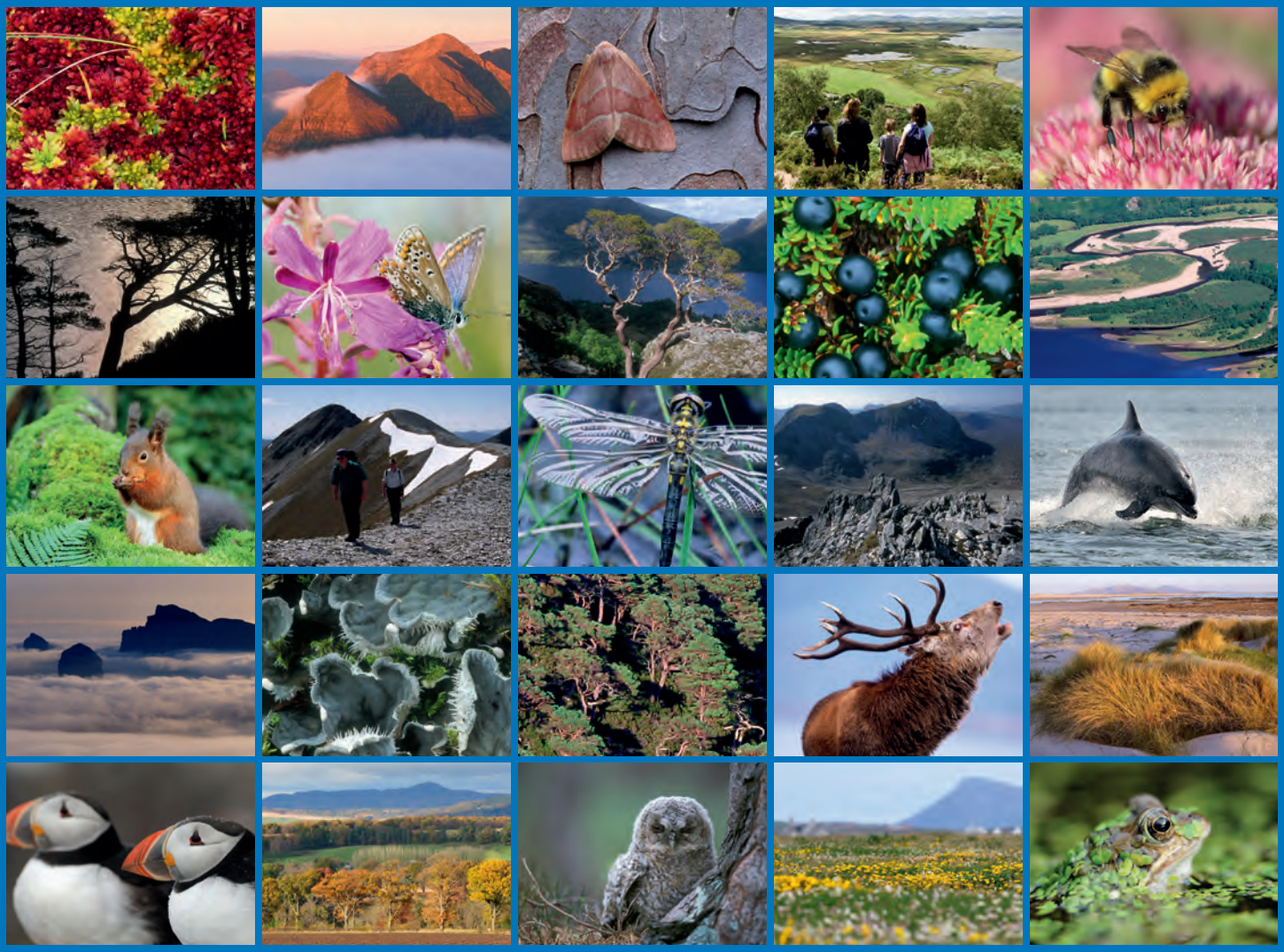
Scottish Natural Heritage
Research Report No. 1178

A woodland profile survey and assessment of herbivore impacts within the Doire Donn Site of Special Scientific Interest (SSSI)



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RESEARCH REPORT

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A woodland profile survey and assessment of herbivore impacts within the Doire Donn Site of Special Scientific Interest (SSSI)

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This report should be quoted as:

Headley, A.D. 2020. A woodland profile survey and assessment of herbivore impacts within the Doire Donn Site of Special Scientific Interest (SSSI). *Scottish Natural Heritage Research Report No. 1178.*

RESEARCH REPORT

Summary

A woodland profile survey and assessment of herbivore impacts within the Doire Donn Site of Special Scientific Interest (SSSI)

Research Report No. 1178
Project No: 117137
Contractor: Alistair Headley
Year of publication: 2020

Keywords

Doire Donn SSSI; oak woodland; Lochaber; herbivore impact assessment; HIA; East Loch Shiel DMG.

Background

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

Main findings

The diameter of all species of tree within 25 sample plots chosen at random throughout the areas of woodland within the protected area were measured in spring and summer 2018. Within the 1.25 ha of woodland that was surveyed a total of 292 seedlings and 18 saplings were found. The numbers of seedlings and saplings where the lead shoot or the majority of shoots were browsed was counted. The diameters of 241 live trees and 37 dead trees were measured. The main findings are as follows:

- Except for 17 small rowan seedlings, the levels of browsing on seedlings of all other species of tree were above 90%.
- Very few seedlings survive to the sapling or to small tree stage. This is almost certainly due to the high levels of browsing, as the levels of shading may only be a factor for shade intolerant species in a fifth of the sample plots.
- Approximately 70% of the woodland canopy is dominated by sessile oak trees in the mature and over-mature life-class. There is virtually no regeneration of sessile oak trees as only one sapling and three young reproductive trees were found in all of the 25 sample plots. There is adequate seedling establishment of sessile oak as there are 64 seedlings per ha. The levels of browsing on the lead shoots of the oak seedlings were 91%, and these levels of browsing are almost certainly the reason for the near complete absence of oak saplings and therefore young oak trees within the wood.

- Downy birch is another major component of the woodland canopy at 87 live trees per ha. The density of birch seedlings is similar to that of oak with 58 seedlings per ha, but more of these seedlings survive to the sapling and young tree stage. A total of 9 saplings and 28 young trees were found. Although browsing levels on birch seedlings (94%) were similar to those on oak, it is widely recognised birch seedlings and saplings can tolerate higher levels of winter browsing than most other species of native deciduous tree.
- The other species of tree present within the wood only amount to 14% of the live trees and they include hazel, holly, rowan, hawthorn, beech, ash, alder, Scots pine and Sitka spruce. As with oak and birch there are good numbers of seedlings of hazel, holly and rowan but few or no saplings or young trees.
- Dead wood is an important micro-habitat for the populations of certain rare species of beetle found in the Doire Donn SSSI. Dead wood in some form was found in 12 of the 25 plots and the supply of dead wood for this group of insects is more than likely to increase over the coming years as more sessile oak trees become senescent and die.
- The trunks and branches of the sessile oak trees support more of the important fern, moss, liverwort and lichen flora, than do the birch trees. Maintaining the populations of the different species of tree is important for the other species that are either directly dependent on these species or on the habitat as a whole. Therefore, to enable new generations of sessile oak and other species of tree to regenerate in the longer term, browsing levels have to be reduced very significantly.
- The only evidence of large herbivore seen within the Doire Donn SSSI at the time of the survey was that of red and roe deer.

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Acknowledgements

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

Nomenclature

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

1. INTRODUCTION

The Doire Donn Site of Special Scientific Interest (SSSI) is located either side of the A861 road on the western shore of Loch Linnhe north of Inverscaddle Bay. This is in the west Lochaber district of the Highland region of Scotland (Figure 1). The following features of nature conservation interest have been listed for the Doire Donn SSSI:

- Upland oak woodland
- Chequered skipper (*Carterocephals palaemon*)
- Beetles

The SSSI covers an area of 167.42 ha, with at least two-thirds being woodland habitat (Figure 1). The beetle assemblage and chequered skipper populations were assessed to be in favourable condition, but the upland oak woodland habitat was assessed in 2003 and March 2015, and reported to be in 'unfavourable declining' condition. The condition assessment identified over-grazing, burning and the presence of invasive non-native species (rhododendron and beech) as the main pressures on the habitat. The Site Management Statement, https://gateway.snh.gov.uk/sitelink/siteinfo.jsp?pa_code=521#featurePressures, has identified the grazing impacts as the reason for the condition targets not being met and, 'therefore, the regeneration target cannot be considered to have been met overall.' The lack of regeneration in the oak population is of particular concern as sessile oaks are the dominant species in the canopy and they, along with the few trees of ash and wych elm, support the nationally rare mosses and liverworts (collectively called bryophytes).

