around Rahoy (Figure 12).

Mature trees were present in 62 (81%) of the sample plots surveyed and the inter-quartile range in the density of mature trees was between 40 and 298 stems per ha (Table 2). Plots with more than 400 mature trees per ha were scattered around the survey area with three of them located around Camas Glas within the Rahoy property (Figure 13). Over-mature trees were more restricted in their distribution, being found mostly around Rahoy and the eastern parts of Dorlin and Glencripesdale (Figure 13).

Senescent trees were found in different areas to the “phoenix” trees with the latter being found mostly in the western part of the Dorlin exclosure and at SNH Glencripesdale (Figure 15). Senescent trees were at their highest densities around Rahoy, Camas Glas and the eastern part of the Dorlin exclosure (Figure 15). The senescent trees and “phoenix” life-classes were at similar frequencies, being present in 21 and 25% of the 77 sample plots.

One or more dead trees were found in 43% of the sample plots and they were at relatively low densities with 79% of the plots having 40 or fewer stems per ha (Table 2). There were on average 11.5 standing dead trees per ha (Table 3). Lying dead trees are an important niche for particular invertebrate communities and there was a total of 26 lying dead stems with diameters of at least 20 cm across the 77 plots that were surveyed. A large proportion, 74%, of all the dead trees was downy birch. Most of the dead trees were found in the eastern half of the Dorlin exclosure, in Glencripesdale and around Rahoy (Figure 15).

3.4 Size/age distribution

The downy birch population is dominated by seedlings and small trees (Table 3 and Figure 16). Not surprisingly there are very few large (dbh 40 to 55 cm), or very large (dbh > 55cm) downy birch trees (Figure 16). Although the sample plots with the highest densities of live birch trees tend to have the lowest densities of birch seedlings and saplings (Figure 17), there is not a significant inverse relationship between the two variables (Figure 18).

The population of sessile oaks within this part of the Sunart SSSI is composed mostly of medium and large trees (Table 3 and Figure 19). The densities of small oak trees (dbh 7 to 25 cm) are low and they were about a third of the medium (dbh 25 to 40 cm) trees and half that of the large trees (Figure 19). The absolute densities of even the medium diameter trees are low at 20.7 stems per ha (Table 3). The low densities of large oak saplings suggest that only 3% of seedlings survive to the large sapling stage which shows that the recruitment of small trees is limited by the survival of the seedlings through to the small and large sapling stages. Most of the sessile oak trees are located around Rahoy (Figure 20).

As with sessile oak the apparent survival rate of rowan seedlings through to the large sapling stage is very low at only 1.4% and is the main reason why there is a low density of rowan trees in the woodland (Table 1). The densities of small and medium sized rowan trees were low at only 10.9 and 0.9 stems per ha, respectively (Table 3). High densities of rowan seedlings show no relationship with the proximity of one or more mature rowan trees in the same or nearby plot (Figure 21).

The size structure of the hazel population looks to be healthy, but in my experience the densities of small and medium sized trees are rather low for an upland oak woodland (Table 3 and Figure 22).

3.5 Basal area

Shading by the canopy can reduce the rate of recruitment of seedlings through to the sapling and young reproductive stages. 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 that were surveyed was 14.6 m^2 per ha (Table 4). This represents less than 0.2% of the ground occupied by the trunks of trees. The median basal area across the 77 plots was 13.4 m^2 per ha and the inter-quartile range is between 7.3 and 25.6 m^2 per ha (Table 4).

Downy birch accounts for 53% of the total basal area of live trees measured with sessile oak contributing another 33% to the total live basal area (Table 4). Although alder has relatively few stems per ha (23.3) it makes a significant contribution to the basal area of trees (6%) due to the large diameters of the trunks of the trees (Tables 1 and 4). Together, all the other species of tree (ash, hazel, rowan, holly, grey willow, sycamore, wych elm and Sitka spruce) account for less than 8% of the basal area of all live trees (Table 4). Most of the basal area is taken up by mature downy birch trees and over-mature sessile oak trees (Table 4). Plots S11, S59 and S183 had unusually high basal areas that were more than 50 m^2 per ha and these plots were in the SNH Glencripesdale part of the SSSI (Figure 23). The plots within the exclosure at Dorlin had rather low basal areas due to there being few or no live trees (Figure 23). The sample plots at the eastern end of SNH Glencripesdale also had generally low basal areas (Figure 23).

3.6 Herbivore impacts

Browsing levels on seedlings, small saplings and large saplings across all the species were 61%, 58% and 37%, respectively (Table 5). Levels of browsing on seedlings and saplings of downy birch were significantly lower than those on hazel, ash, holly, oak and alder (Table 5). Browsing levels on seedlings of sessile oak, willows, ash, hazel, holly and hawthorn were very high at over 85% (Table 5). The lower browsing on rowan (57%) and downy birch (52%) seedlings may in part be due to the small size of these far more numerous seedlings resulting in them being partly hidden in the field layer during the summer months. The browsing levels on small saplings of ash, holly and willows are higher than the other species, with alder and downy birch having the lowest levels of browsing on the small saplings (Table 5). It must be noted that there were only 9 small saplings of alder in the 77 plots and therefore, the levels of browsing for this life-stage of this species may or may not be representative of the population as a whole.

When the browsing levels are analysed across individual plots the inter-quartile range for browsing on seedlings was between 67 and 100% with the median browsing level being 97% (Table 5). The median browsing level on small saplings was 91% and the inter-quartile range was between 46 and 100% (Table 5).

There is no specific pattern in the distribution of browsing impacts on seedlings, small saplings and large saplings (Figures 24, 25 and 26).

Browsing levels on epicormic shoots could not be assessed in 35 sample plots because they were absent or it was not applicable due to the absence of mature trees. The levels of grazing on the sward could only be assessed in 27 plots due to the assessment being carried out too early in the season to see the levels of grazing on the herbaceous species (Table 6). The majority of the herbivore impacts are high for each of the indicators, except for bark stripping as fraying and bark stripping on seedlings and sapling was very rarely observed (Table 6). The most frequent herbivore impact for the overall browsing/grazing was High, with Moderate impacts being the next most frequent (Table 6). A number of the plots with Very High or Very

High/High herbivore impacts are around Rahoy, whilst many of the plots with Moderate, Moderate/Low or Low herbivore impacts are at the western end of the Dorlin exclosure and at the eastern end of Glencripesdale (Figure 27).

3.7 Herbivores

The large herbivores that were observed during the survey within the Sunart SSSI that are resulting in most of the browsing impacts on the tree seedlings and/or saplings are almost exclusively deer (roe and red). No sheep were observed in any of the areas surveyed. Cattle and sheep do graze the area immediately outside the deer fence that surrounds the Dorlin area.

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

3.8 Potential for tree regeneration

All areas of the Sunart SSSI that were surveyed have the potential to support tree regeneration. There are plenty of seed sources for the regeneration of downy birch, rowan and oak. There are plenty of niches for tree seedlings to establish as shown by the abundance of seedlings found in this survey. However, relatively few seedlings of sessile oak were found in this survey.

3.9 Invasive non-native species

One tree of the non-native Sitka spruce was found in plot S67 and seedlings and/or saplings of this non-native species were found in a total of 10 sample plots.

One sycamore tree was recorded in plot S88.

No rhododendron bushes were found in any of the plots in this part of the Sunart SSSI, though rhododendron is known to be present in some areas in this part of the SSSI.

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 the small sapling generation is low (Figure 19). The densities of oak seedlings were lower than that of the mature and over-mature tree cohorts (Table 1). 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 largely viable as there are higher densities of seedlings and small saplings than mature trees (Table 1). Having said this, the density of large saplings, pole stage and young reproductive trees are lower than that of mature trees (Table 1).

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

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, 5, 7 and 8 are satisfied. In terms of target 5 both criteria are met as there were 10 standing dead stems per ha and on average there were 3.8 fallen trees per ha with a minimum diameter of 20 cm. Deliberately planted trees were seen in this survey. Non-native species, Sitka spruce and sycamore, make up much less than 1% of the tree canopy (Table 4), and no rhododendron was seen during this survey, although it is known to be present in the wider SSSI.

Target 1 is only satisfied in that large saplings (3 to 5 metres tall) were present in 34% of the sample plots, but the understorey cover is well below 20% and probably only amounts to a few percent.

Sessile oak, downy birch and hazel are the commonest trees in the Sunart SSSI upland oak woodland habitat. Downy birch satisfies target 3 listed above as there are plenty of seedlings, saplings and mature trees present for this species. The population of hazel probably satisfies target 3 as there are seedlings, saplings and trees of this species. However, sessile oak is largely lacking the large sapling, pole stage and young reproductive tree generations and therefore target 3 is not satisfied with respect to this species of tree which largely defines the upland oak woodland habitat.

Seedlings are not growing through to sapling and young reproductive tree stages at sufficient density to maintain the existing canopy cover, but it may take more than 10 years for this to become evident. It is therefore difficult to assess whether target 6 is satisfied or not.

4.3 Site Management Statement

It is possible to make comments on some of the targets in the Site Management Statement.

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 being achieved at present within this part protected area as well as for 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. Some areas of woodland may have been lost as a number of plots had to be moved up to 150 metres in order that some trees were present within the plot.

4.4 Reasons for lack of regeneration

The median diameter of all the live sessile oak trees measured was 34 cm. Assuming a typical annual radial growth rate of 1 to 2 mm per annum, the majority (inter-quartile range) of the trees (24 to 43 cm diameter) were established between about 71 and 215 years ago (Büyüksair *et al.*, 2018). Therefore, the sessile oak population was probably mainly established during the peak of the Highland clearances in the nineteenth century when red and roe deer numbers were also low. During this period there was an increase in the amount of tree planting for deer parks as well as charcoal and tannin production. Whether the oak trees within the woodland surveyed were planted or not is open to question and may vary throughout the SSSI.

The lack of oak seedlings observed in this survey cannot be attributed to them being overlooked as the majority of the survey was carried out before the sward/field layer had started to grow and come into leaf. The absence of even small oak seedlings cannot be attributed to shading by mature trees as acorn germination and initial seedling growth is not affected by this factor (Jarvis, 1964; Březina & Dobrovolný, 2011). High levels of browsing on the small number of seedlings available in winter are a likely factor contributing to the absence of saplings. The low density of seedlings could also be due to either insufficient acorn production and/or predation of the acorns by voles, squirrels and various species of bird (Shaw, 1968). The presence of a large number of over-mature, senescent and “phoenix” trees in the population is likely to contribute to a low acorn production. When there is a low supply of acorns the predation of the acorns will be a more important factor in resulting in the low regeneration of oak seedlings (Shaw, 1968).

The downy birch population within the Sunart SSSI has a less than perfect inverted J-shaped frequency-size/age distribution curve (Figure 16). This is because the cohorts of seedlings and saplings are at lower densities than the generation of small trees (dbh 5 to 25 cm). As birch is a prolific producer of wind dispersed seeds, seed availability is unlikely to be limiting. It is more likely that niches for seedling establishment are more likely to be limiting its regeneration. The apparent survival rates of downy birch seedlings to the sapling stage are relatively good at 61% and the densities of large saplings are 55% of that of small saplings (Table 1).

Browsing by deer is almost certainly limiting the regeneration of hazel, ash, rowan, holly and willows as well as the sessile oak population. This is indicated by the high rates of browsing on the seedlings and small saplings of hazel, ash, holly and willow (Table 5). Although the apparent rates of browsing on rowan seedlings is not as high there is an apparently poor rate of survival rate (1.4%) to the large sapling stage (Table 1).

The three most likely factors preventing the recruitment of saplings from the seedling stage are browsing by large herbivores, insufficient light or disease. There was no evidence that plant pathogens had resulted in the death of any of the sessile oak, downy birch and rowan seedlings and saplings. Low light levels can result in the death of light demanding species of tree, such as downy birch (Price & MacDonald, 2012). The basal area of trees can be used as a surrogate for the amount of light likely to reach the floor of conifer plantations and allow the natural regeneration of trees (Hale, 2004). Sessile oak is a moderately shade tolerant species and can apparently tolerate shading levels as low as 50% of ambient light (Jarvis, 1964; Annighöfer *et al*., 2015; Březina & Dobrovolný, 2011). A stand of Scots pine trees with a basal area of about 25 m^2 per ha has light levels reduced to 35% of ambient light (Hale, 2004). However, Scots pine is an evergreen conifer and that even-aged plantations were examined which would have maximum shading would result in the greatest level of shading for the given basal area. The fact that high densities of sessile oak and downy birch seedlings are seen at basal areas of 34 to 38 m^2 per ha suggests that this level of shading does not restrict germination and initial seedling establishment (Figure 28). Out of the 77 plots covered by this survey only 6 plots had basal areas greater than 40 m^2 ha^{-1}. Therefore shading could only be a factor in the establishment of seedlings and saplings in less than 8% of the woodland surveyed.

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

4.5 Prognosis

If current levels of browsing continue, the dominance of the woodland canopy by oak will be gradually reduced as the old and senescing trees die. Currently the only tree that is being recruited in any significant way is downy birch, and as this is species is more resilient to browsing and is also less palatable (see Forestry Commission Scotland woodland grazing toolbox) this species is likely to become the dominant species in the canopy. Therefore, in the long term the woodland is most likely to change from one dominated by large over-mature sessile oak trees to one dominated by downy birch. The maintenance of a healthy population of large oak trees is important for this SSSI. This is because the upland oak woodland on the Atlantic seaboard of Scotland are internationally important for their lichen and bryophyte communities. The shade and higher levels of humidity maintained by the presence of a canopy of trees is important for bryophytes and other plants growing on rocks and the ground. Although hazel, ash and rowan (as well as oak) can also support the rarer and more species-rich 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.

There are deer fences around most of the woodlands surveyed. However, the deer fence at Dorlin within the Drimnin estate is at least 10 years old. Whether deer are getting in through gaps through the fence or swimming around the ends of the fence where it goes into Loch Sunart is not known. There may have been a benefit of the erection of these deer fences as there are higher densities of birch and rowan seedlings within the exclosure at Dorlin, but these seedlings have established long after the fence was originally erected.

5. CONCLUSIONS

- Taken as a whole, the age structure of the Sunart SSSI that lies within the Morvern DMG is poor, due to a low number of large saplings, pole stage and young reproductive trees.
- The woodland canopy is dominated by downy birch and sessile oak is currently a significantly smaller component.
- More young trees of sessile oak are needed to replace the ageing and dying populations of sessile oak trees.
- Browsing by deer is largely responsible for the low survival of sessile oak, hazel, rowan and holly seedlings through to the small and large sapling stages.
- The low densities of sessile oak seedlings in certain parts of the woodland habitat may also be related to poor acorn production by the low numbers of trees and/or the low productivity of ageing/senescing oak trees in the area.
- If nothing is done to encourage an increase in the regeneration of sessile oak the woodland will gradually change to a birchwood.
- The exclosures around Dorlin and Rahoy are clearly not currently effective in stopping the encroachment of red deer into these areas as carcasses of these animals were found as well as the faeces of red deer.
- Without some interventions to reduce the red deer numbers as well as boosting the oak population, the woodland will lose some of its conservation interest in terms of its epiphytic lichen and bryophyte flora.

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ANNEX 1: TABLES

Table 1. The stem density (stems per ha) of each life-class for each species of tree surveyed across the Morvern 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	197.8	121.5	67.3	89.0	15.1	120.4	27.5	6.2	4.7	**649.6**	17.5
rowan	437.5	23.3	6.1	2.7	1.2	5.6	0.9	0.9	0.0	**478.1**	0.3
hazel	64.5	41.2	23.0	23.1	0.0	8.9	0.6	0.0	0.3	**161.6**	0.6
sessile oak	10.0	6.1	0.3	0.0	0.0	14.5	24.0	2.4	1.5	**59.0**	2.4
ash	36.7	12.4	1.5	1.8	0.6	0.9	0.6	0.0	0.0	**54.4**	0.3
holly	18.8	4.2	0.3	0.3	0.0	2.1	0.0	0.0	2.1	**27.8**	0.0
grey willow	0.6	11.2	6.1	0.3	0.0	5.0	0.6	0.0	0.0	**23.8**	0.0
alder	5.2	2.7	0.3	0.9	0.3	8.6	3.3	0.3	1.8	**23.3**	1.2
unassigned willow	0.0	12.7	1.2	0	0.0	0.0	0.0	0.0	0.0	**13.9**	0.0
Sitka spruce	4.5	2.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	**7.0**	0.0
silver birch	4.8	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**6.9**	0.0
wych elm	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	**1.8**	0.0
hawthorn	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.6**	0.0
unknown species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	**0.6**	1.5
eared sallow	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.3**	0.0
sycamore	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	**0.3**	0.0
All species	**780.7**	**240.2**	**106.0**	**118.0**	**17.2**	**166.5**	**59.2**	**10.4**	**10.4**	**1,508.6**	**23.7**

Table 2. Summary statistics on the data collected from across the 84 sample plots surveyed within the Sunart SSSI.