1.1 Aims

Appropriate robust and reliable data needed to be collected to inform sound decisions on the management of the woodland habitat within the Doire Donn SSSI. The specific conservation objectives for the Doire Donn SSSI are:

- To maintain the overall extent of native woodland and where possible extend to suitable adjacent ground, preferably through natural regeneration.
- To restore the woodland to favourable condition by:
  a) Ensuring deer grazing and browsing are at levels low enough to allow development of seedling and sapling trees.
  b) Removal of invasive non-native tree and shrub species, especially beech and rhododendron.
  c) Maintaining a diverse woodland structure with a significant proportion of saplings, mature trees and dead wood present for all locally occurring native species.
  d) Maintaining the species-richness or abundance of native woodland flora including ferns, mosses, liverworts and lichens.
  e) Safeguarding against fire damage.
- To maintain the favourable condition of the beetle fauna by: Maintaining the habitat in sound condition, especially a plentiful supply of deadwood.
- To maintain the favourable condition of the chequered skipper population by:
  a) Maintaining open glades within the woodland.
  b) Safeguarding against fire.

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, especially of 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 are resulting in the lack of regeneration in the population of trees.

2. METHODS

2.1 Woodland profile

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

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

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

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

2.2 Sampling strategy

Approximately 1% (1.25 ha) of the upland oak woodland habitat was sampled across the whole of the Doire Donn SSSI by taking a total of 25 plots. Each plot covered an area of 500 m^2 and was circular in outline. The sample plots were taken at random within areas known to have some trees present within the SSSI and the location of these plots is shown in Figure 2.

2.3 Field survey

2.3.1 Woodland profile

Eighteen of the 25 plots were surveyed on the 19th and 20th April 2018, but the surveys had to be cut short due to the presence of a pair of breeding birds that are on Schedule 1 of the Wildlife & Countryside Act (1981 as amended). The remaining seven plots, towards the centre of the wood, were surveyed on the 8th August.

The surveyors navigated their way to the sample plot locations using maps and hand-held GPS receivers (typically Garmin GS12s). Several plots had to be moved a short distance so that they could be accessed safely, where the original plot was on steep slopes or around rock outcrops, or where there were no trees, seedlings or saplings. In every instance the grid reference at the centre of the plot was recorded and this point was marked with a wooden post with a numbered tag. All but two of the 25 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. One plot (DD23) was 10 metres and the other (DD17) was 23 metres from the given grid reference for the random point. In both these cases the plots were moved due to a lack of trees.

In every instance all trees, seedlings and saplings were counted and measured within 12.6 metres of 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).

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

2.3.2 Herbivore impacts

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

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

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

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, Fraser Milne and Gus Routledge) to clarify the methods, the

interpretation of the various indicators and the standardisation of the various threshold levels to assign each impact level. Initially several plots were assessed together. When there was a high level of harmonisation, further sample plots were assessed individually and the results compared. Where appropriate, discrepancies were discussed and adjustments made by the surveyors to their interpretation or judgement of the indicators.

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

2.4 Data analysis

2.4.1 Age-structure

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

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

A minimum diameter of 5 cm was used for small trees as two trees in the pole stage life-class had diameters less than 7 cm.

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

2.4.2 Calculation of browsing impacts

The 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 of trees, seedlings and saplings

At least one live tree was found in every plot, and the overall density of live trees was 193 per ha (Table 1). One or more seedlings were found in 20 of the 25 plots whilst small and large saplings were found in only 4 and 2 of the sample plots, respectively (Figures 11, 12 and 13). A total of 292 seedlings were counted giving an overall density of 234 seedlings per ha (Table 1). Only four small and 14 large saplings were recorded, which gives a total density of only 14.4 saplings per ha (Table 1).

3.2 Extent of woodland habitat

Although this survey was not designed or intended to survey the extent of woodland habitat, it was clear from the survey that there were very few trees on the upper slopes. For instance plot DD17 had to be moved 23 metres in order that at least one tree was present. Plots DD13, DD15, DD17, DD18, DD20 and DD24 also had very few trees and it is clear that the canopy cover in these areas is well below 30%, which is the minimum target cover of trees used in the condition assessment of woodland habitats (Figure 25).

One of the CSM targets is that the extent of semi-natural stands of woodland should not decrease. An examination of the 1947 one-inch to the mile map compared with the current location of areas with a closed canopy of trees indicates that there has been a loss of some areas of woodland on the upper slopes, especially the area immediately south-east of Meall an Doire Dhuinn.

3.3 Species composition

Overall, downy birch (*Betula pubescens*) and sessile oak (*Quercus petraea*) were the most abundant species within the Doire Donn SSSI (Figure 3). Hazel (*Corylus avellana*) and holly (*Ilex aquifolium*) were the next most abundant species followed closely by rowan (*Sorbus aucuparia*). These numbers include all seedlings, saplings as well as trees. When the densities of live trees are compared ash has a higher density than holly and rowan, but downy birch and sessile oak were still the most abundant species of tree (Table 1). Hawthorn (*Crataegus monogyna*), beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), alder (*Alnus glutinosa*), Scots pine (*Pinus sylvestris*) and the non-native Sitka spruce (*Picea sitchensis*) are relatively minor components making up only 4% of the live trees within the the Doire Donn SSSI (Table 1 and Figure 5).

Wych elm (*Ulmus glabra*) and gean (*Prunus avium*) are noted as being a component of the woodland in the citation for this SSSI, but no seedlings, saplings or trees of this species occurred in any of the plots. The survey, however, covered only about 1% of the woodland, and none of the ground between the road and the margin of Loch Linnhe.

3.4 Woodland structure

When all the seedlings are counted together irrespective of the species, there is a higher density of seedlings than any other life-class, but saplings, pole stage and young reproductive trees are at much lower densities than the seedlings, mature and over-mature trees (Figure 4 and Table 1). All life-classes of tree are represented, but the combined density of the pole stage and young reproductive life-classes is low at only 27 individuals per ha compared to the other life-classes (Table 1 and Figure 4). The combined densities of small and large saplings are even lower at 14.4 individuals per ha (Table 1).

When the data is analysed with respect of individual species the situation is even worse with respect to regeneration. There are more mature and/or over-mature trees than seedlings,

saplings or young trees for most species, except for downy birch. For example no seedlings or saplings of Scots pine, ash and alder were found in this survey (Table 1). Similarly the populations of sessile oak, holly and hazel have few or no saplings or young reproductive trees (Table 1). The seedling stage is dominated mostly by downy birch, sessile oak, hazel and holly (Figure 5). The only species that were found to have any small saplings in this survey was downy birch, hazel and rowan (Table 1 and Figure 5). The few large saplings found in this survey were restricted to downy birch, rowan and sessile oak (Table 1 and Figure 5). The saplings that were found were found on steep banks of streams or on rock outcrops that were largely inaccessible to large herbivores. The small sapling density is 1.3% of the seedling density, which shows that the mortality of seedlings is very high. There were too few small and large saplings to comment on the rate of survival of small saplings through to the large sapling stage, but it is likely to be very low.

Seedlings were found in most parts of the woodland habitat, but the densities vary widely between plots (Figure 11 and Table 2). Most importantly sessile oak seedlings were present in many parts of the wood and were present in 12 of the 25 plots (Figure 11). Birch seedlings were not so widely distributed as they were present in only nine plots, but where they were present they were abundant (Figure 11). Figures 12 and 13 show the location of the plots where the small and large saplings were found.

Most of the pole stage and young reproductive trees were of downy birch. Only two young reproductive trees of sessile oaks were found in this survey and alder, beech, ash and rowan were represented by either a single pole stage or young reproductive tree. Young reproductive trees were scattered throughout the wood in nine of the plots whilst the pole stage birch trees were found in only one plot near Gorsten Cottage (Figure 14).

There are higher densities of mature downy birch trees than sessile oak, whilst sessile oak has higher densities of over-mature trees than downy birch (Figure 5). The over-mature trees were mostly concentrated in plots on the lower slopes of the wood, but both mature and over-mature trees were at lower densities on the upper slopes (Figure 15).

The densities of senescent and “phoenix” life-classes are lower than the mature and over-mature life-classes, which indicates that not too many trees are dying of old age at present.

3.5 Size/age distribution

Medium sized trees were the most abundant size class of sessile oak tree whilst the majority of birch trees were small (Table 3 and Figures 6 and 7). The median size of sessile oak tree was 35 cm in diameter with an inter-quartile range from 25.1 to 44.7 cm. Assuming an average radial growth rate of between 1 to 2 mm per annum these trees are likely to have established between about 70 and 220 years ago (Büyüksair *et al.*, 2018; Härdtle *et al*., 2013).