Species/ variable	Life-class	Statistic						
		Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
Stem density of all species (stems per ha)	Seedling	983	2,373	0	80	220	580	14,200
	Small sapling	349	696	0	0	40	280	3,800
	Large sapling	105	301	0	0	0	40	1,600
	Pole	277	703	0	0	0	140	4,466
	Young reproductive	26	99	0	0	0	0	812
	Mature	192	222	0	40	102	298	1,015
	Over-mature	61	72	0	0	40	120	305
	Senescent	10	25	0	0	0	0	160
	"Phoenix"	14	32	0	0	0	0	120
	All live trees	578	798	0	180	301	621	4,974
	All dead trees	27	49	0	0	0	40	300
alder density	Seedlings	9	49	0	0	0	0	406
	Small saplings	2	15	0	0	0	0	120
	All live trees	26	122	0	0	0	0	1,015
ash density	Seedlings	154	1,330	0	0	0	0	11,673
	Small saplings	27	180	0	0	0	0	1,523
	Large saplings	7	58	0	0	0	0	508
	All live trees	9	59	0	0	0	0	508
downy birch density	Seedlings	212	639	0	0	40	160	5,013
	Small saplings	186	553	0	0	0	80	3,857
	Large saplings	68	247	0	0	0	20	1,825
	All live trees	375	524	0	40	241	441	2,500
grey willow density	Small saplings	38	258	0	0	0	0	2,200
	Large saplings	5	46	0	0	0	0	401
	All live trees	5	30	0	0	0	0	241
hazel density	Seedlings	63	216	0	0	0	0	1,143
	Small saplings	43	173	0	0	0	0	1,083
	Large saplings	24	106	0	0	0	0	822
	All live trees	95	551	0	0	0	0	4,669
holly density	Seedlings	17	38	0	0	0	0	160
	Small saplings	7	27	0	0	0	0	203
	All live trees	6	27	0	0	0	0	203
rowan density	Seedlings	514	1,366	0	0	40	301	7,004
	Small saplings	35	130	0	0	0	0	796
	Large saplings	8	25	0	0	0	0	120
	All trees	13	27	0	0	0	0	120
sessile oak density	Seedlings	10	44	0	0	0	0	341
	Small saplings	5	35	0	0	0	0	301
	Large saplings	0	2	0	0	0	0	20
	All live trees	44	85	0	0	0	40	341
Sitka spruce	Seedlings	4	13	0	0	0	0	80
	Small saplings	2	12	0	0	0	0	100
	All live trees	1	2	0	0	0	0	20
sycamore	All live trees	0.3	2.3	0	0	0	0	20
wych elm	All live trees	2	14	0	0	0	0	120

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

Species of tree	**Number of stems per ha**						
	small trees	medium trees	large trees	very large trees	standing dead	fallen dead	dead stump
downy birch	214.5	40.2	4.1	0.3	6.8	9.2	1.5
sessile oak	6.2	20.7	12.4	2.7	1.8	0.6	0.0
hazel	32.5	0.6	0.3	0.0	0.3	0.3	0.0
alder	10.1	3.0	1.8	0.0	0.9	0.3	0.0
rowan	10.9	0.9	0.0	0.0	0.3	0.0	0.0
grey willow	5.9	0.0	0.0	0.0	0.0	0.0	0.0
holly	4.1	0.0	0.0	0.3	0.0	0.0	0.0
ash	3.0	0.0	0.6	0.3	0.0	0.3	0.0
wych elm	0.9	0.9	0.0	0.0	0.0	0.0	0.0
sycamore	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Sitka spruce	0.3	0.0	0.0	0.0	0.0	0.0	0.0
unknown species	0.6	0.0	0.0	0.0	1.5	0.0	0.0
All species	289.0	66.3	19.5	3.8	11.5	10.6	1.5

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**
downy birch	0.825	0.164	4.747	1.547	0.207	0.193	0.630	**7.683**
sessile oak	0.000	0.000	1.225	3.392	0.145	0.136	0.202	**4.898**
alder	0.010	0.006	0.546	0.250	0.018	0.062	0.167	**0.891**
hazel	0.125	0.000	0.153	0.043	0.000	0.001	0.000	**0.321**
ash	0.018	0.012	0.070	0.148	0.000	0.000	0.004	**0.248**
rowan	0.012	0.016	0.135	0.035	0.018	0.000	0.001	**0.215**
holly	0.002	0.000	0.033	0.000	0.000	0.125	0.000	**0.160**
wych elm	0.000	0.000	0.000	0.072	0.000	0.000	0.000	**0.072**
grey willow	0.001	0.000	0.064	0.004	0.000	0.000	0.000	**0.070**
sycamore	0.000	0.000	0.039	0.000	0.000	0.000	0.000	**0.039**
Sitka spruce	0.000	0.000	0.012	0.000	0.000	0.000	0.000	**0.012**
unknown species	0.000	0.000	0.000	0.000	0.013	0.000	0.015	**0.013**
All species	**0.992**	**0.198**	**7.024**	**5.491**	**0.401**	**0.516**	**1.019**	**14.622**

Basal Area (m^2 per ha)		Statistic						
		Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
	All species	17.2	14.5	0	7.3	13.4	25.6	72.9

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

Species of tree	Seedlings			Small saplings			Large saplings			**All seedlings & saplings**	
	Un-browsed	Browsed		Un-browsed	Browsed		Un-browsed	Browsed			
		number	%		number	%		number	%	**number**	**% browsed**
rowan	624	820	57	28	49	64	14	6	30	**1,541**	**57**
downy birch	313	340	52	230	171	43	129	93	42	**1,276**	**47**
hazel	24	189	89	35	101	74	70	6	8	**425**	**70**
ash	1	120	99	3	38	93	5	0	0	**167**	**95**
holly	2	60	97	2	12	86	1	0	0	**77**	**94**
all willows	0	2	100	13	67	84	2	22	92	**106**	**86**
sessile oak	0	33	100	9	11	55	1	0	0	**54**	**81**
alder	5	12	71	6	3	33	0	1	100	**27**	**59**
silver birch	16	0	0	7	0	0	0	0	NA	**23**	**0**
Sitka spruce	9	6	40	1	6	86	0	0	NA	**22**	**55**
hawthorn	0	1	100	1	0	0	0	0	NA	**2**	**50**
All species	**994**	**1,583**	**61**	**335**	**458**	**58**	**222**	**128**	**37**	**3,720**	**58**

Life-class	Statistic						
	Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
Seedlings	81	26	0	67	97	100	100
Small saplings	69	38	0	46	90	100	100
Large saplings	33	43	0	0	0	85	100

Table 6. 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 Morvern DMG. Numbers highlighted in yellow indicate the median impact level for that indicator.

Browsing impact indicator	Herbivore Impact Class							Not applicable
	Very High	Very High/High	High	High/Moderate	Moderate	Moderate/Low	Low	
Basal shoots	9	2	35	0	12	0	5	14
Epicormic shoots	0	1	28	0	9	0	4	35
Seedlings and saplings	11	4	30	6	12	1	3	10
Preferentially grazed spp.	5	1	33	6	3	2	6	21
Sward	2	0	16	0	3	0	6	50
Bark Stripping	0	0	2	0	7	1	61	6
Overall Impact	**4**	**3**	**44**	**5**	**11**	**2**	**8**	**0**

ANNEX 2: FIGURES

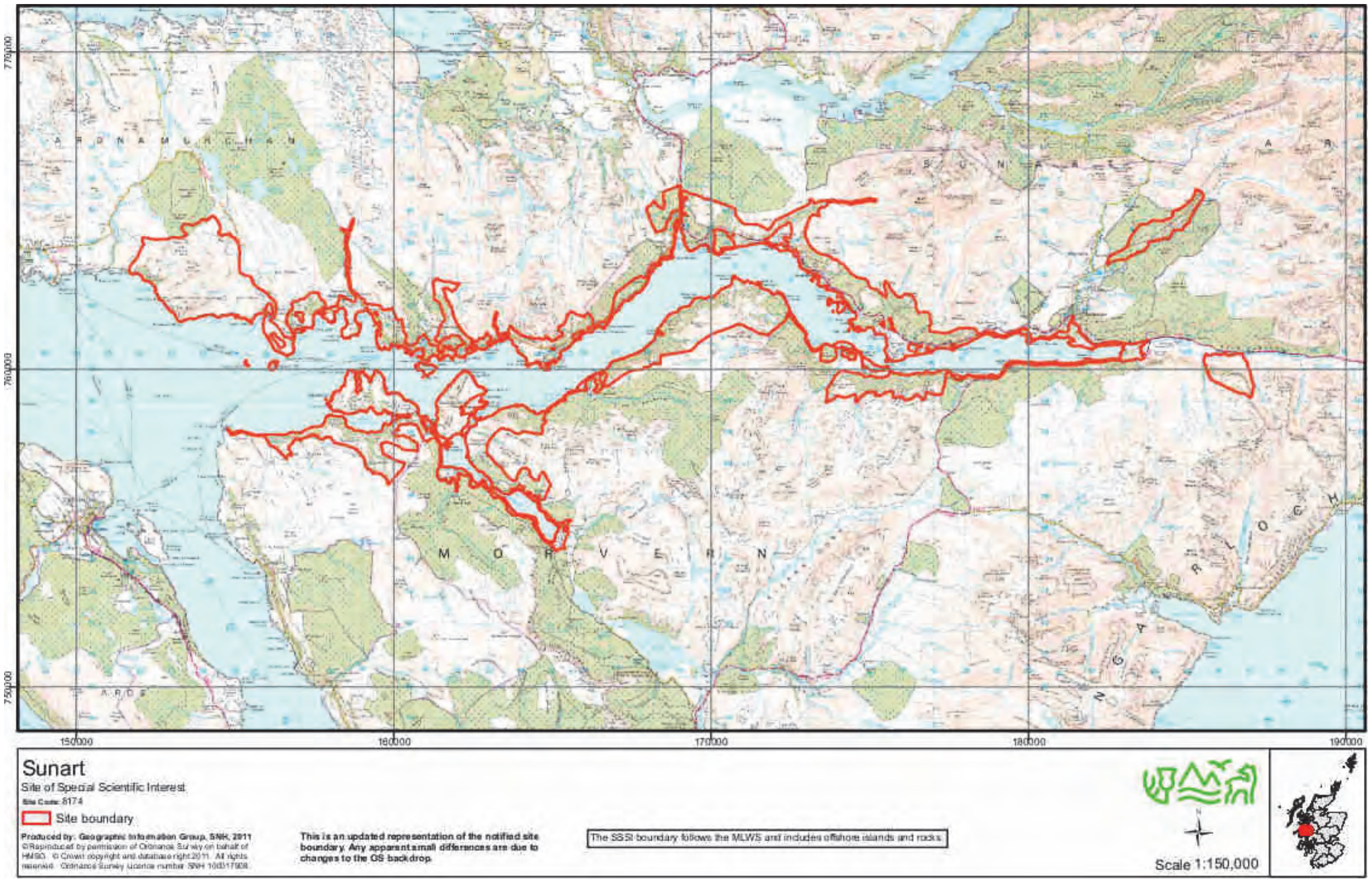


Figure 1. Map showing the location and boundary of the Sunart SSSI.

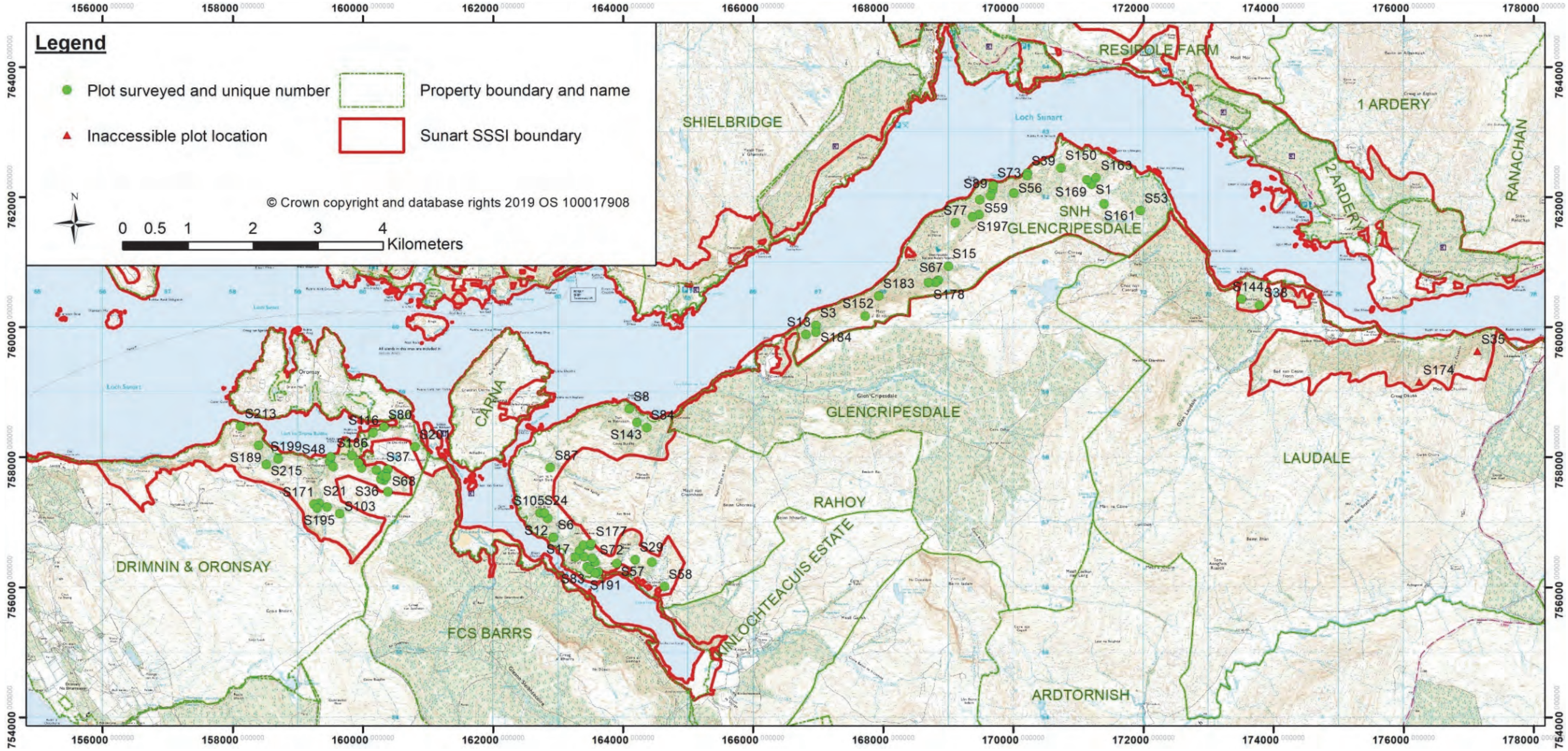


Figure 2. Map showing the location of the 79 sample plots within the Morvern Deer Management Group (DMG) part of the Sunart SSSI taken to describe the structure and assess the herbivore impacts on the upland oak woodland habitat.

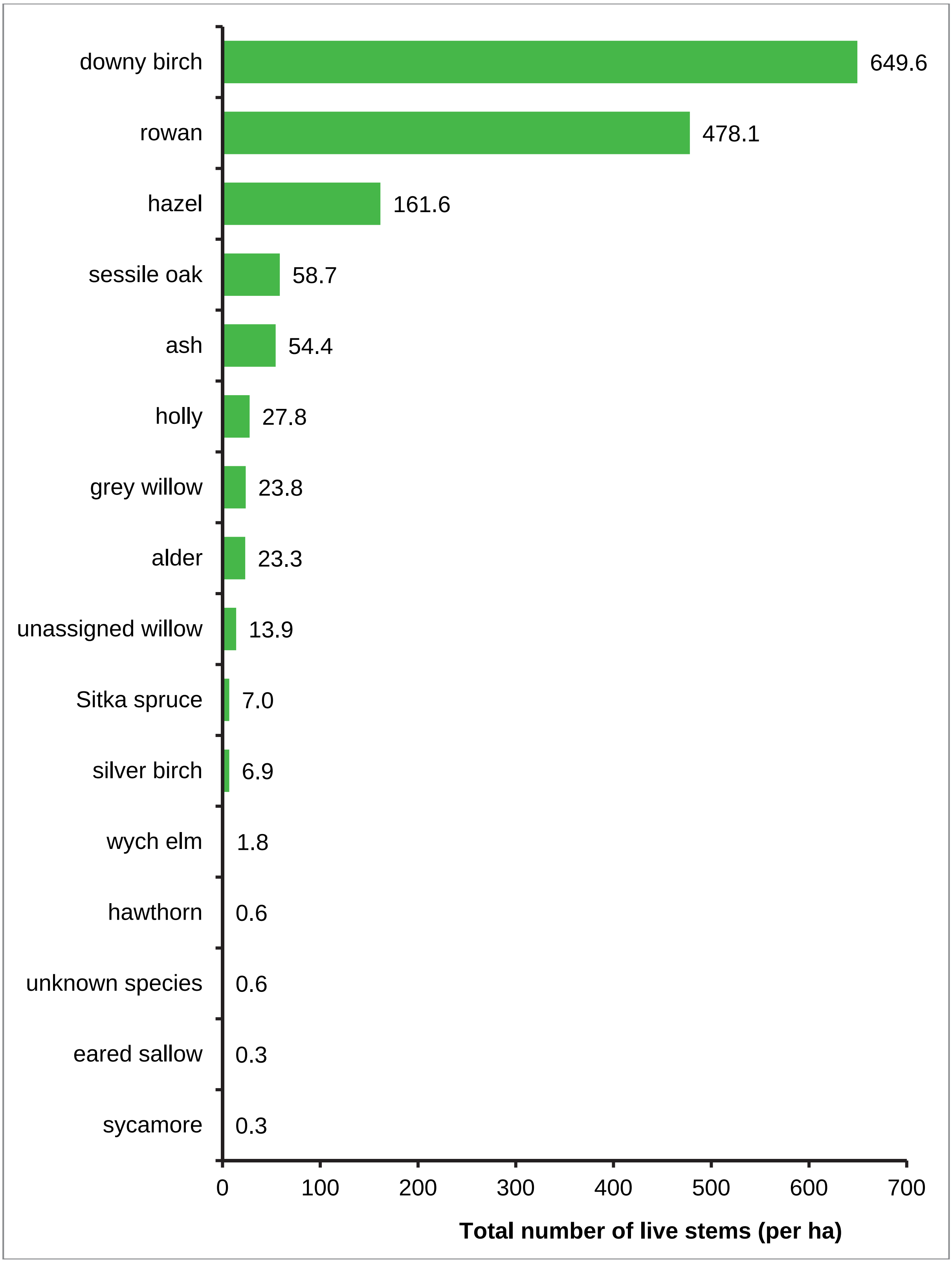


Figure 3. The total density of seedlings, saplings and live trees measured and counted for each species of tree surveyed across the Sunart SSSI that was also within the Morvern DMG.

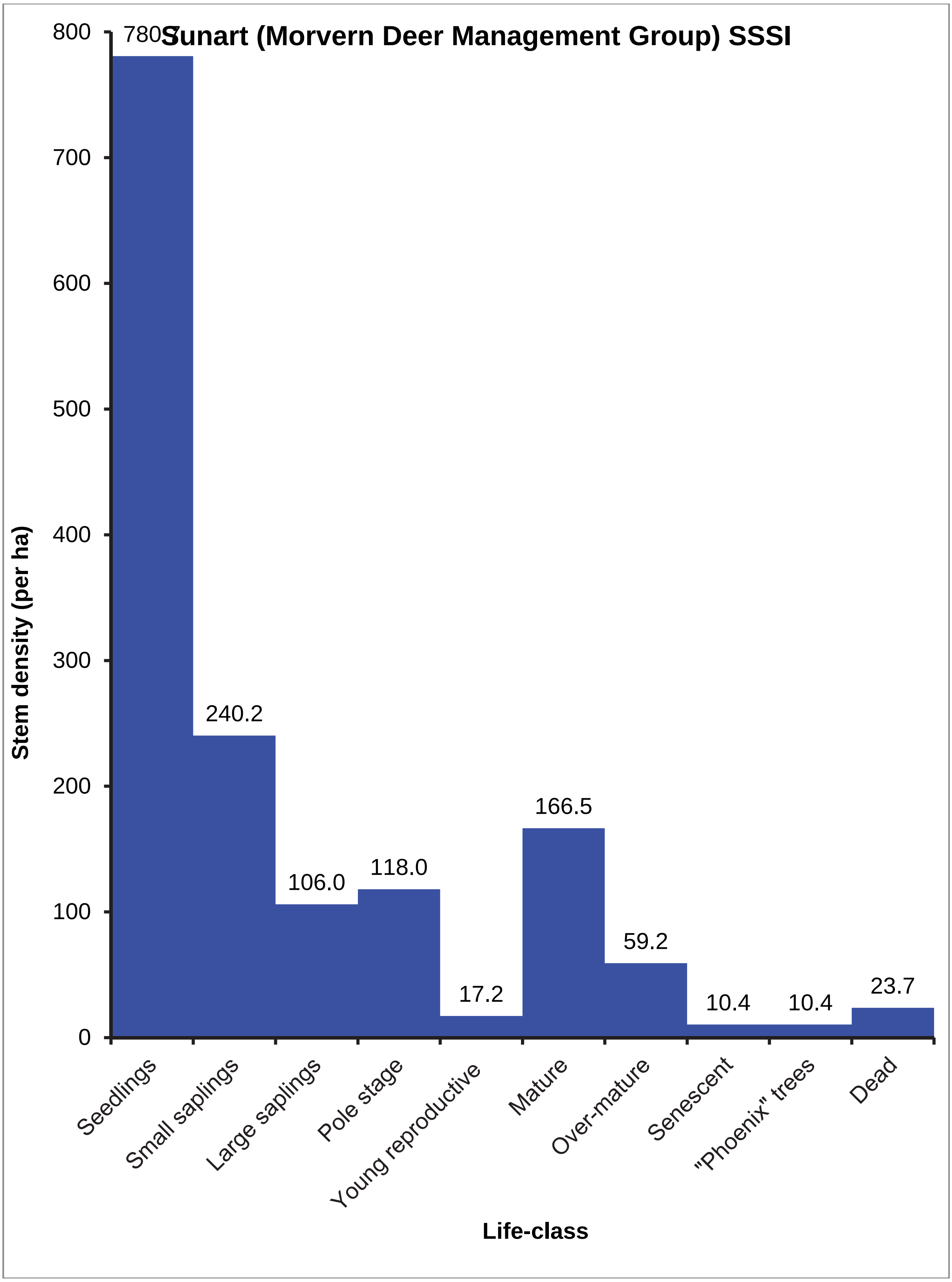


Figure 4. The stem density of all species of tree in each life-class surveyed across the part of the Sunart SSSI that are also within the Morvern DMG.

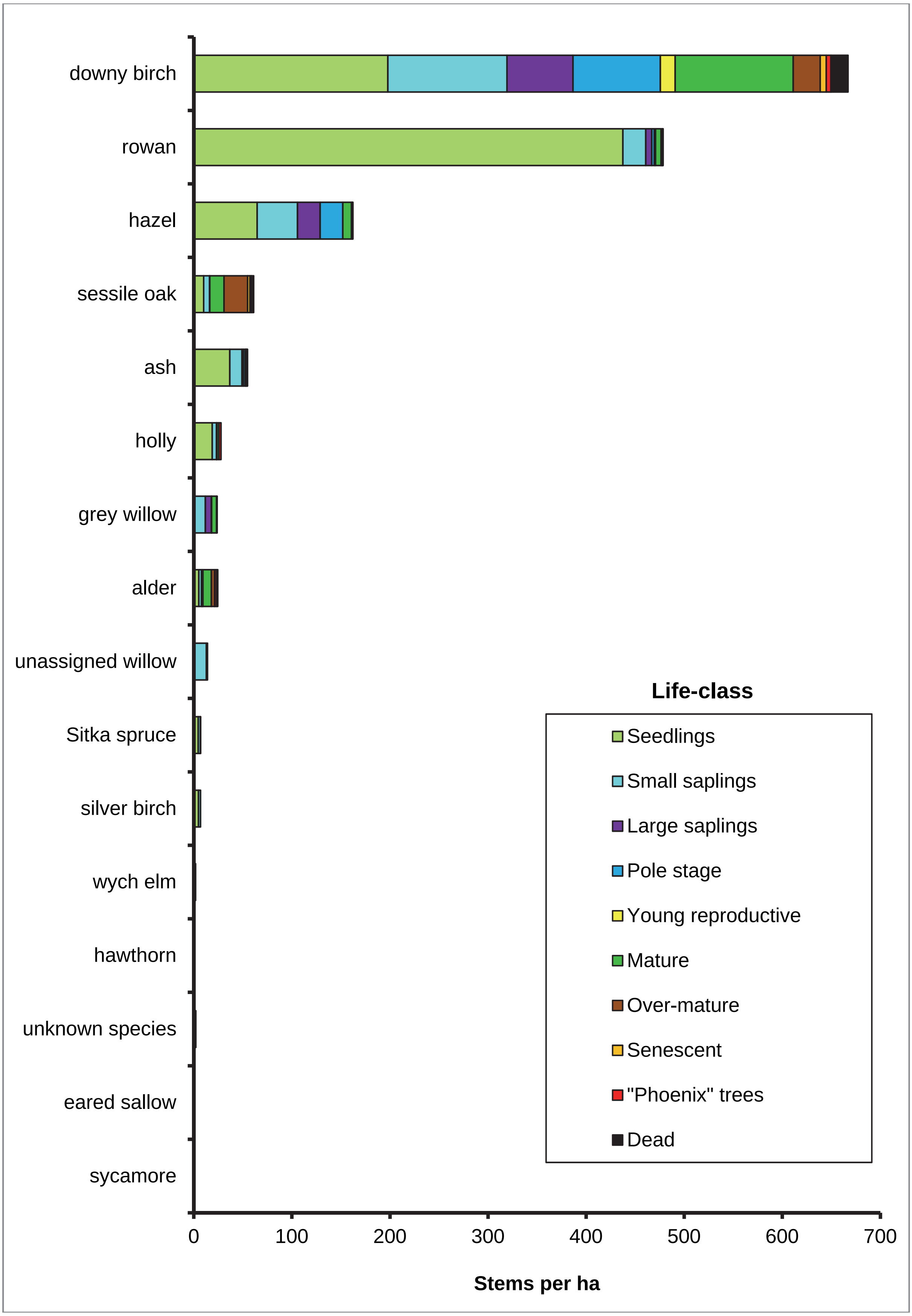


Figure 5. The stem density (per ha) for each life-class for each species of tree surveyed across the Sunart SSSI that are also within the Morvern DMG.

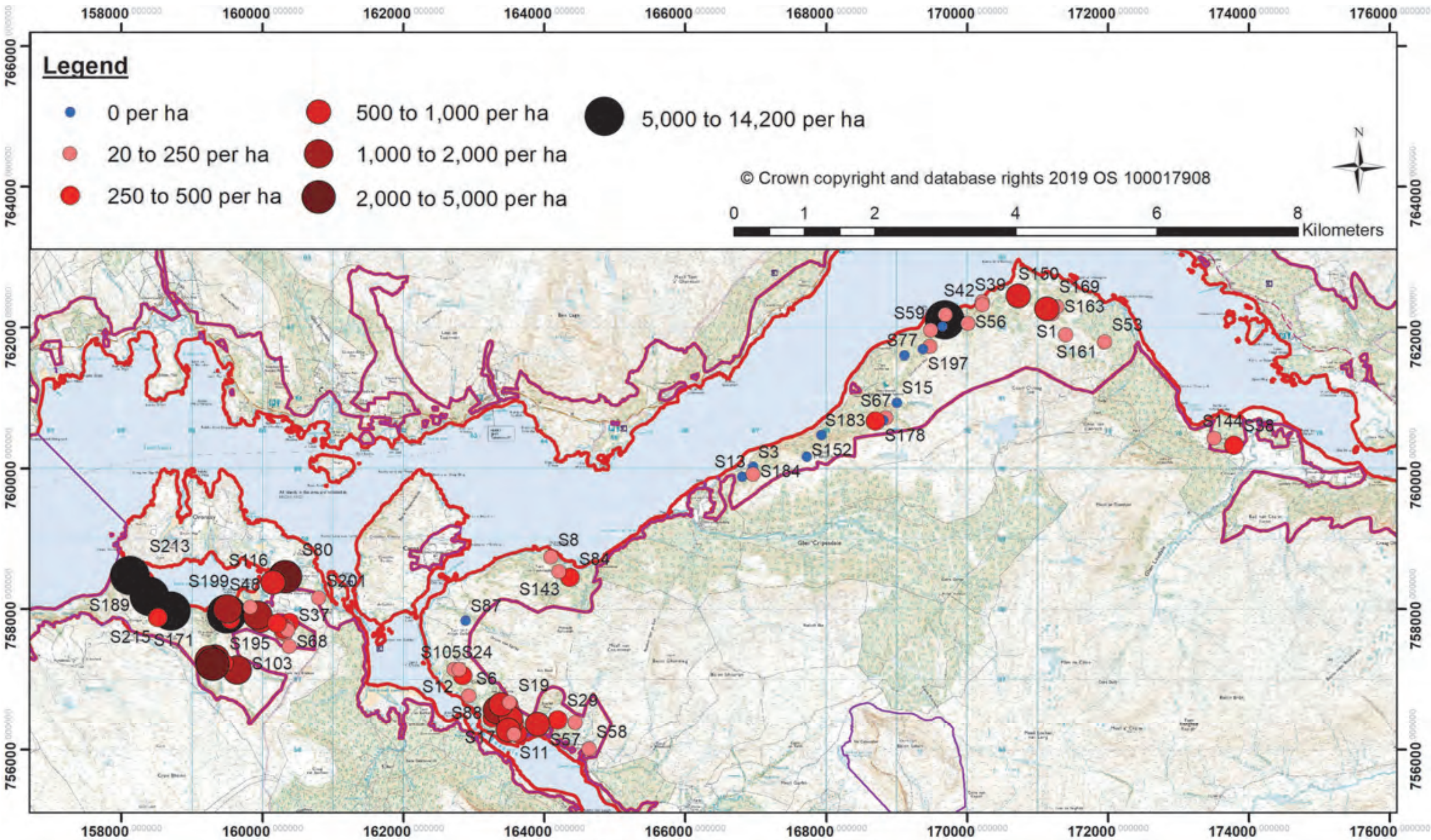


Figure 6. The density of all seedlings (per ha) in the plots surveyed across the Sunart SSSI that are also within the Morvern DMG.

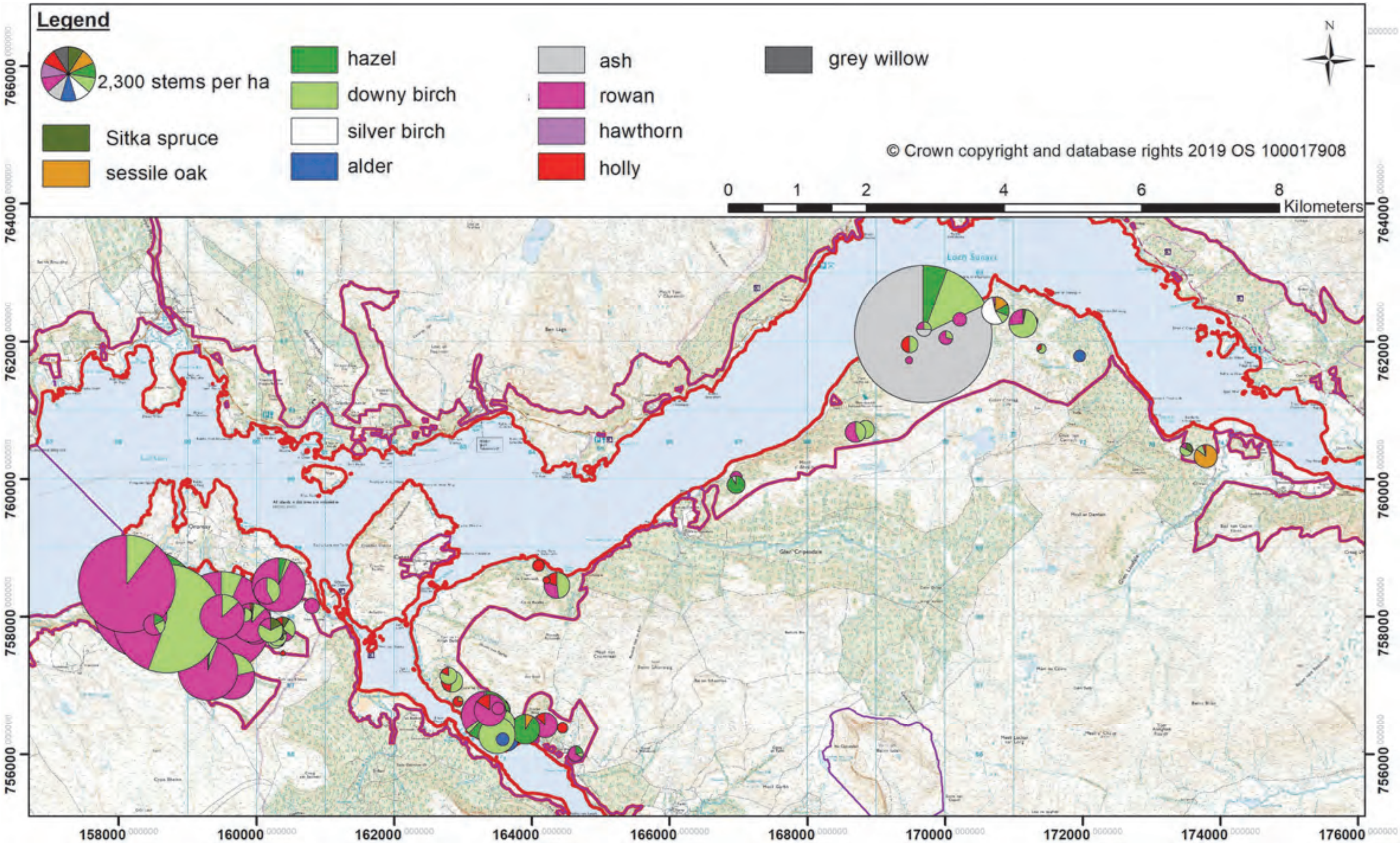


Figure 7. The species of composition of the seedling populations in each of the 77 plots surveyed.

The area of the pies is proportional to the cumulative density of seedlings.