The near complete lack of saplings and smaller trees and the fact that the smallest sessile oak tree had a diameter of 10 cm shows that sessile oak trees have not been establishing in the last 35 to 50 years or so.

3.6 Basal area

The basal area averaged across all live trees that were surveyed was 16.5 m^2 per ha (Table 4). This represents 0.17% of the ground occupied by the trunks of trees. Because of the presence of a few plots with high basal areas the median value is a better measure of the central tendency in the data. The median basal area is only 14.7 m^2 per ha (Table 5). The inter-quartile range in basal area is between 10.4 and 23.3 m^2 per ha (Table 5).

Sessile oak accounts for 69% of the total basal area of live trees measured, with downy birch contributing only 21% to the total live basal area (Table 4). Ash, holly, hazel and beech trees each make about 1.7 to 2.8% of the total basal area (Table 4). Alder, rowan, Scots pine and Sitka spruce make only a very small contribution to the total basal area (Table 4).

3.7 Dead wood habitat

The senescent, “phoenix” and dead trees supply dead wood which is an important for the beetle assemblage within this site. The senescent trees that were found in this survey were found in the south-western end of the wood, whilst four of the eight plots with “phoenix” trees were in plots on the upper slopes (Figure 16). Dead trees, either as standing dead, lying dead or as stumps, were present in nearly half of the plots (12) and these plots were scattered throughout the wood (Figure 18).

3.8 Herbivore impacts

Browsing levels on seedlings, small saplings and large saplings across all the species were 88%, 25% and 36%, respectively (Table 6). Levels of browsing on seedlings of downy birch, sessile oak, holly, hazel, beech and hawthorn were between 91% and 100% (Table 6). In contrast there was no visible browsing of the leading shoots of the 17 rowan seedlings (Table 6). The apparent absence of browsing on rowan seedlings is almost certainly due to the small size, typically less than 20 cm tall, of the rowan seedlings that were found. This would result in the seedlings being hidden from the view of a large herbivore, such as a red deer.

Very little can be read into the apparently lower levels of browsing on small saplings than that on seedlings. This is because only four small saplings were found in this survey (Table 6). Similarly the levels of browsing on large saplings are artificially low as most of the large saplings were restricted to inaccessible locations, such as rock outcrops and steep stream banks.

When the browsing levels on seedlings are analysed across individual plots the inter-quartile range was between 93 and 100% with the median browsing level being 98% (Table 7). The median browsing level on small saplings was 34% and the inter-quartile range was between 0 and 100% (Table 7).

The high levels of browsing on all seedlings were relatively uniform throughout the wood (Figure 20). None of the wood that was surveyed was within a deer exclosures or other type of fence.

Browsing levels on basal or epicormic shoots could not be assessed in seven and 14 sample plots, respectively, because in most cases they were absent (Table 8). The herbivore impacts are High or Very High for most of the indicators and the High impact class was the most frequent one for browsing on basal shoots, epicormic shoots, preferentially grazed species and for the overall herbivore impact (Table 8). Bark stripping or fraying of the saplings was low in all but one of the 18 samples where it could be assessed for this indicator (Table 8). There is no particular clustering of plots with either the Very high or High overall herbivore impacts in any particular part of the wood (Figure 20).

3.9 Herbivores

The large herbivores that were observed during the survey within the Doire Donn SSSI that are resulting in most of the browsing impacts on the tree seedlings and/or saplings are deer (roe and red). Neither sheep nor cattle are known to graze the wood as far as the surveyors are aware.

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

3.10 Potential for tree regeneration

All areas of the Doire Donn SSSI that were surveyed have the potential to support tree regeneration. There are plenty of seed sources for the regeneration of sessile oak, downy birch and rowan. There were many seedlings in plots with closed vegetation, including relatively open areas on the upper slopes where there was a good cover of bracken and other herbaceous species.

3.11 Invasive non-native species

Rhododendron (*Rhododendron ponticum*) was not encountered in any of the plots that were surveyed, but it was present elsewhere in the wood.

A single Sitka spruce (*Picea sitchensis*) tree was found in one plot (DD9), but no seedlings were found.

Two mature trees and one young reproductive tree of beech were found in plot DD23. The only two seedlings of beech were found in this same plot.

4. DISCUSSION

In order that the Doire Donn SSSI continues to support the upland oak woodland habitat, there must be a continued replacement of dead and dying oak trees and other species characteristic of the wood with young trees. In this survey only two young trees were found, yet there were eleven senescent and dying trees. The life-class structure and size distribution all show that the woodland is composed of older trees with virtually no young trees. The site management statement identifies the need for 'a significant proportion of saplings, mature trees and dead wood present for all locally occurring native species'. The saplings of all species of tree, which are dominated by birch, make up only 6% of all saplings, live and dead trees. The presence of only one oak sapling and the complete absence of saplings of Scots pine, alder, ash, hawthorn and holly in this survey is even more worrying and shows that the site is not meeting at least one of the Site Management Statement objectives. It also does not satisfy the 'regeneration potential' attribute in the Site Condition Monitoring assessment. Less than 2% of the seedlings are growing through to the sapling or young tree stage.

The four most likely factors preventing the establishment of tree seedlings and saplings are:

- browsing by large herbivores;
- insufficient light;
- lack of seed production;
- the presence of pathogenic organism, especially fungi.

The reasons for the lack of regeneration are highly unlikely to be due to an inadequate supply of seed production and establishment of seedlings as there were good numbers of oak and birch seedlings found in this survey. Neither is it considered to be due to disease as there were no signs of disease/plant pathogens on any of the seedlings, saplings or trees at the time of the survey.

Excessive shading can prevent seedlings and saplings from establishing in the more light demanding species, as shown for birch (Jarvis, 1964). Sessile oak, however, 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). 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 to allow for the natural regeneration of trees (Hale, 2004). 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). Only five of the 25 plots surveyed had basal areas greater than 25 m^2 ha^{-1} and only three of these had basal areas between 35 and 37 m^2 per ha, which are probably sufficient to prevent the regeneration of seedlings of the more light demanding species of tree.

Given the lack of evidence for shading and disease for preventing the regeneration of sessile oak within the woodland habitat at Doire Donn SSSI it only leaves browsing as the most likely factor. Browsing of the leading shoots of all seedlings, apart from rowan, were very high at over 90%. Browsing is, therefore, considered to be the main, and almost certainly the only reason for the lack of regeneration of trees within the woodland habitat at Doire Donn SSSI. The only large herbivore considered to be responsible for this browsing are deer as this wood is not used by livestock for grazing, nor was the presence of hares or rabbits detected. There was plenty of evidence of red deer, including one hind that was found dying at the time of the survey in April.

The evidence for the impact of sheep and/or deer in preventing the regeneration of broad-leaved trees in upland woodland is long-standing and widespread (Shaw, 1968; Pigott, 1983; Beaumont *et al*., 1995; Rao, 2017).

Currently the Doire Donn SSSI may fail the SCM assessment for woodlands on the basis that it does not currently satisfy the following generic CSM targets:

- The extent of the woodland habitat has declined.
- Seedlings are not growing through to the sapling stage and then on to young trees at sufficient density to maintain the current canopy density.
- The understorey (2-5m high trees and shrubs) is not present over at least 20% of the woodland.

One of the other generic CSM targets is that the canopy cover should be between 30 and 90%. The canopy cover was certainly below 30% in at least 4 of the plots, which represents 16% of the woodland that was sampled. This is also symptomatic of a lack of regeneration of new trees in areas with ageing trees.

5. CONCLUSIONS

- Taken as a whole the age structure of the trees is poor, due to a near complete absence of small and large saplings and very low densities of young reproductive and/or pole stage trees.
- Browsing levels on the seedlings is very high (more than 90%) and is the main reason, if not the only reason, for the low survival of the seedlings of all species to the small sapling stage.
- The canopy of the wood is dominated by mature and over-mature sessile oak trees, and these trees will not be replaced as they die, under the current management regime.
- If nothing is done to encourage an increase in the regeneration of sessile oak the woodland will gradually change to a birchwood.
- Without some interventions to reduce the red deer numbers in the local area, the upland oak woodland habitat will lose some of its other conservation interest, in particular the ferns, mosses, liverworts and lichens that grow on the bark of the sessile oak and other species of large deciduous trees, other than birch.

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ANNEX 1: TABLES

Table 1. The number of trees (per ha) in each life-class for each species of tree surveyed across Doire Donn SSSI.