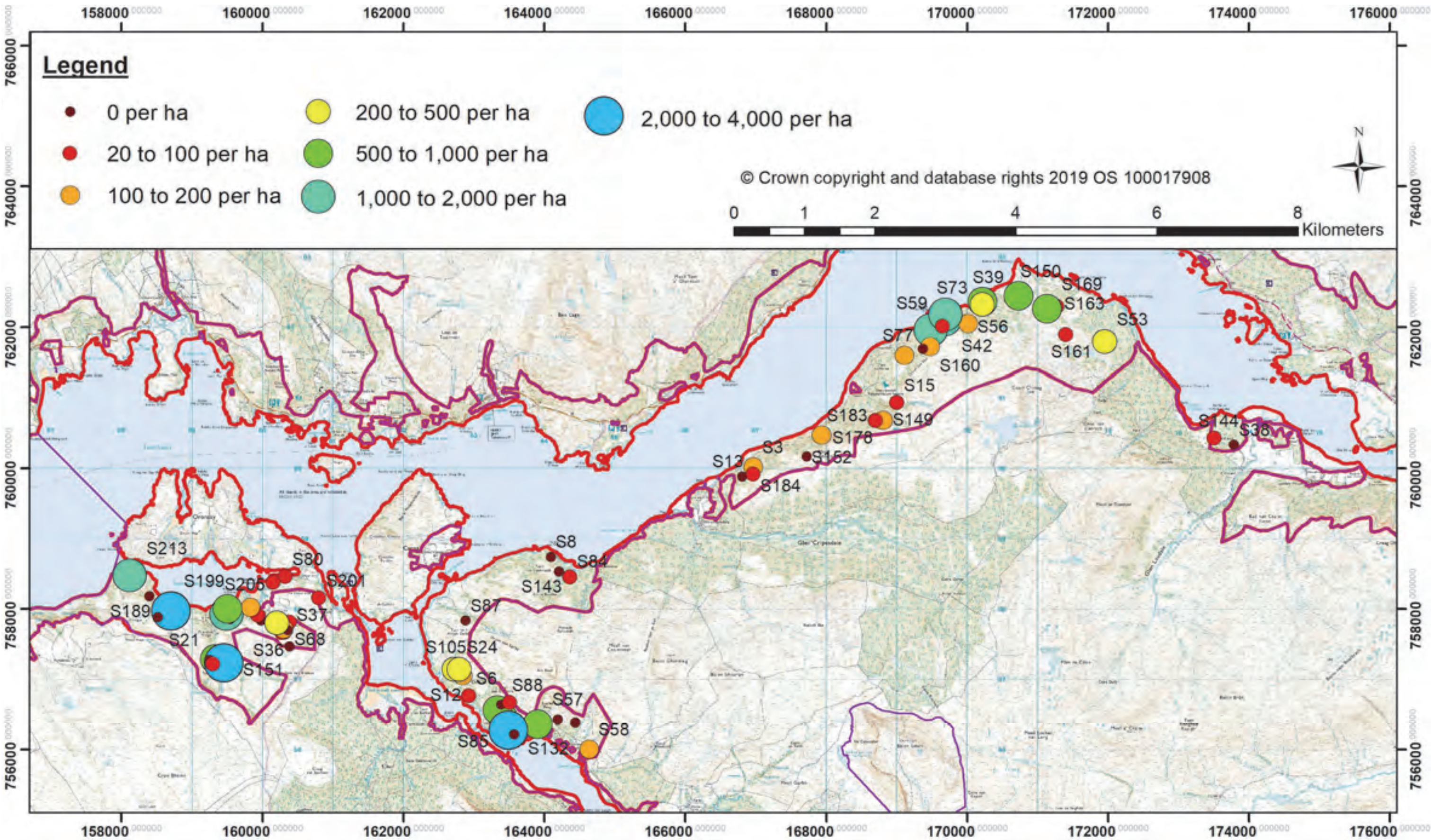


Figure 8. The density of small saplings (per ha) in the plots surveyed across the Sunart SSSI that are also within the Morvern DMG.

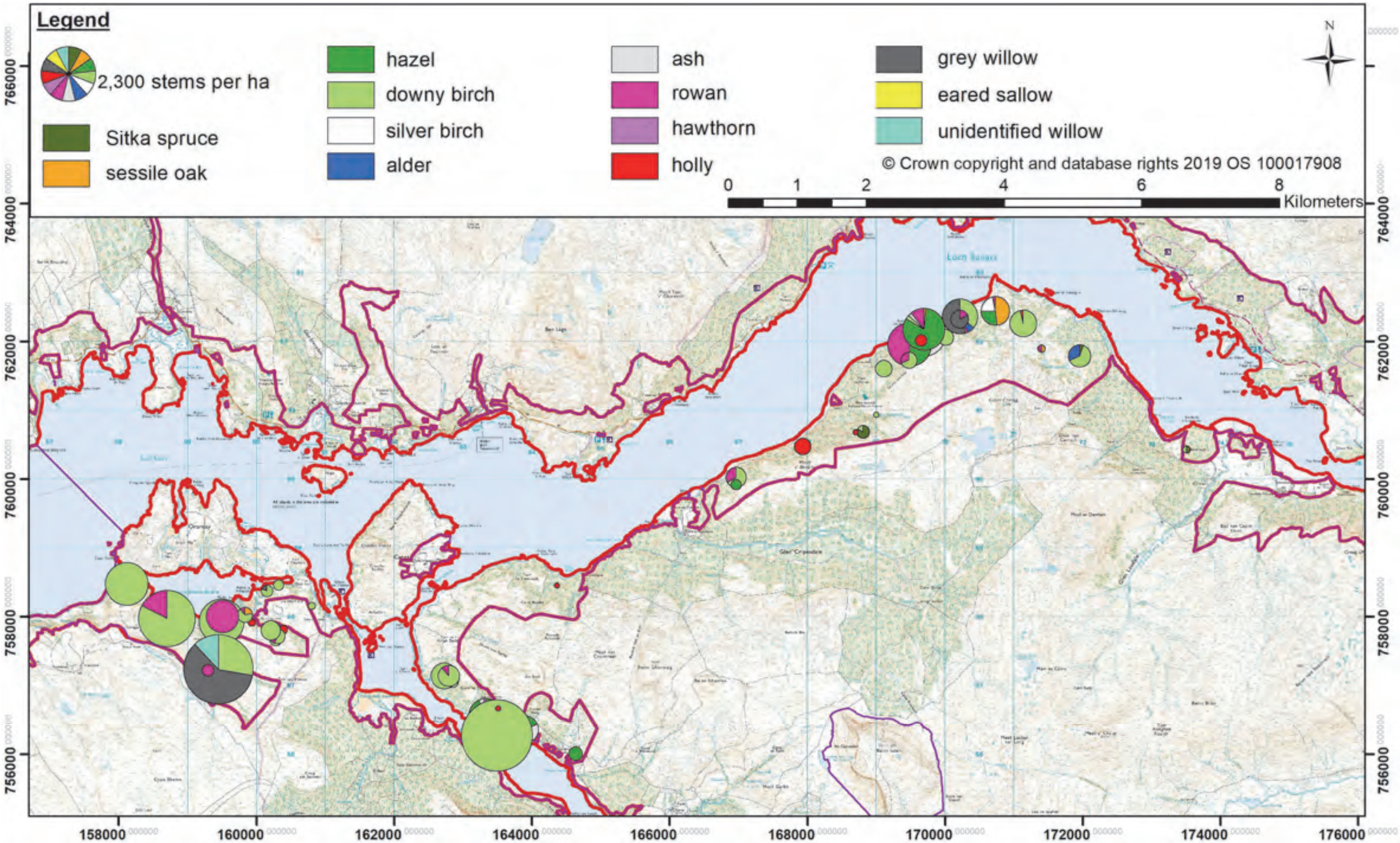


Figure 9. The species of composition of the small sapling populations in each of the 77 plots surveyed.

The area of the pies is proportional to the cumulative density of small saplings (stems per ha).

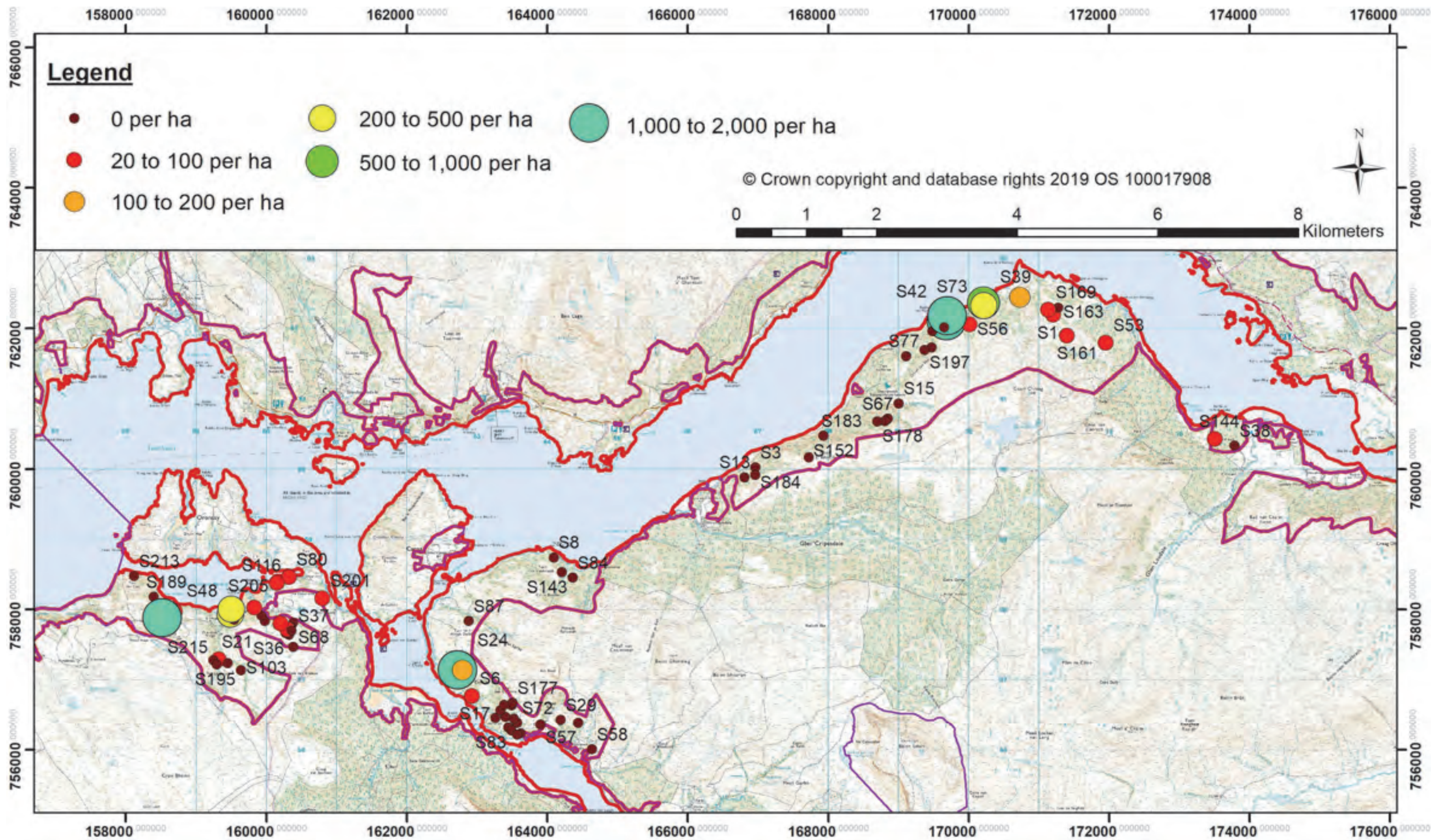


Figure 10. The density of large saplings (per ha) in the plots surveyed across the Sunart SSSI that are also within the Morvern DMG.

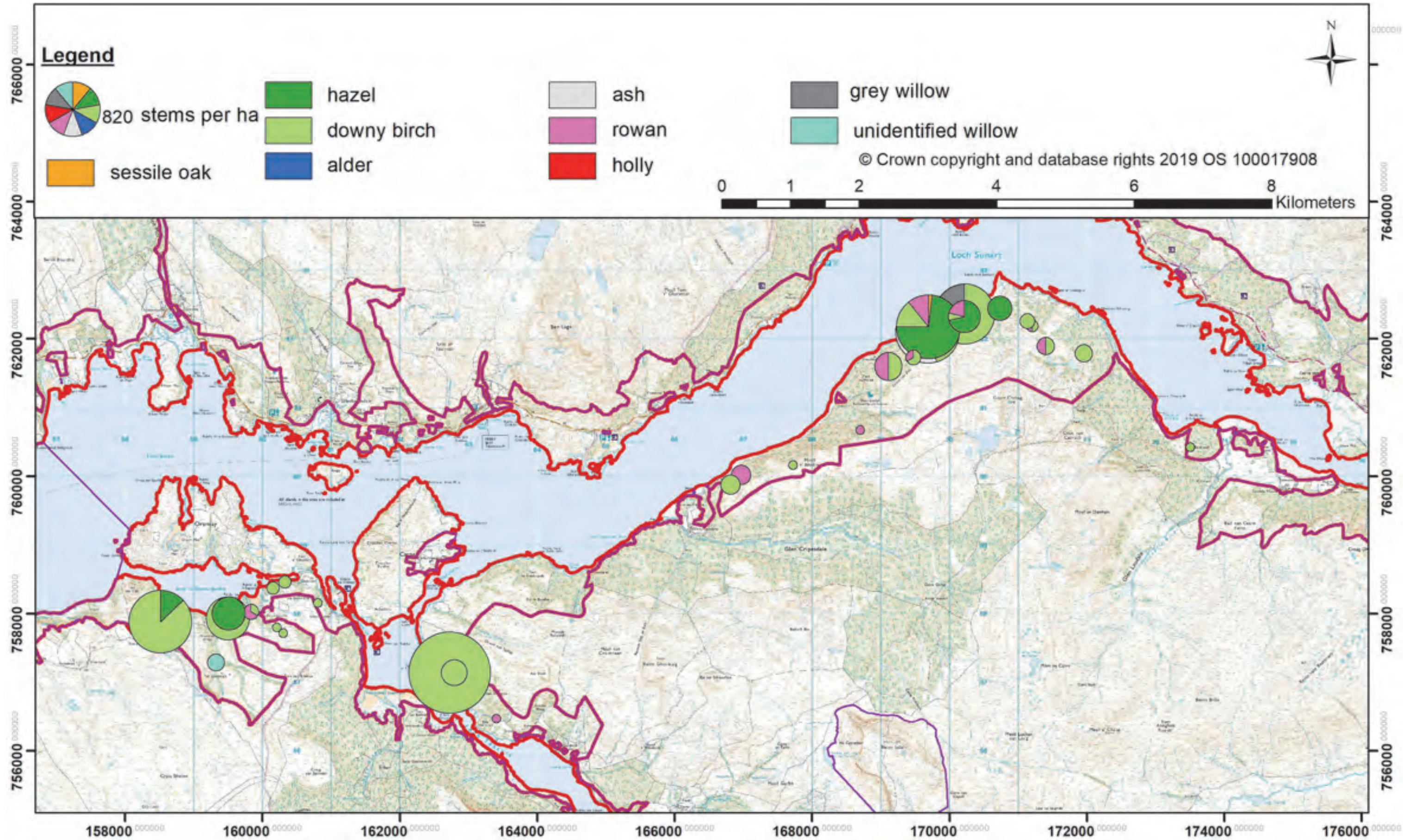


Figure 11. The species of composition of the large sapling populations in each of the 77 plots surveyed.

The area of the pies is proportional to the cumulative density (stems per ha) of large saplings.

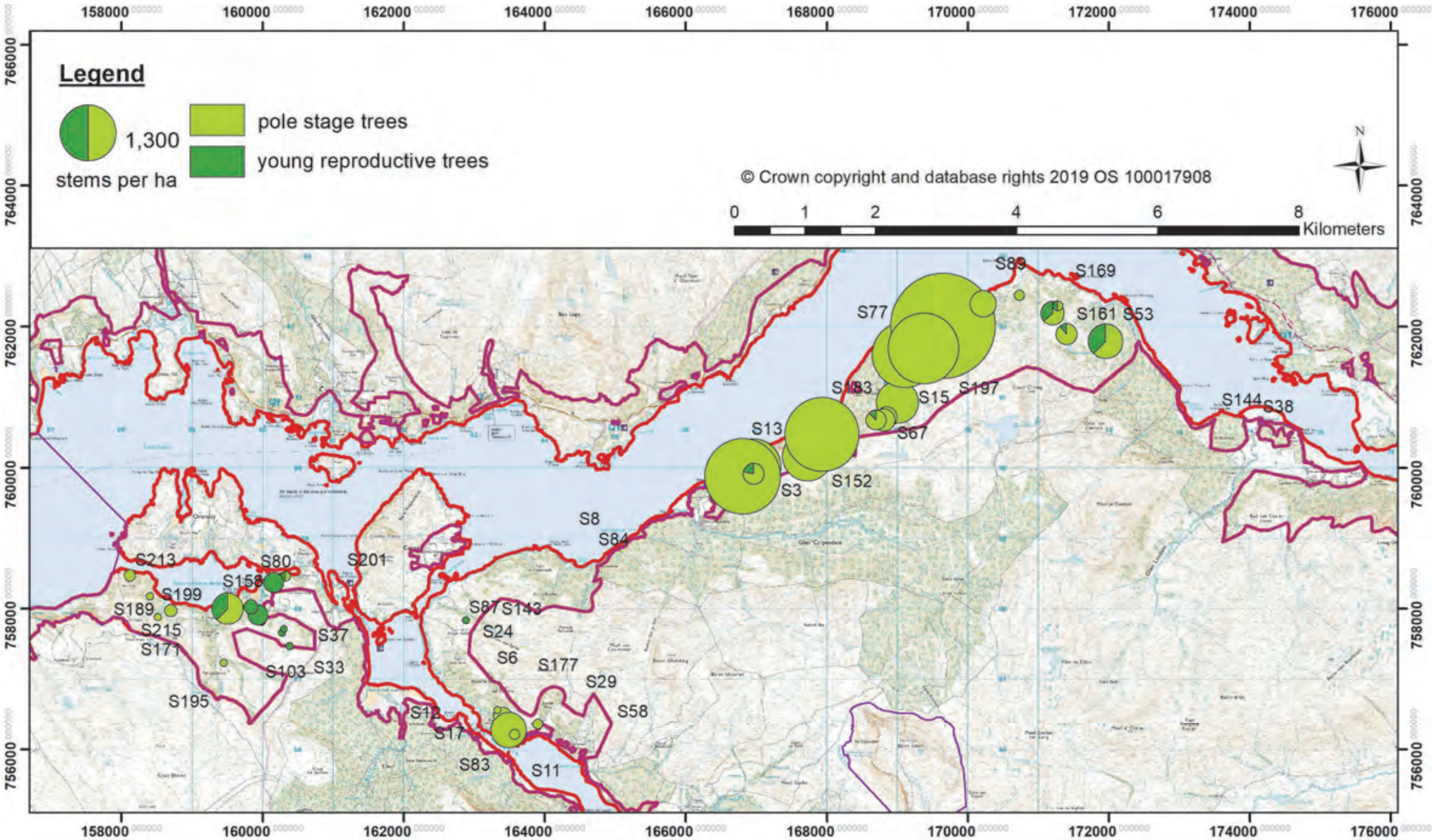


Figure 12. The density of pole stage and young reproductive trees (per ha).

The area of the pies is proportional to the sum of the densities for the two life-classes.

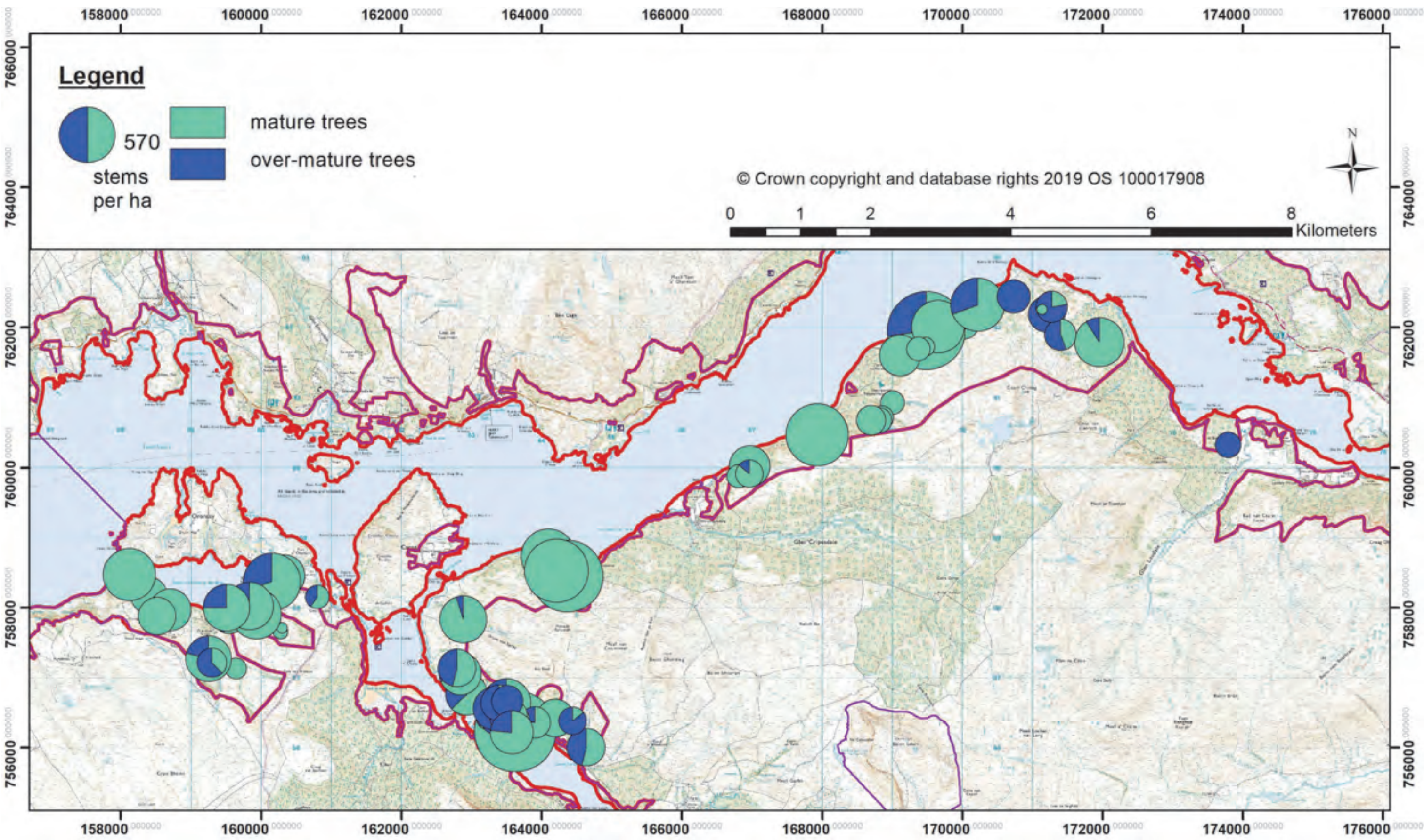


Figure 13. The density of mature and over-mature trees (per ha).

The area of the pies is proportional to the sum of the densities for the two life-classes.

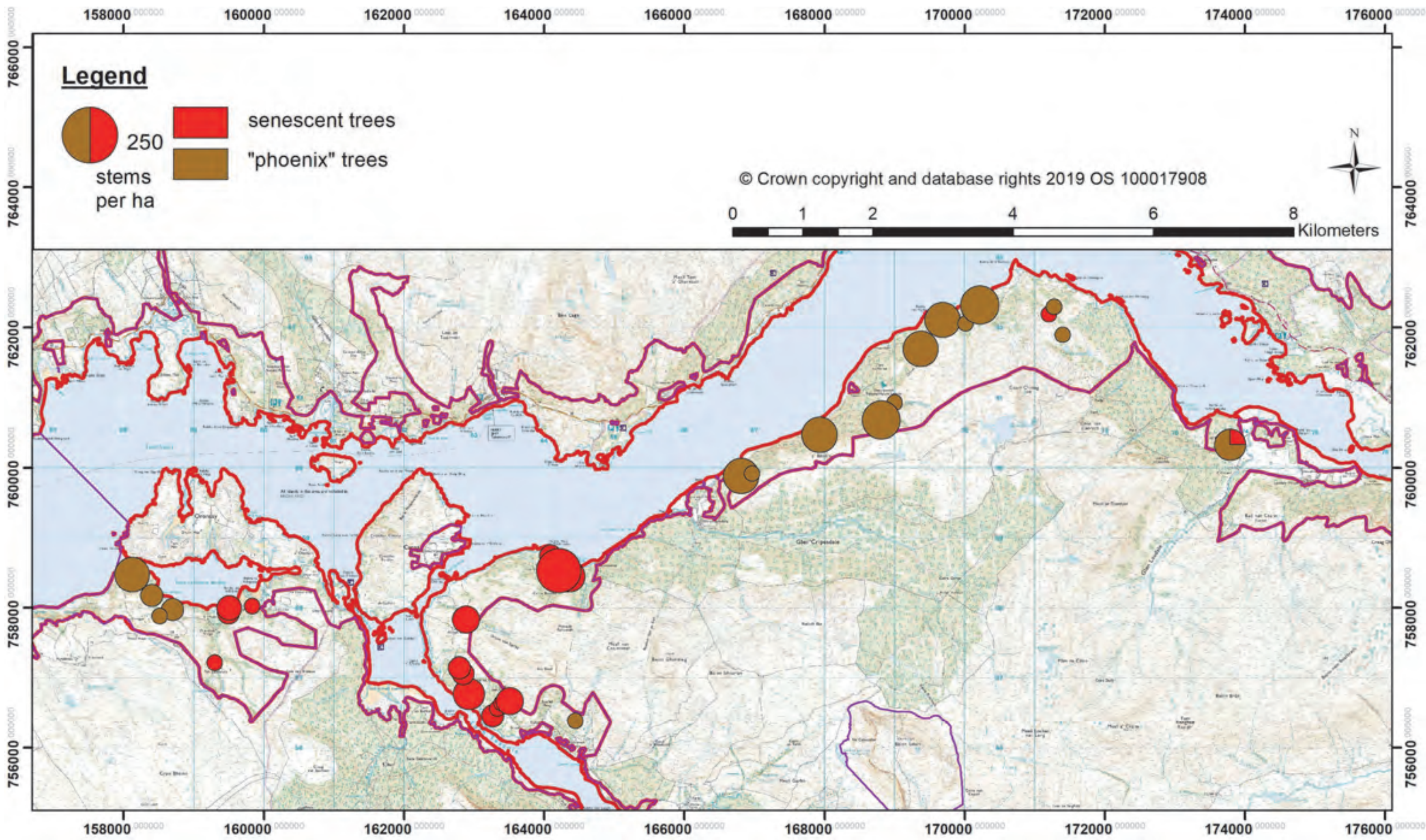


Figure 14. The density of senescent and "phoenix" stage trees (stems per ha).

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

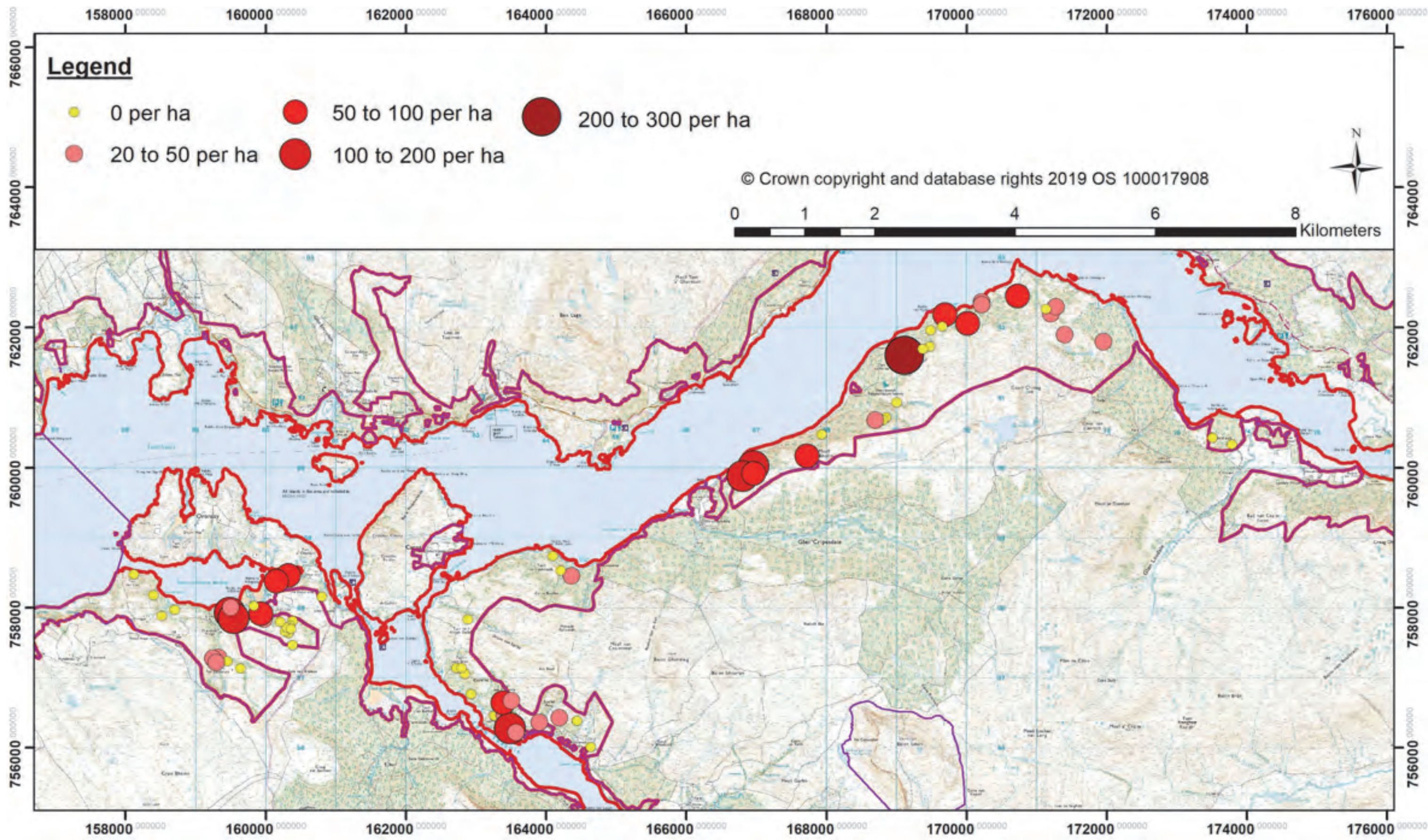


Figure 15. The density of dead trees (stems per ha).

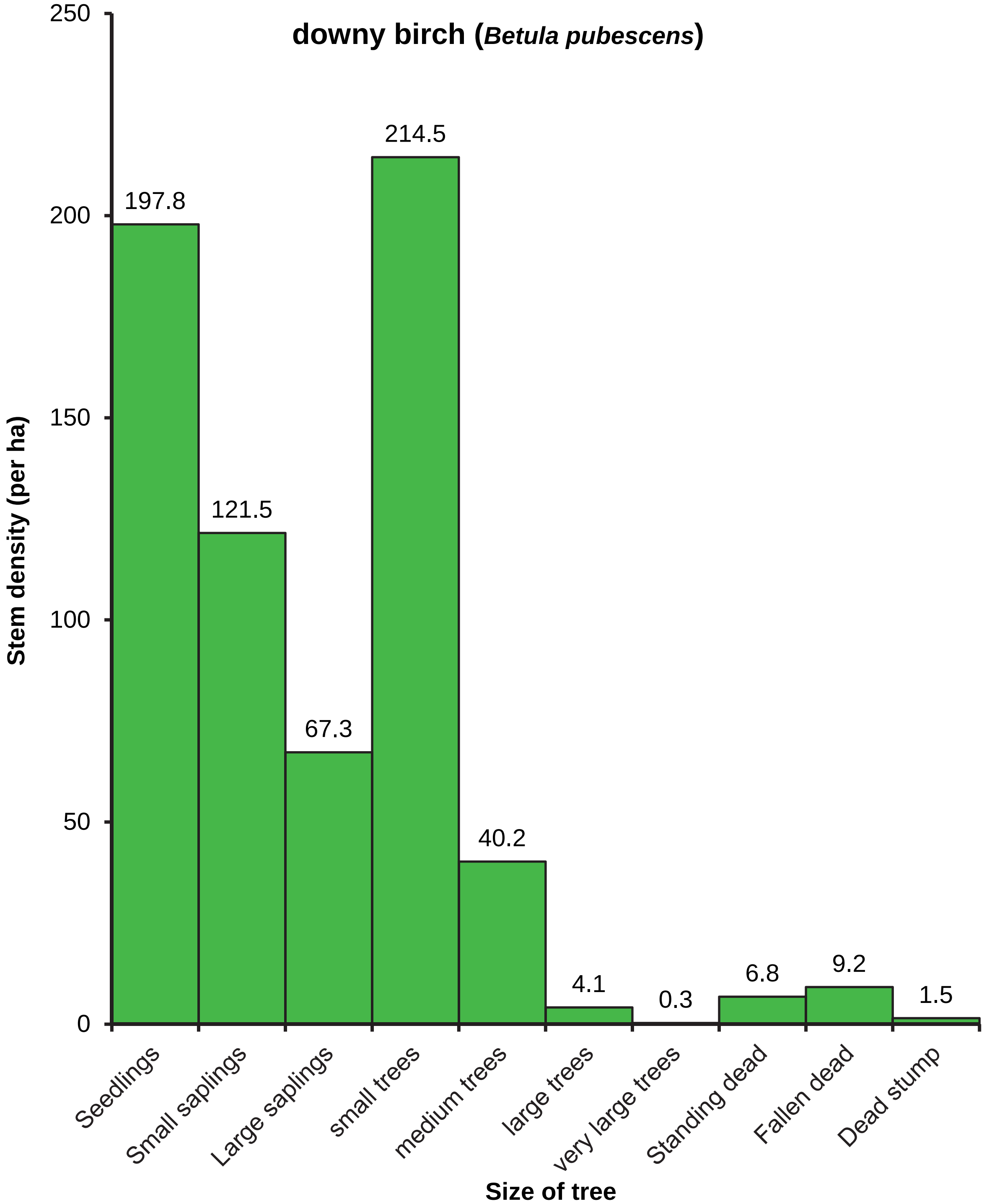


Figure 16. The size distribution of the downy birch population surveyed within the Sunart SSSI that are also within the Morvern DMG.