Species of tree	Life-class										
	Seed-lings	Small saplings	Large saplings	Pole stage	Young reproductive	Mature	Over-mature	Senescent	"Phoenix"	**Total Live Trees**	Dead
downy birch	57.7	1.6	5.6	9.6	12.8	39.3	12.8	2.4	9.6	**86.6**	21.7
sessile oak	64.2	0.0	0.8	0.0	1.6	20.9	48.1	5.6	3.2	**79.4**	3.2
hazel	48.1	0.8	0.0	0.0	0.0	8.8	3.2	0.0	2.4	**14.4**	0.0
ash	0.0	0.0	0.0	0.0	0.8	2.4	0.0	0.8	0.0	**4.0**	0.0
holly	42.5	0.0	0.0	0.0	0.0	1.6	0.8	0.0	0.0	**2.4**	0.0
beech	1.6	0.0	0.0	0.0	0.8	1.6	0.0	0.0	0.0	**2.4**	0.0
alder	0.0	0.0	0.0	0.8	0.0	0.8	0.0	0.0	0.0	**1.6**	0.0
rowan	13.6	0.8	4.8	0.0	0.8	0.0	0.0	0.0	0.0	**0.8**	0.0
Scots pine	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.5	0.0	**0.8**	1.6
Sitka spruce	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	**0.8**	0.0
hawthorn	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
unknown species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	3.2
All species	**234.2**	**3.2**	**11.2**	**20.0**	**7.2**	**77.0**	**65.0**	**8.8**	**15.2**	**193.3**	**29.7**

Table 2. Summary statistics for the density (per ha) of seedlings, small saplings, large saplings and all live trees collected from each of the 25 sample plots surveyed.

Species	Life-class	Statistic						
		Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
Density of all plants of all species (per ha)	Seedlings	367	299	0	40	261	481	1,664
	Small saplings	6	15	0	0	0	0	60
	Large saplings	7	32	0	0	0	0	160
	Pole stage	10	52	0	0	0	0	260
	Young reprod’	17	35	0	0	0	20	160
	Mature	76	74	0	20	60	120	240
	Over-mature	65	63	0	0	60	100	220
	Senescent	9	20	0	0	0	0	80
	“Phoenix”	17	32	0	0	0	20	120
	All live trees	193	146	0	120	180	260	720
	All dead trees	30	68	0	0	0	40	340
sessile oak	Seedlings	64	107	0	0	0	80	420
	Large saplings	1	4	0	0	0	0	20
	All live trees	79	85	0	0	40	140	280
downy birch	Seedlings	58	140	0	0	0	40	600
	Small saplings	2	6	0	0	0	0	20
	Large saplings	6	28	0	0	0	0	140
	All live trees	86	142	0	20	60	100	700
rowan	Seedlings	146	254	0	0	0	140	980
	Small saplings	3	11	0	0	0	0	40
	Large saplings	1	4	0	0	0	0	20
	All trees	1	4	0	0	0	0	20
holly	Seedlings	42	78	0	0	0	40	280
	All live trees	2	7	0	0	0	0	20
hazel	Seedlings	48	183	0	0	0	0	900
	Small saplings	1	4	0	0	0	0	20
	All live trees	14	45	0	0	0	0	220
beech	Seedlings	2	8	0	0	0	0	40
	All live trees	2	12	0	0	0	0	60
ash	All live trees	4	16	0	0	0	0	80
alder	All live trees	2	6	0	0	0	0	20
hawthorn	Seedlings	6	19	0	0	0	0	80
Scots pine	All live trees	13	40	0	0	0	0	200
Sitka spruce	Seedlings	3	15	0	0	0	0	100
	All live trees	3	22	0	0	0	0	160

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

	Number of stems per ha						
Species of tree	small trees (dbh 7-25 cm)	medium trees (dbh 25-40 cm)	large trees (dbh 40-55 cm)	very large trees (dbh >55 cm)	standing dead	fallen dead	dead stump
downy birch	65.0	16.0	5.6	0.0	21.7	2.4	0.0
sessile oak	17.6	35.3	16.8	10.4	0.0	0.0	0.0
hazel	15.2	1.6	0.0	0.0	0.0	0.0	0.0
ash	0.8	0.8	2.4	0.0	0.0	0.0	0.0
holly	0.8	0.8	0.0	0.8	0.0	0.0	0.0
beech	0.8	0.0	1.6	0.0	0.0	0.0	0.0
rowan	1.6	0.0	0.0	0.0	0.0	0.0	0.0
alder	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Sitka spruce	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Scots pine	0.0	0.8	0.0	0.0	1.6	0.0	0.0
unknown species	0.0	0.0	0.0	0.0	1.6	0.8	0.0
All species	103.5	56.9	26.5	11.2	24.9	3.2	0.0

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

Species of tree	Life stage							
	Pole stage	Young reproductive	Mature	Over-mature	Senescent	"Phoenix" trees	Dead	**Total live**
sessile oak	0.000	0.025	2.771	7.803	0.368	0.477	0.150	**11.444**
downy birch	0.126	0.113	2.141	0.596	0.074	0.432	0.423	**3.483**
ash	0.000	0.015	0.344	0.000	0.106	0.000	0.000	**0.466**
holly	0.000	0.000	0.222	0.096	0.000	0.000	0.000	**0.318**
hazel	0.000	0.000	0.221	0.046	0.000	0.026	0.000	**0.293**
beech	0.000	0.003	0.278	0.000	0.000	0.000	0.000	**0.281**
Scots pine	0.000	0.009	0.087	0.000	0.002	0.000	0.043	**0.099**
Sitka spruce	0.000	0.000	0.064	0.000	0.000	0.000	0.000	**0.064**
alder	0.000	0.014	0.040	0.000	0.000	0.000	0.000	**0.054**
rowan	0.000	0.006	0.000	0.000	0.000	0.000	0.000	**0.006**
unknown species	0.000	0.000	0.000	0.000	0.013	0.000	0.100	**0.000**
All species	**0.126**	**0.186**	**6.169**	**8.542**	**0.550**	0.935	**0.717**	**16.508**

Table 5. Summary statistics for the basal area (m^2 per ha) of all live trees calculated for each of the 25 sample plots surveyed.

Species	Statistic						
	Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
alder	0.1	0.2	0	0	0	0	1.0
ash	0.5	1.8	0	0	0	0	9.0
birch	3.6	5.0	0	0.3	1.4	4.8	21.2
beech	0.3	1.4	0	0	0	0	7.0
hazel	0.3	0.8	0	0	0	0	3.0
holly	0.3	1.1	0	0	0	0	5.3
rowan	<0.1	<0.1	0	0	0	0	0.2
Scots pine	0.1	0.4	0	0	0	0	2.2
sessile oak	14.9	22.3	0	0	10.5	19.0	36.8
Sitka spruce	0.1	0.3	0	0	0	0	1.6
All	20.1	21.3	0.3	10.4	14.7	21.2	36.8

Table 6. The number of un-browsed and browsed seedlings, small saplings and large saplings for each species of tree surveyed within the Doire Donn 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**
birch	4	68	94	2	0	0	7	0	0	**81**	**84**
sessile oak	7	73	91	0	0	NA	1	0	0	**81**	**90**
hazel	5	55	92	1	0	0	0	0	NA	**61**	**90**
holly	1	52	98	0	0	NA	0	0	NA	**53**	**98**
rowan	17	0	0	0	1	100	1	5	83	**24**	**25**
hawthorn	0	8	100	0	0	NA	0	0	NA	**8**	**100**
beech	0	2	100	0	0	NA	0	0	NA	**2**	**100**
All species	**34**	**258**	**88**	**3**	**1**	**25**	**9**	**5**	**36**	**310**	**85**

Table 7. The summary statistics calculated for the levels of browsing on seedlings, small saplings and large saplings in each of the 25 sample plots surveyed.

Life-class	Statistic						
	Mean	s.d.	Min.	25%tile	Median	75%tile	Max.
Seedlings	98	4	62	93	100	100	100
Small saplings	35	49	0	0	34	75	100
Large saplings	0	0	0	0	0	0	0

Table 8. The number of sample plots with different levels of herbivore impact for each of six indicators in the vegetation within the part of the Doire Donn SSSI. 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	1	0	16	0	1	0	0	7
Epicormic shoots	0	0	10	0	1	0	0	14
Seedlings and saplings	15	0	5	1	0	0	0	4
Preferentially grazed spp.	3	0	16	0	1	0	0	5
Bark Stripping	0	0	1	0	1	0	17	6
Overall Impact	**3**	**4**	**17**	**0**	**1**	**0**	**0**	**0**

ANNEX 2: FIGURES

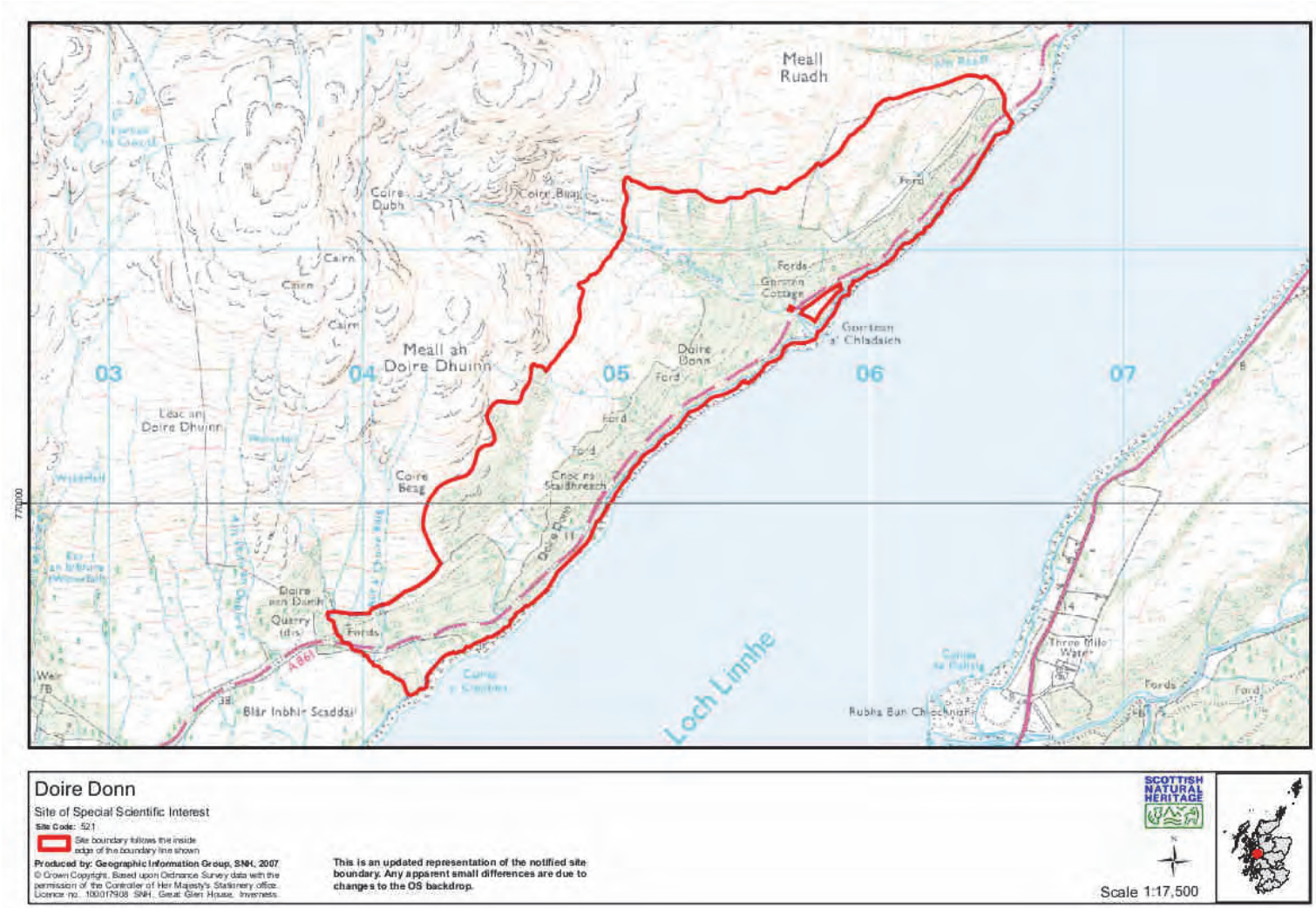

Figure 1. Map showing the location and boundary of the Doire Donn SSSI.

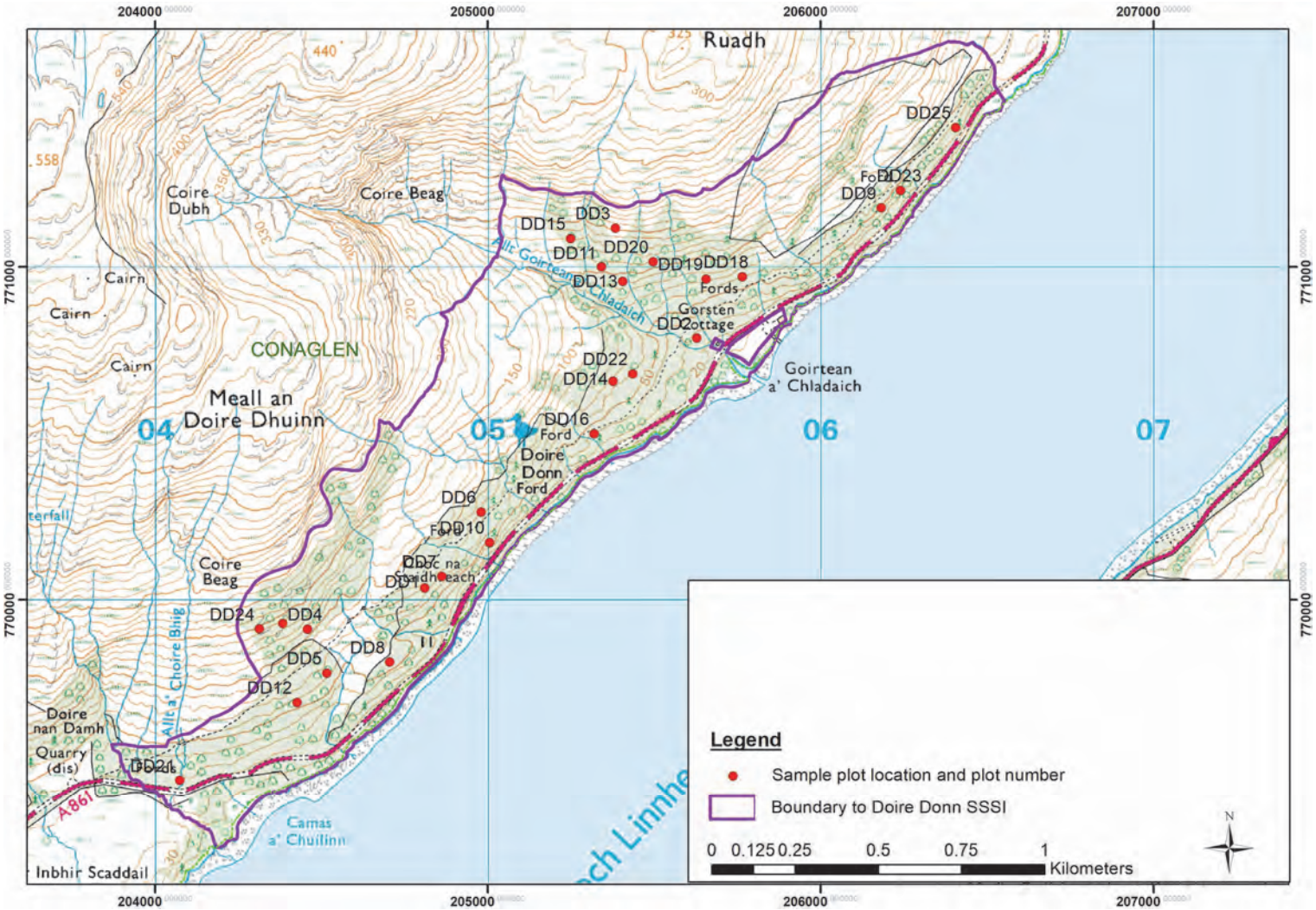

Figure 2. Map showing the location of the 25 sample plots within the Doire Donn SSSI taken to describe the structure and assess the herbivore impacts on the upland oak woodland habitat. The 25m diameter sample plots (red circles) are shown to scale on this map. © Crown copyright and database right 2018. Ordnance Survey 100017908.