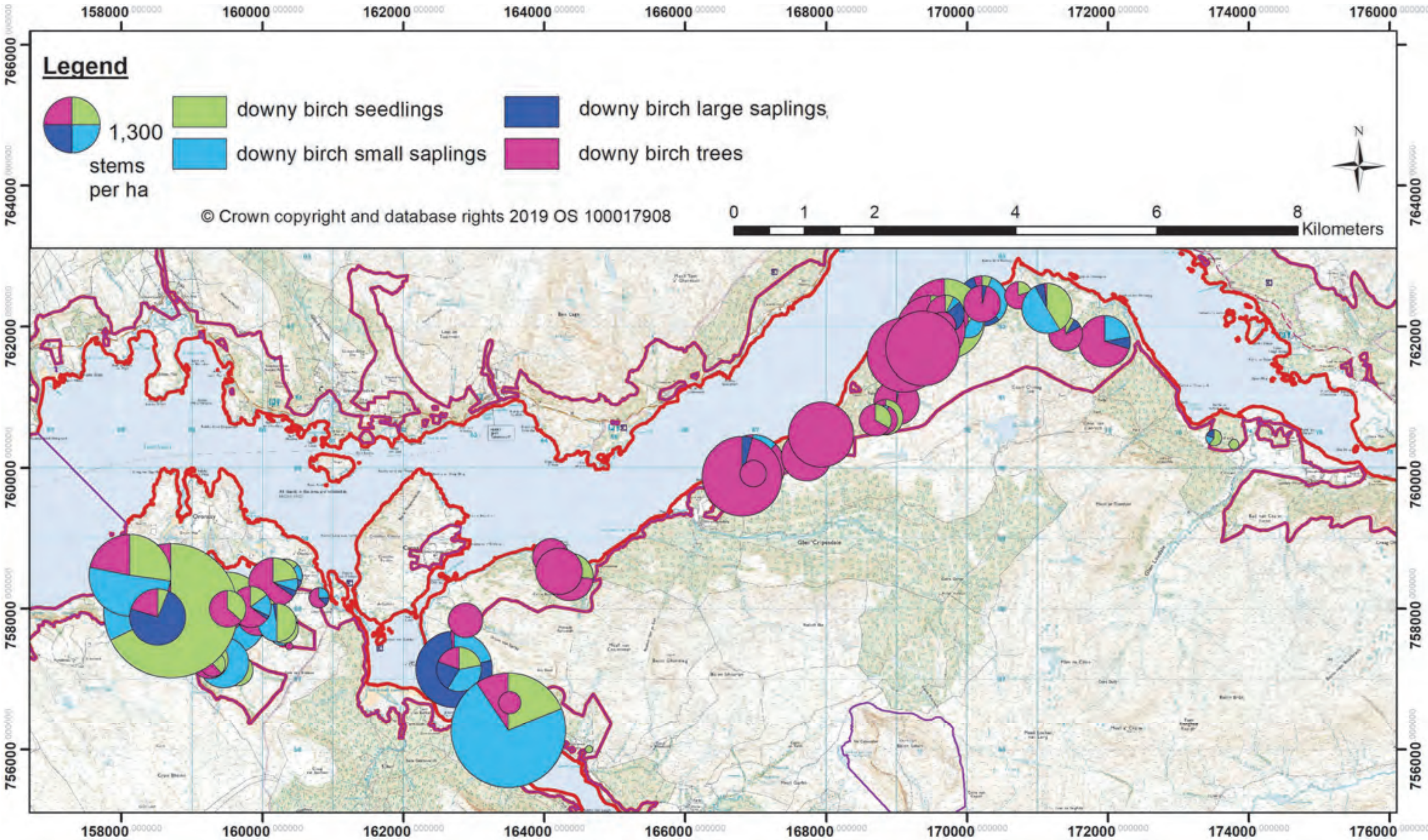
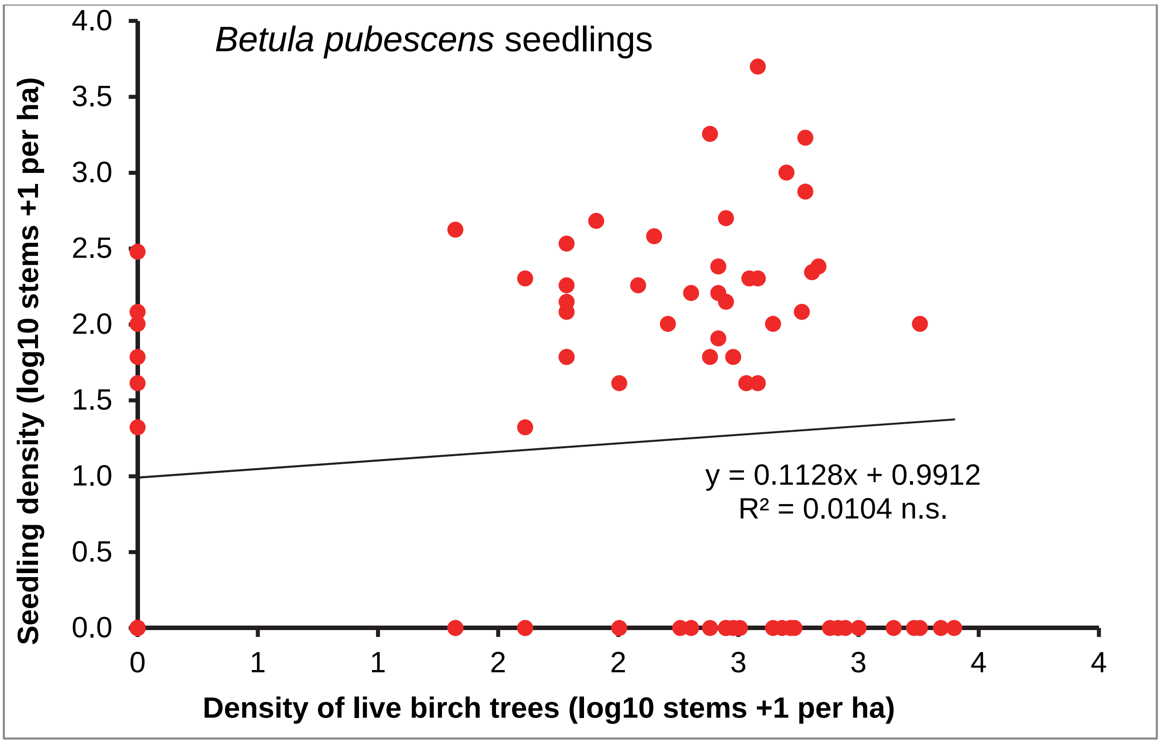


Figure 17. The stem density (per ha) of downy birch seedlings, saplings and live trees in the different plots surveyed across the part of the Sunart SSSI that are also within the Morven DMG.

a)


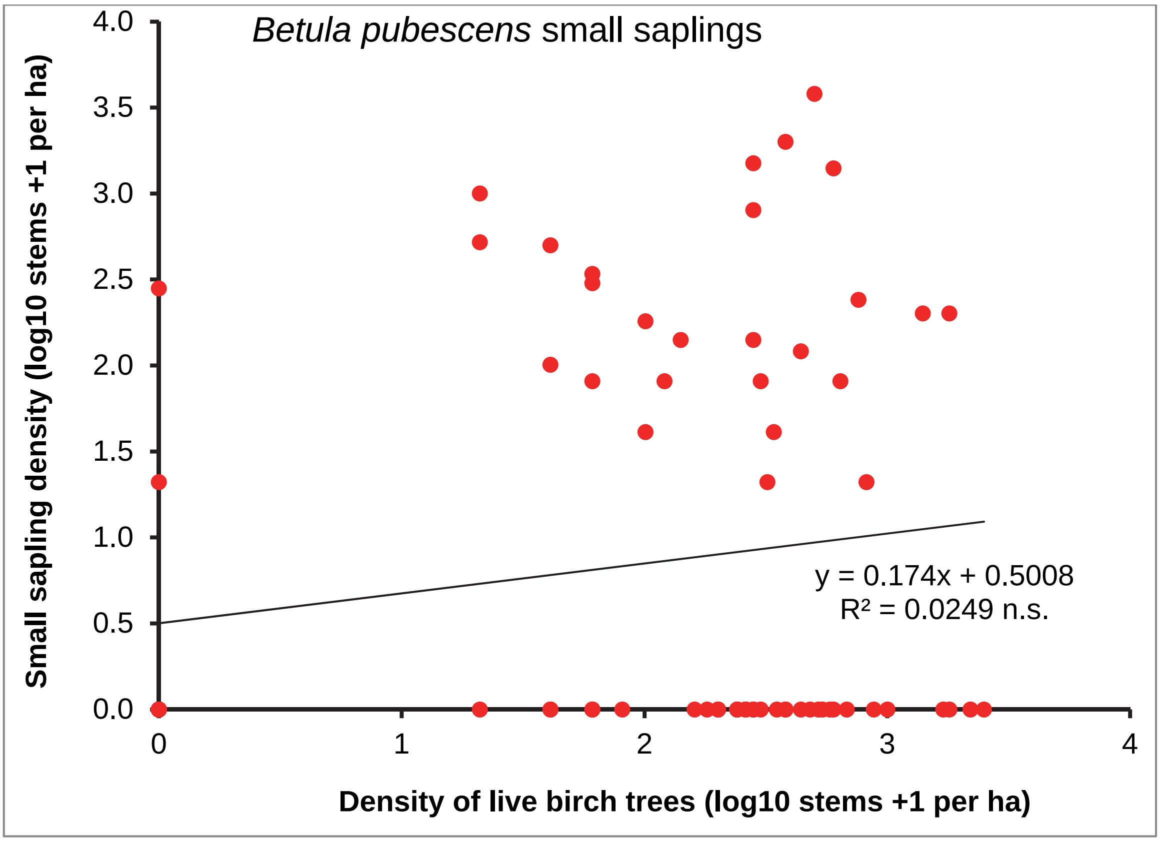
b)


Figure 18. The relationship between a) the density of birch seedlings and the density of live birch trees, and b) the density of small birch saplings and the density of live birch trees. The densities of seedlings, small saplings and live trees have been transformed (Log10) after adding one to each value.

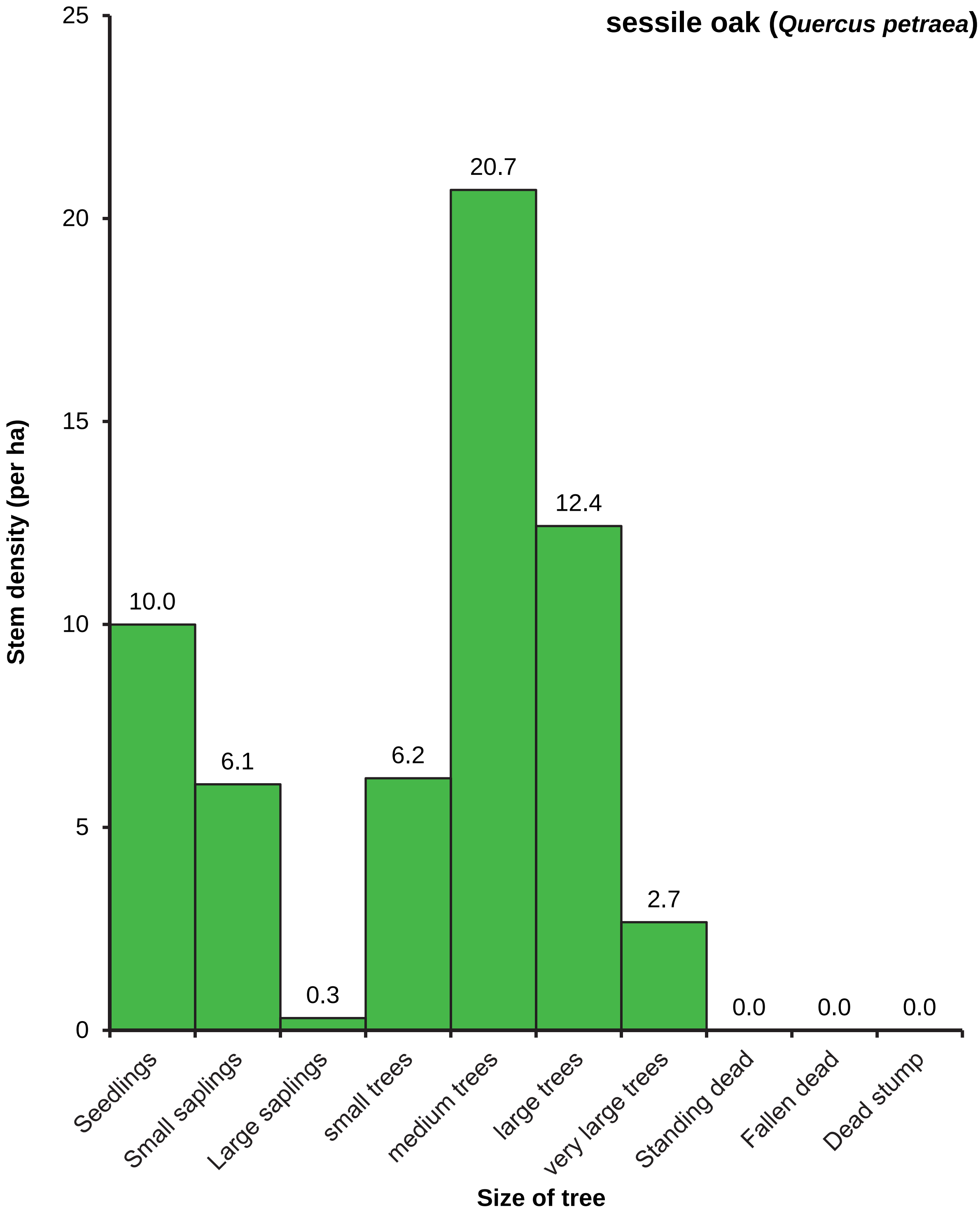


Figure 19. The size distribution of the sessile oak population in the plots surveyed within the Sunart SSSI that is also within the Morvern DMG.

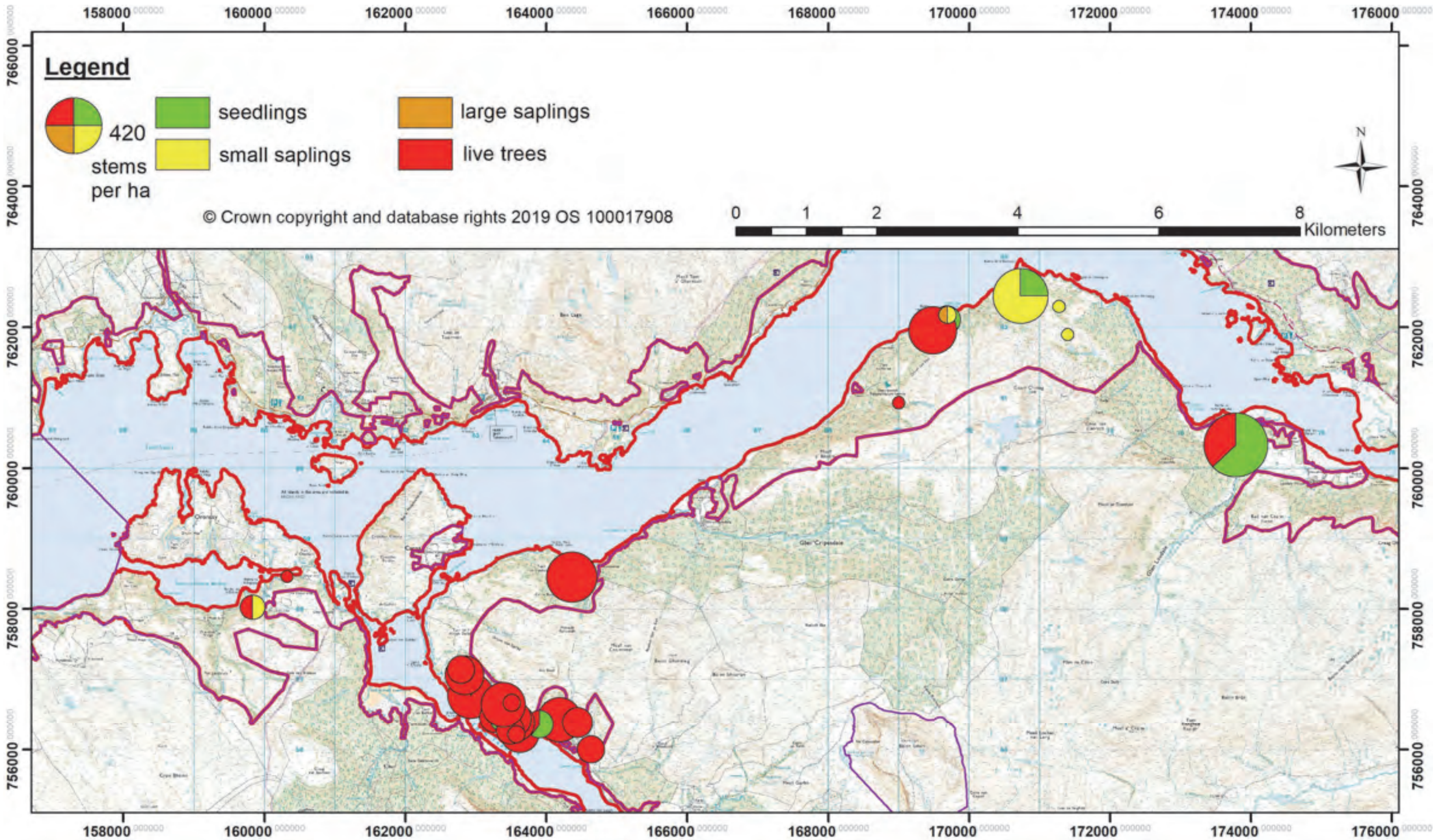


Figure 20. The stem density (per ha) of sessile oak seedlings, small and large saplings and live trees in the different plots surveyed across the part of the Sunart SSSI that are also within the Morven DMG.