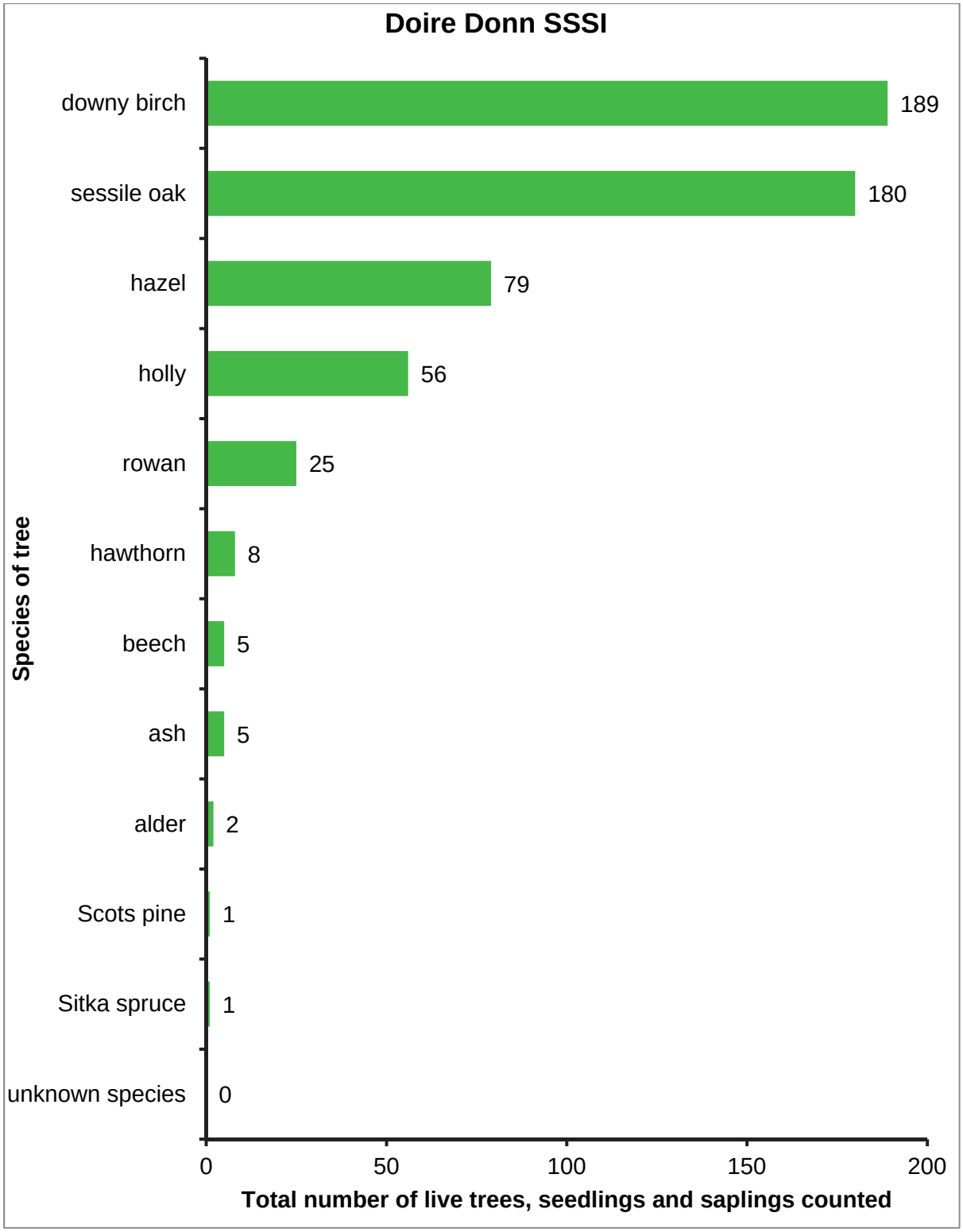

Figure 3. The total number of seedlings, saplings and live trees measured and counted for each species of tree surveyed across the Doire Donn SSSI.

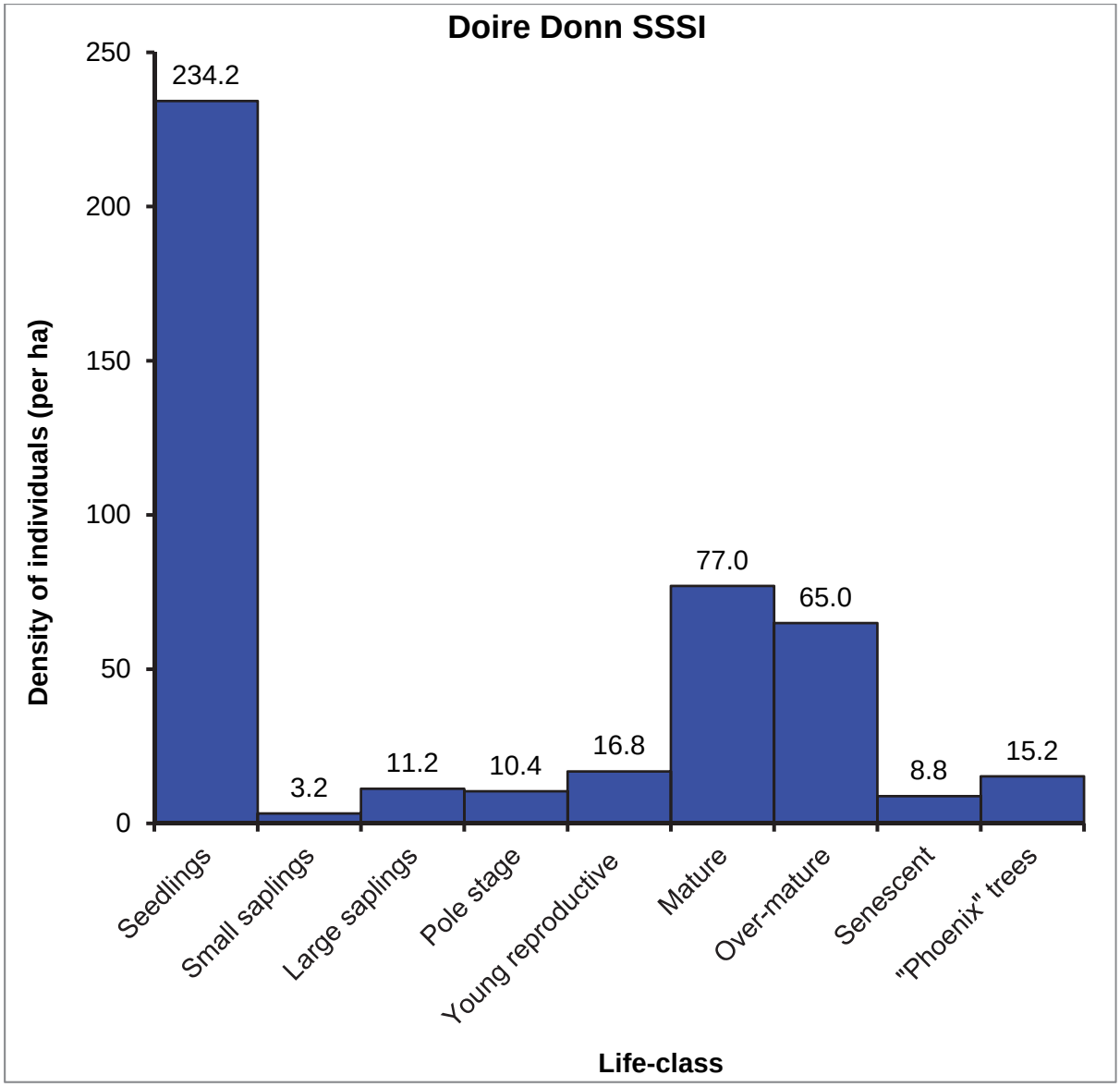

Figure 4. The density of individuals of all species of tree in each life-class surveyed across the Doire Donn SSSI.

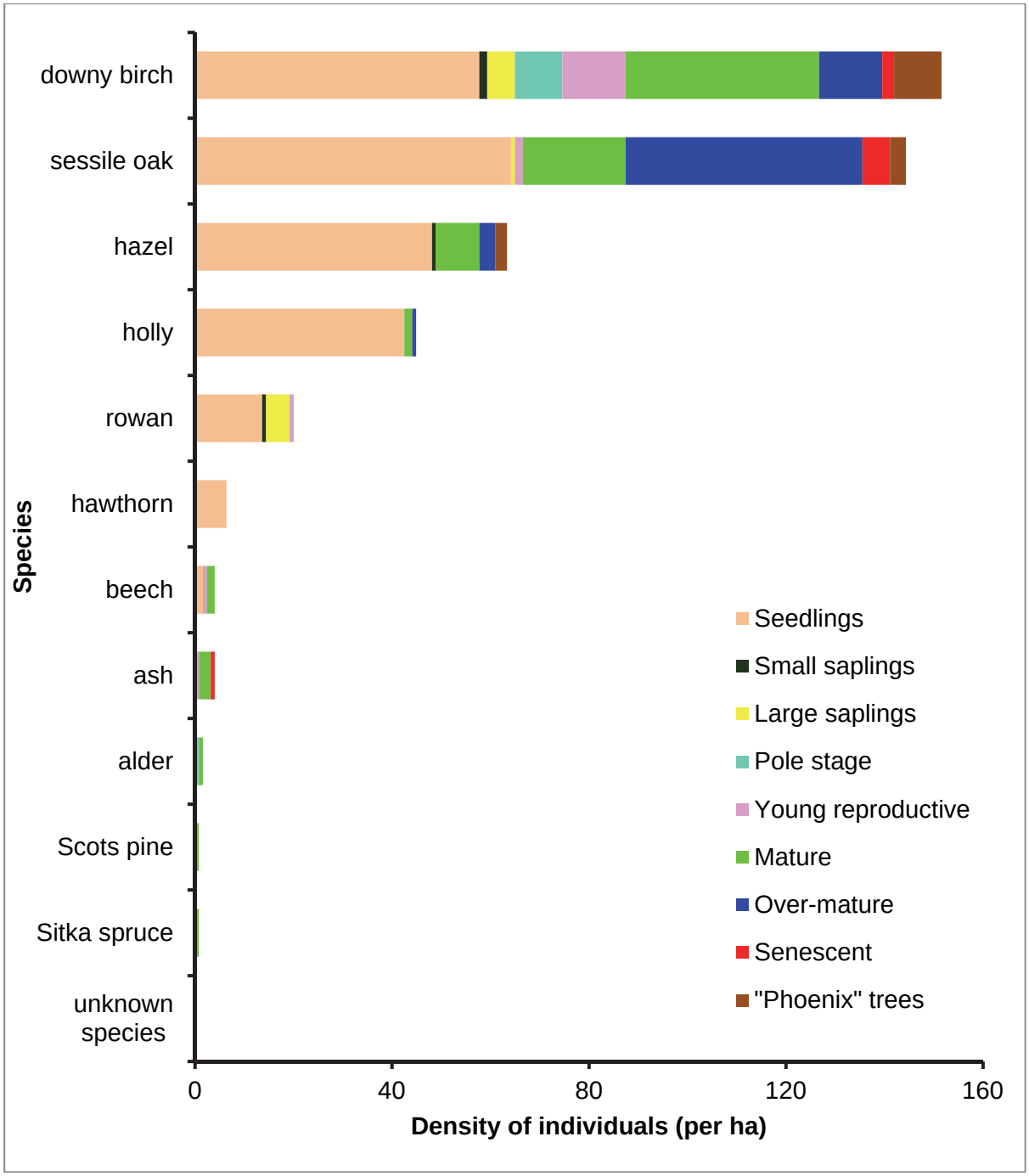

Figure 5. The density of individuals in each life-class (per ha) for each life-class for each species of tree surveyed across the Doire Donn SSSI.

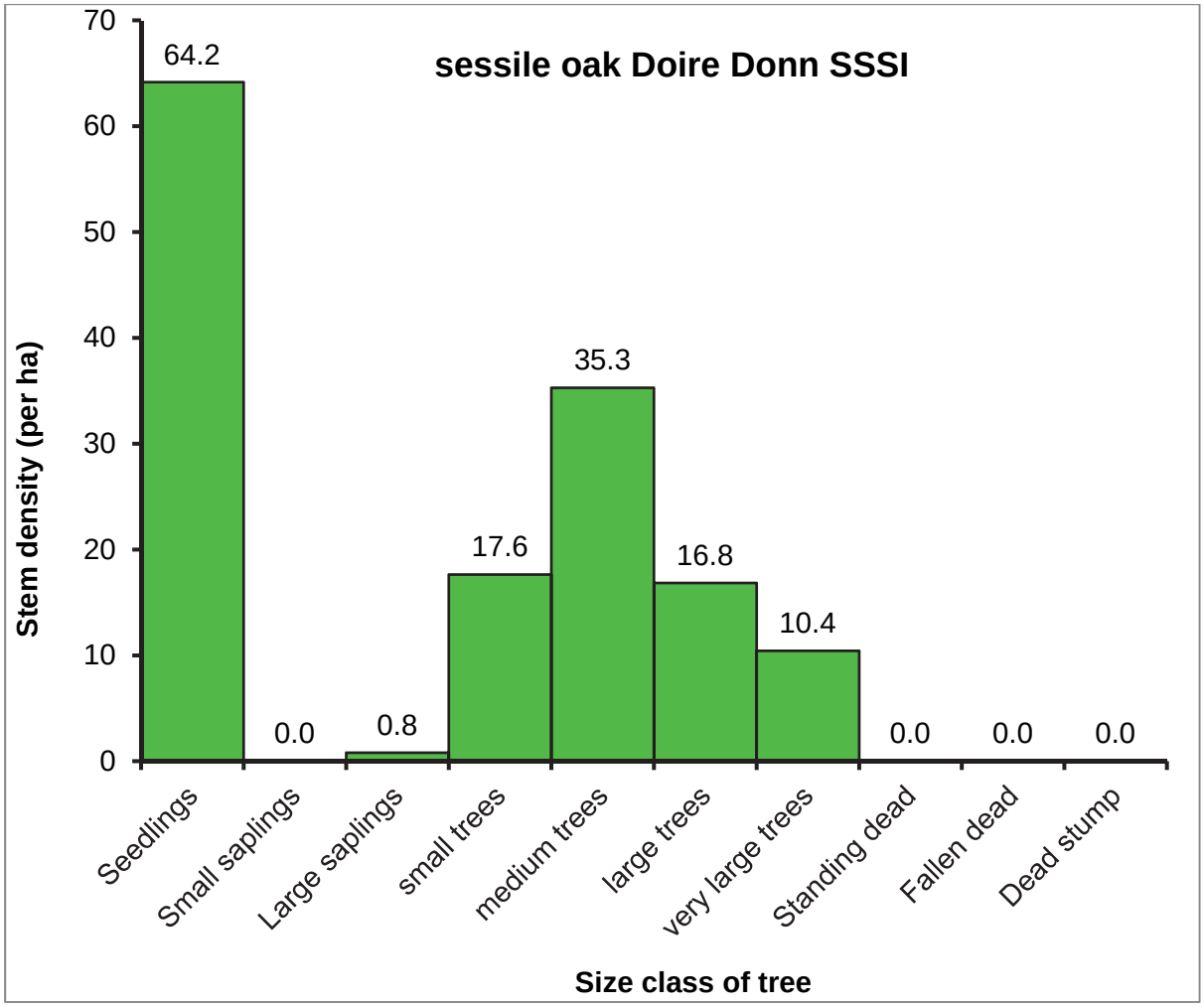

Figure 6. The size distribution of the sessile oak population within the Doire Donn SSSI.