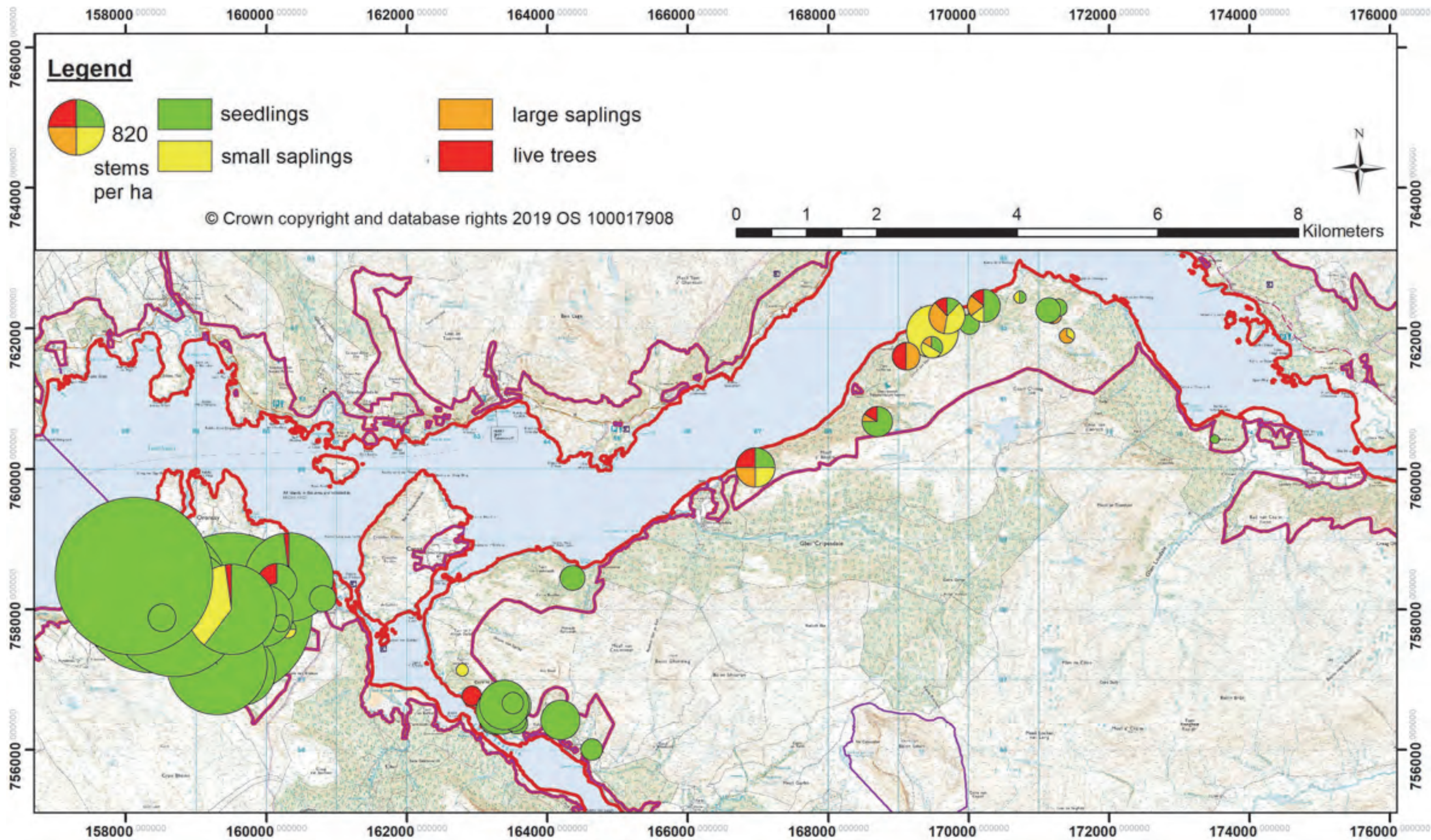


Figure 21. The stem density (per ha) of rowan seedlings, small saplings, large saplings and live trees in the different plots surveyed across the part of the Sunart SSSI that are also within the Morven DMG.

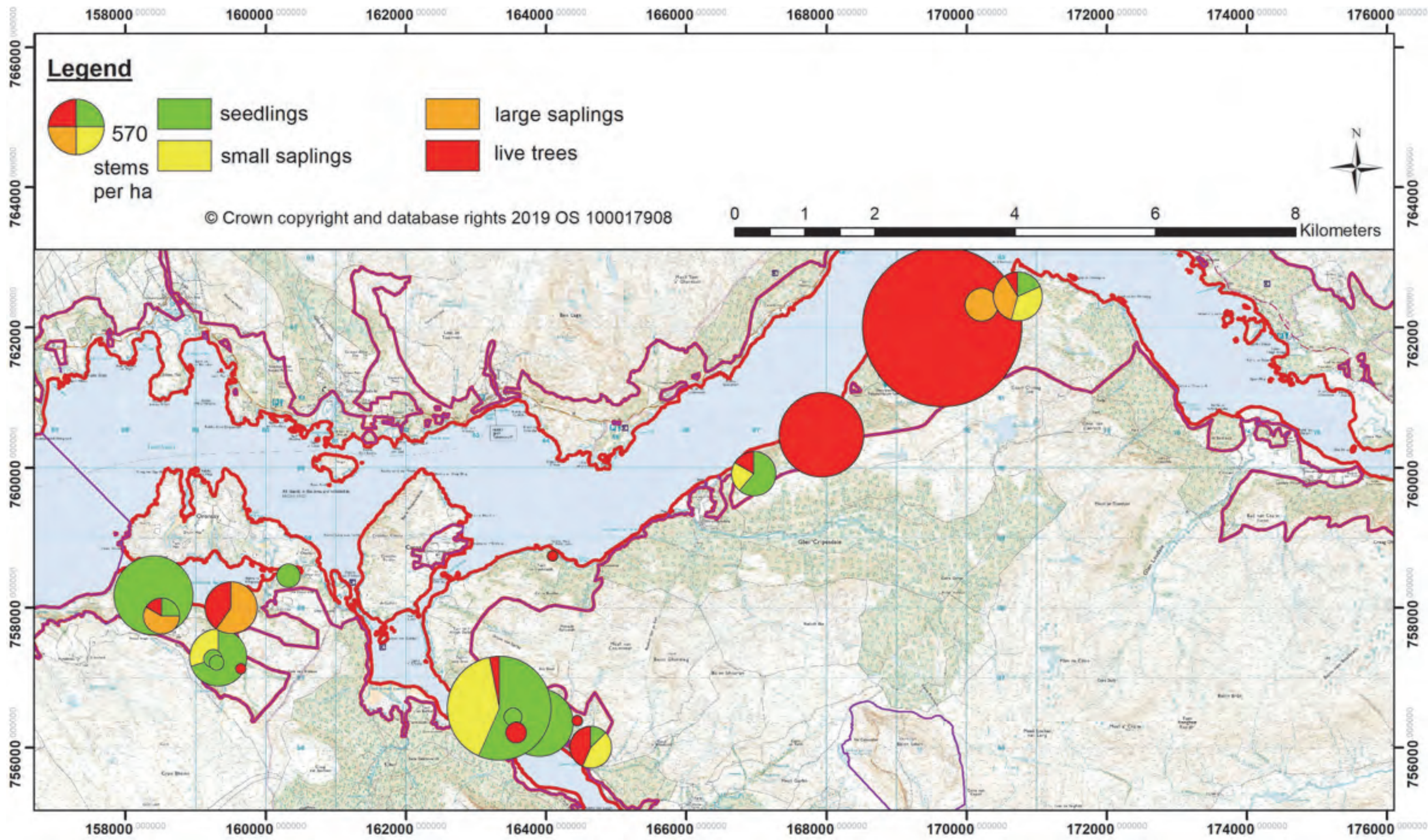


Figure 22. The stem density (per ha) of hazel seedlings, small saplings, large saplings and live trees in the different plots surveyed across the part of the Sunart SSSI that are also within the Morven DMG.

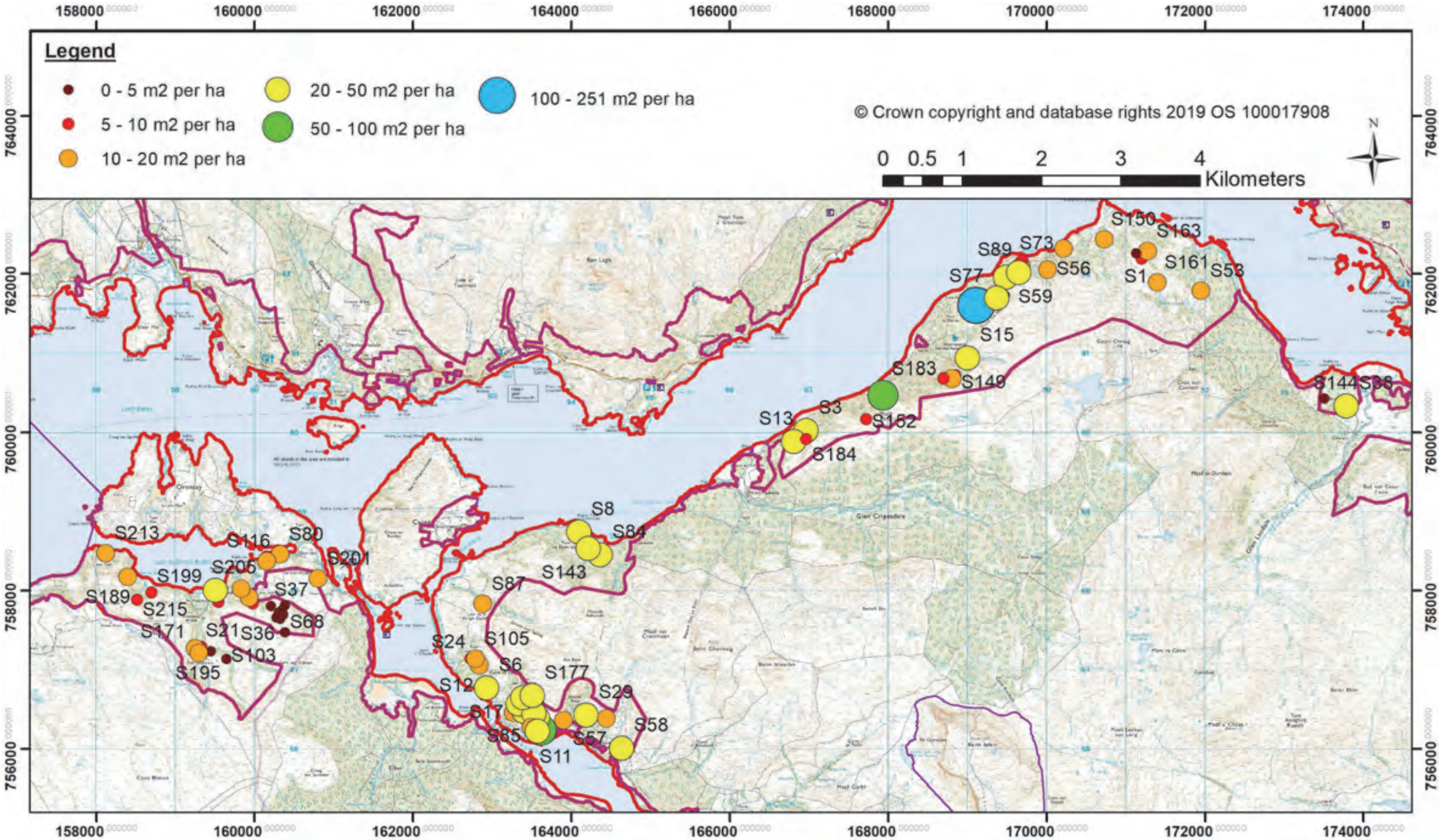


Figure 23. The basal area (m^2 per ha) of all live trees in the plots surveyed within the Sunart SSSI that also within the Morvern DMG.

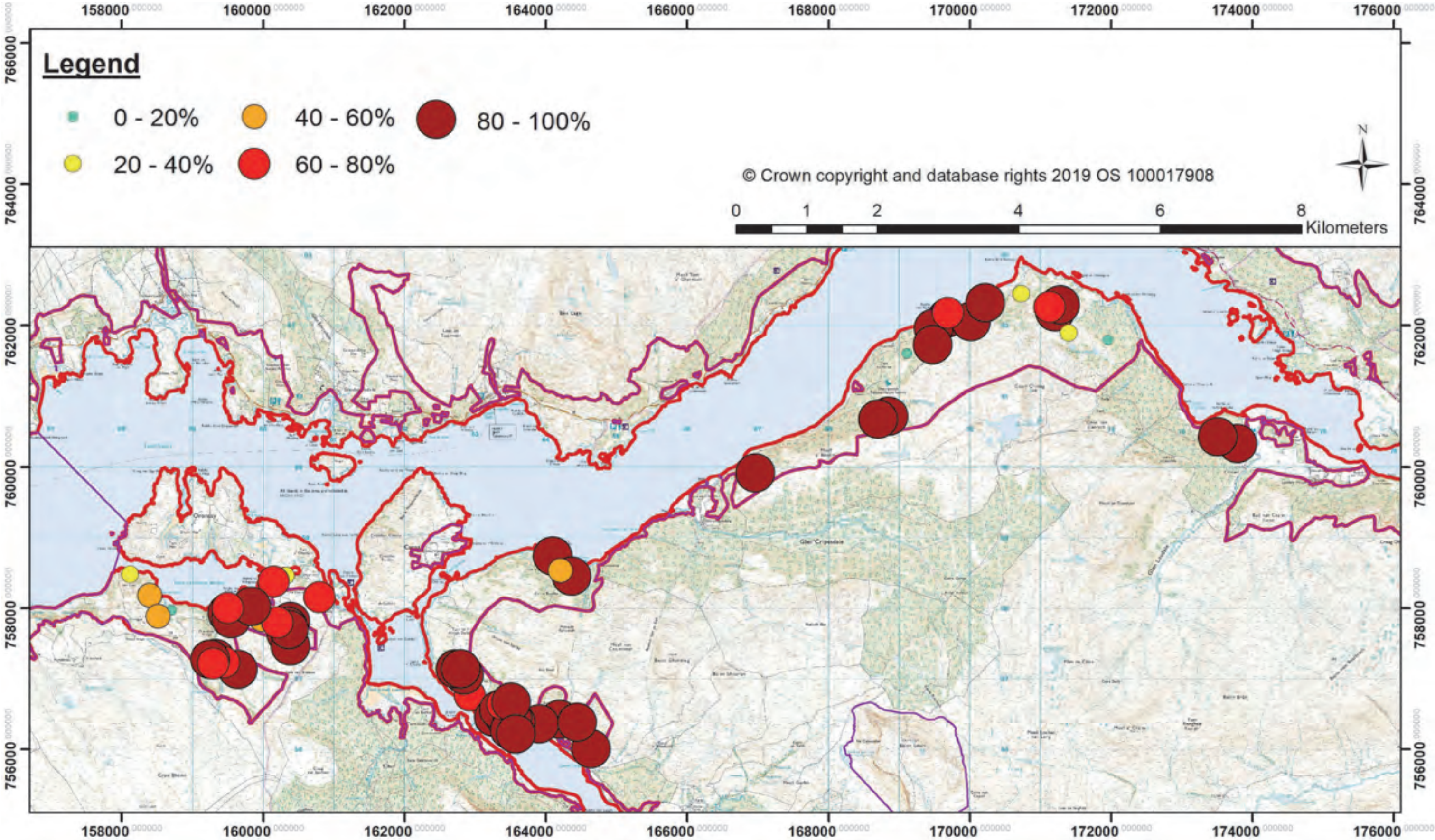


Figure 24 The levels of browsing (%) on seedlings of all species of tree surveyed within the Sunart SSSI that are also within the Morvern DMG.

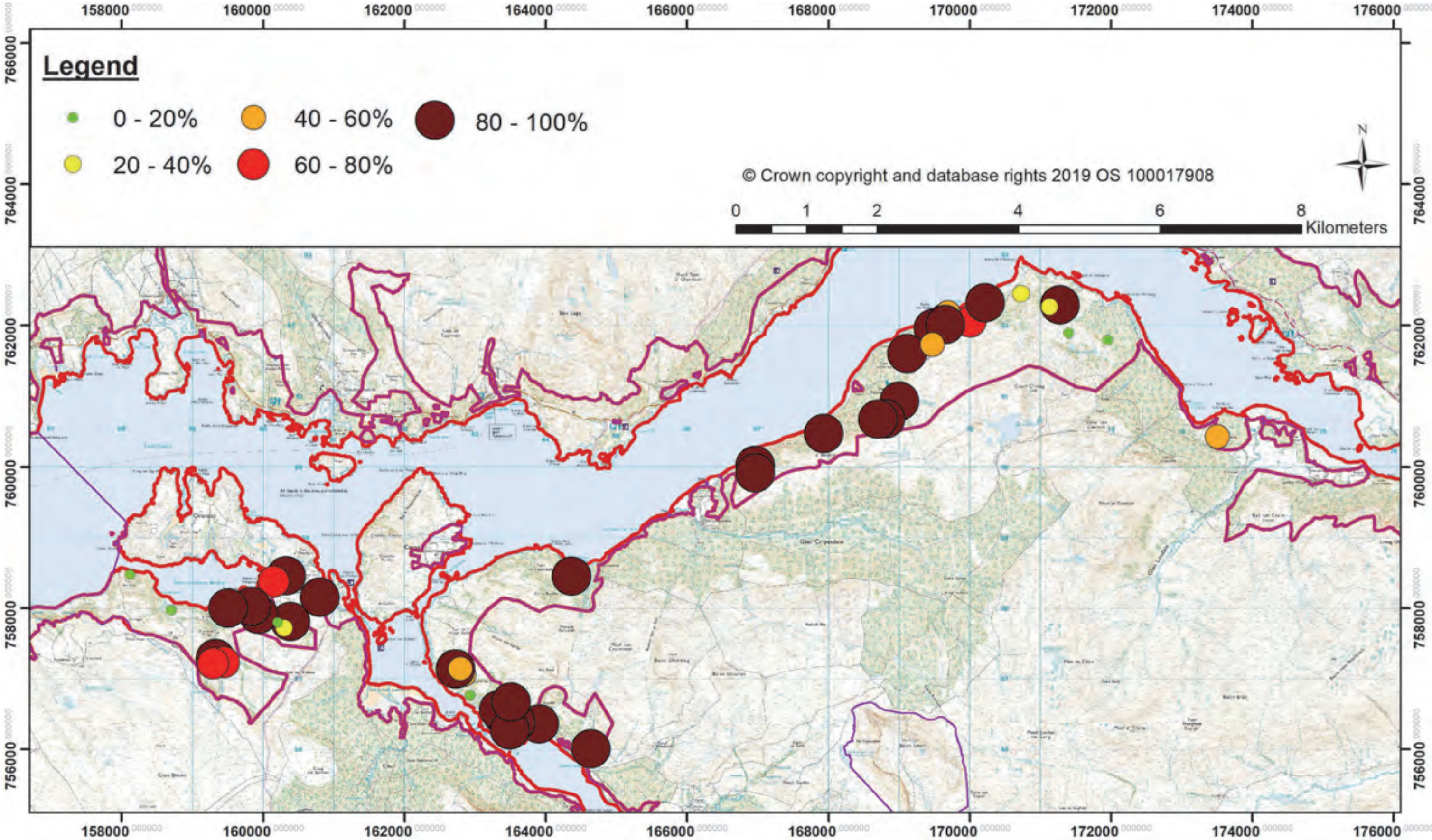


Figure 25. The levels of browsing (%) on small saplings of all species of tree surveyed within the Sunart SSSI that are also within the Morvern DMG.

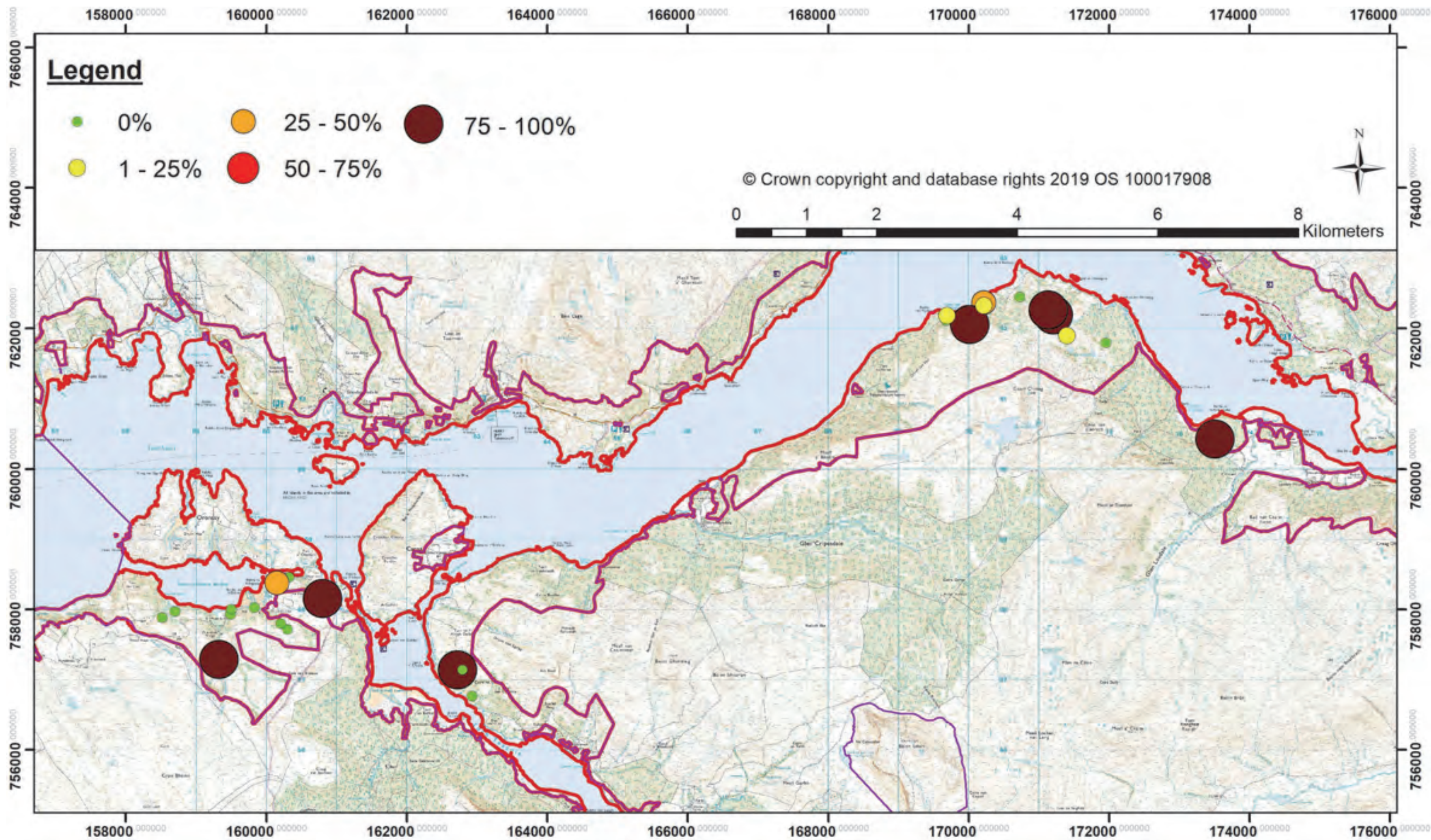


Figure 26. The levels of browsing (%) on large saplings of all species of tree surveyed within the Sunart SSSI that are also within the Morvern DMG

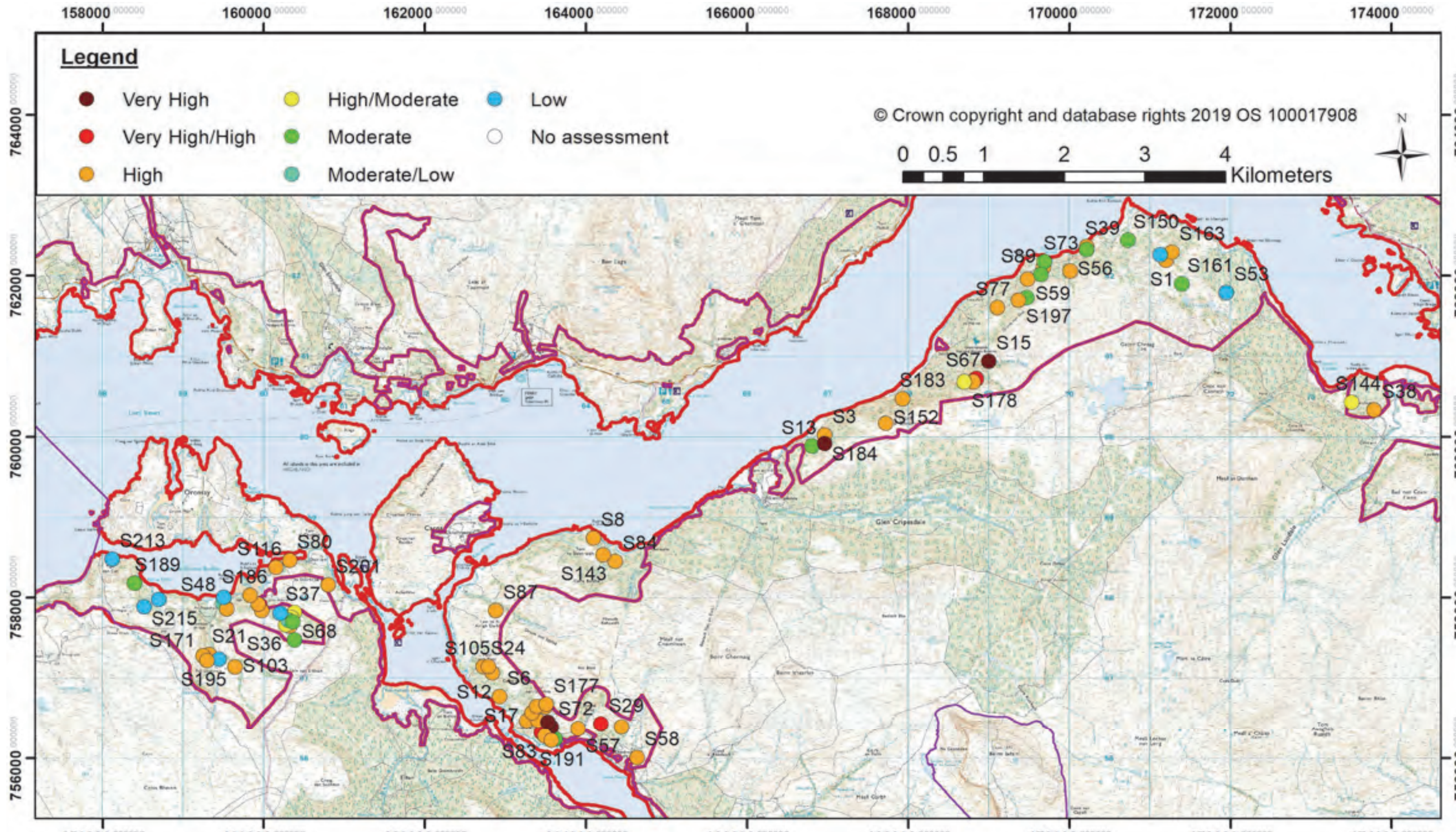
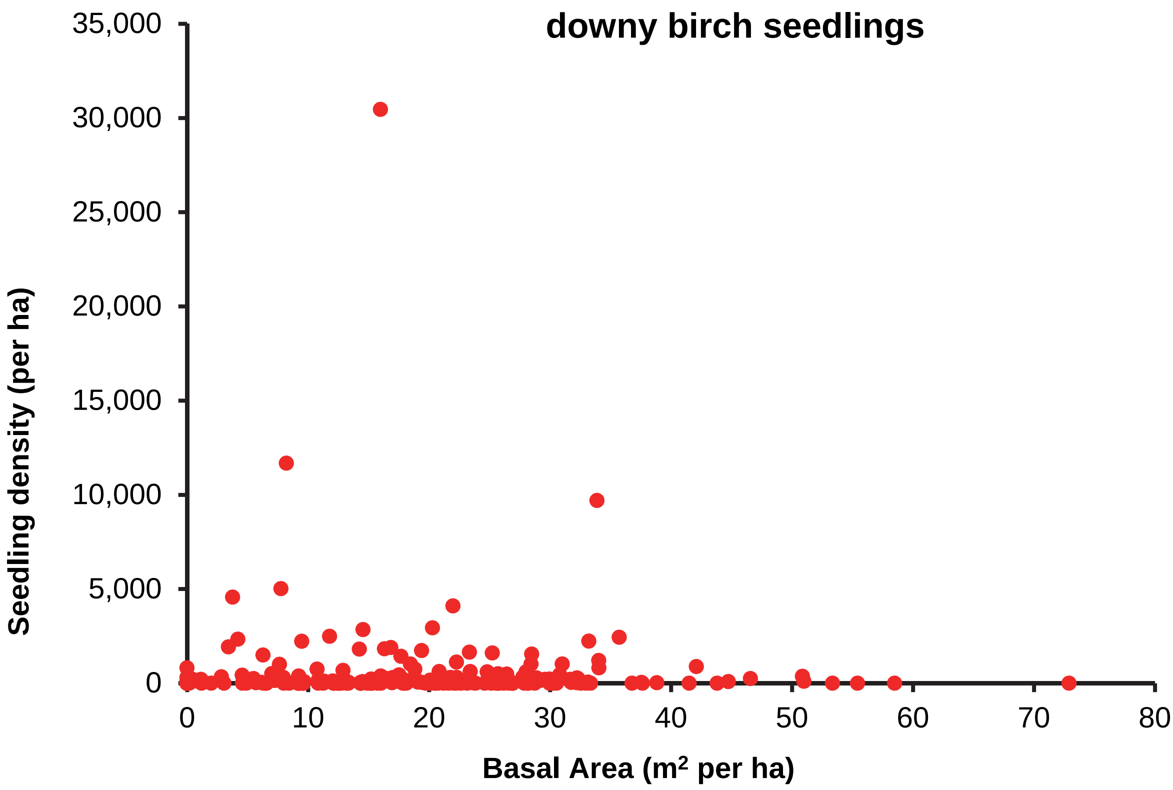


Figure 27. The overall herbivore impact levels in the plots surveyed within the Sunart SSSI that are also within the Morvern DMG.



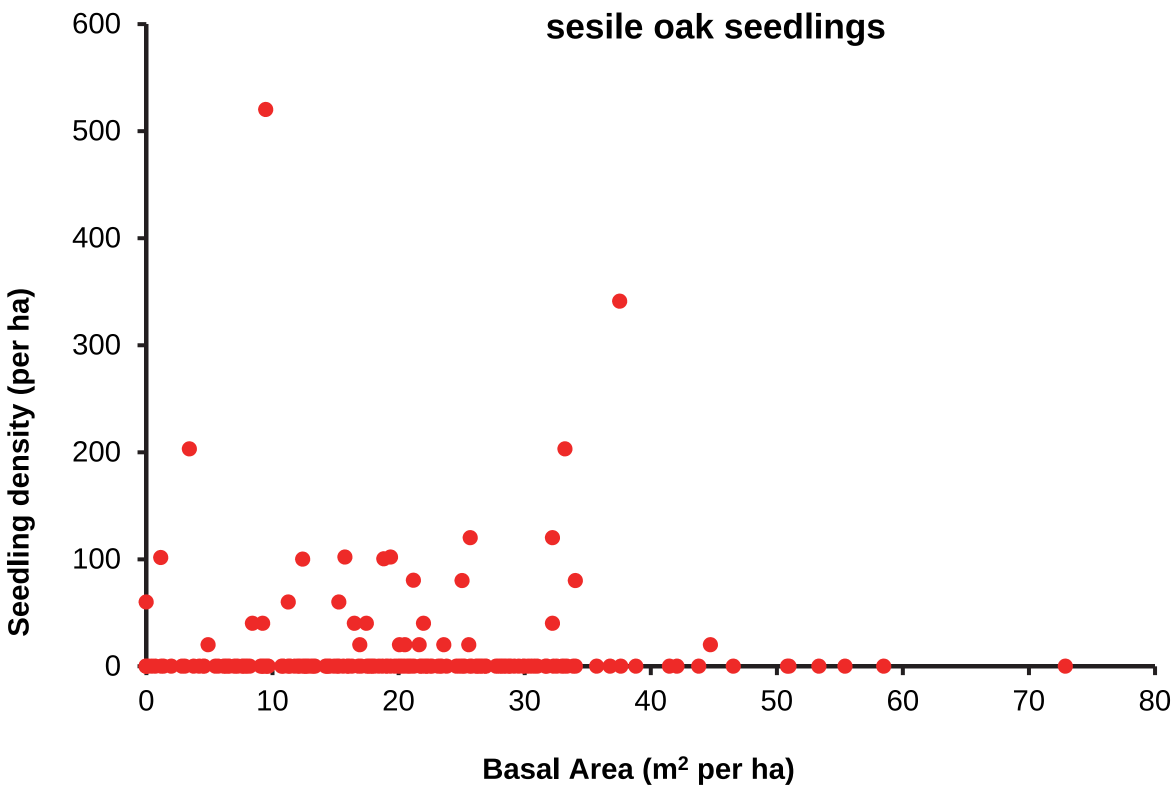


Figure 28. The density of downy birch and sessile oak seedlings and the amount of likely shading as indicated by the basal area of trees within the same plot.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 11. Guide to Browsing Rates

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

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

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

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

Table 13. Palatability of key field layer species.

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

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

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

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

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