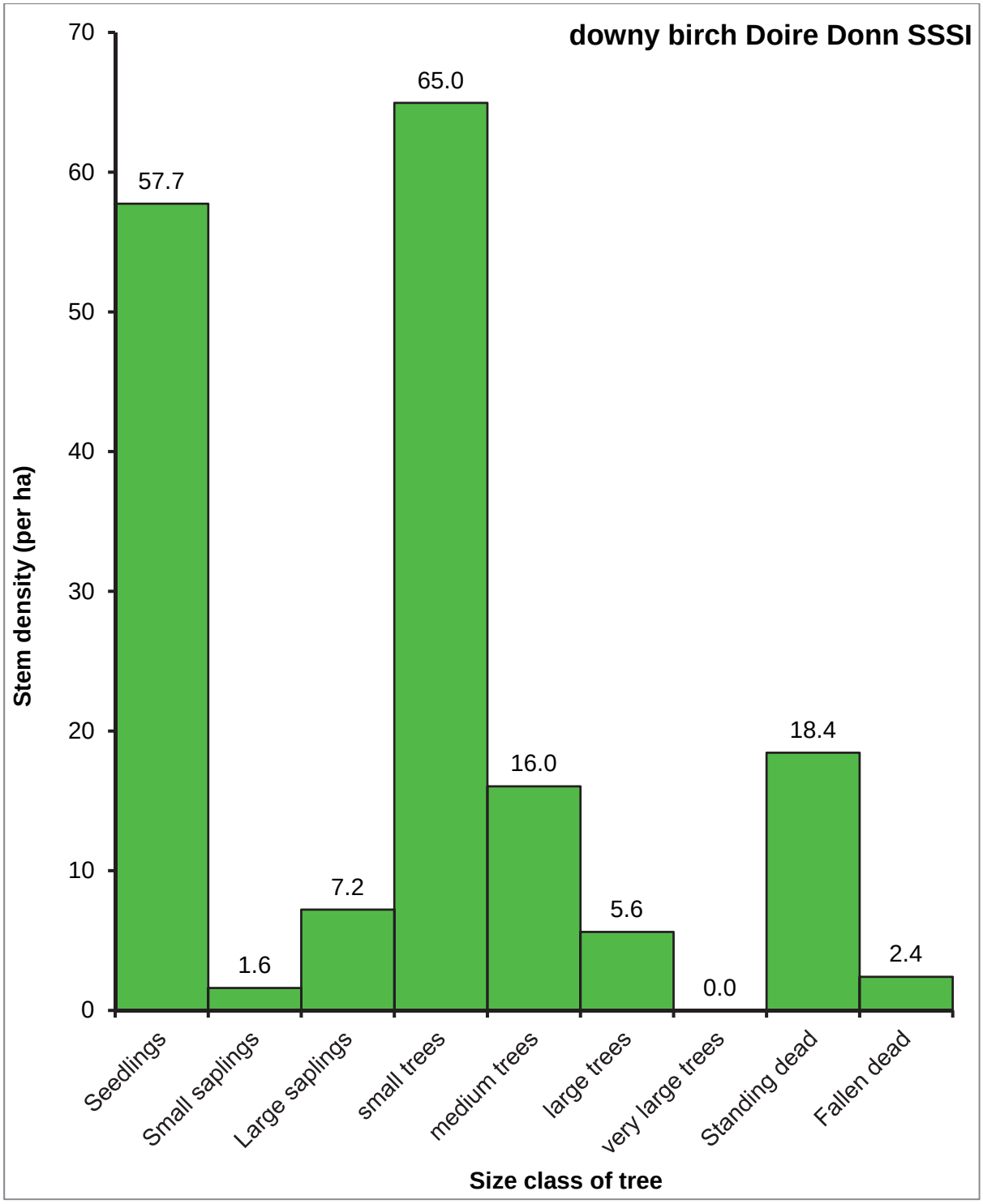

Figure 7. The size distribution of the downy birch population within the Doire Donn SSSI.

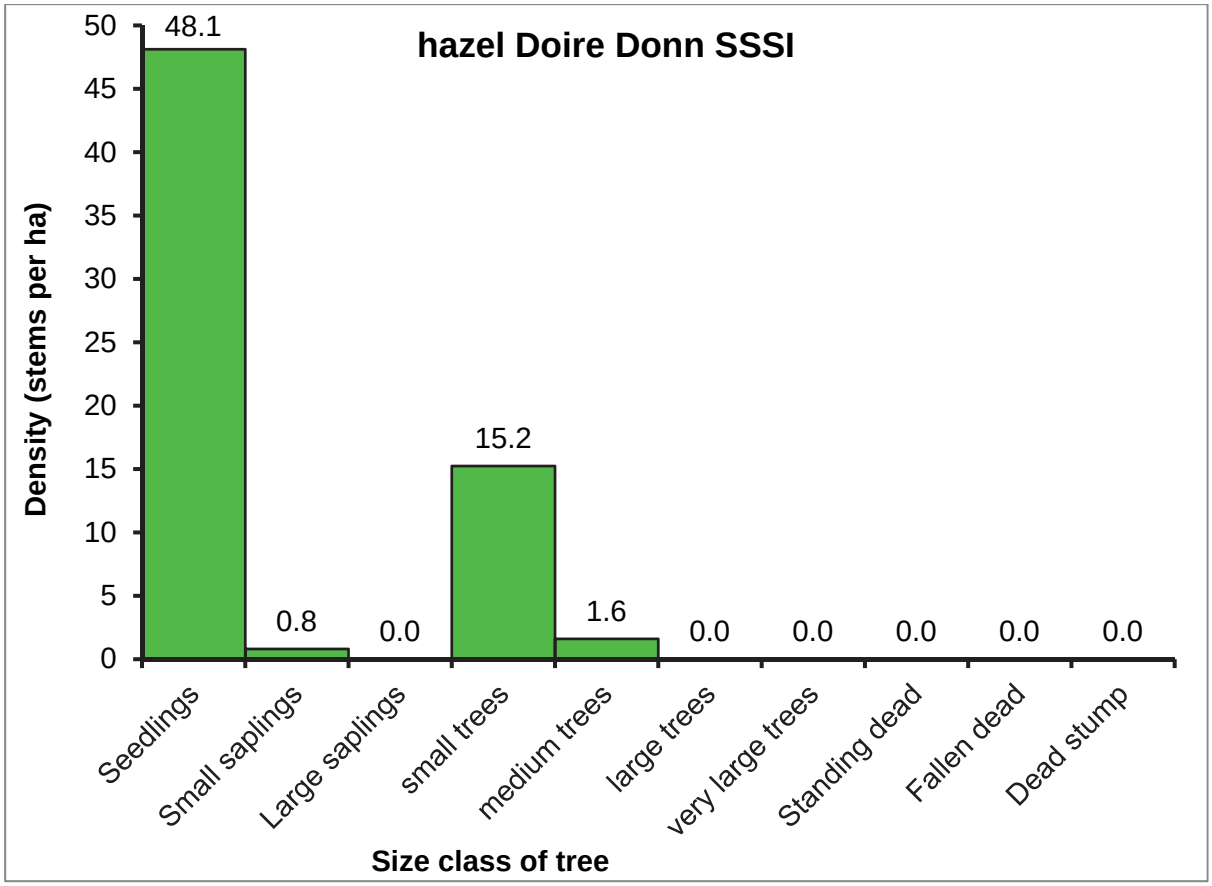

Figure 8. The size distribution of the hazel population within the Doire Donn SSSI.

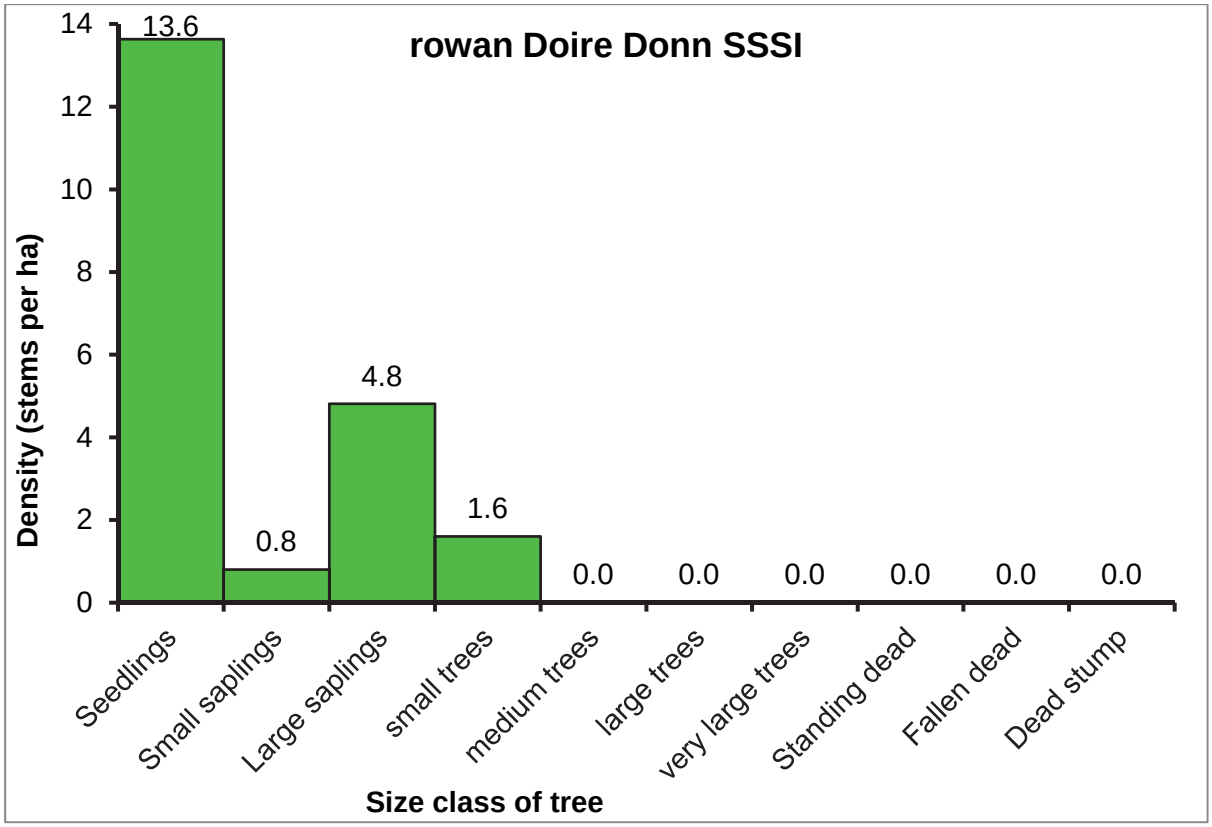

Figure 9. The size distribution of the rowan population within the Doire Donn SSSI.

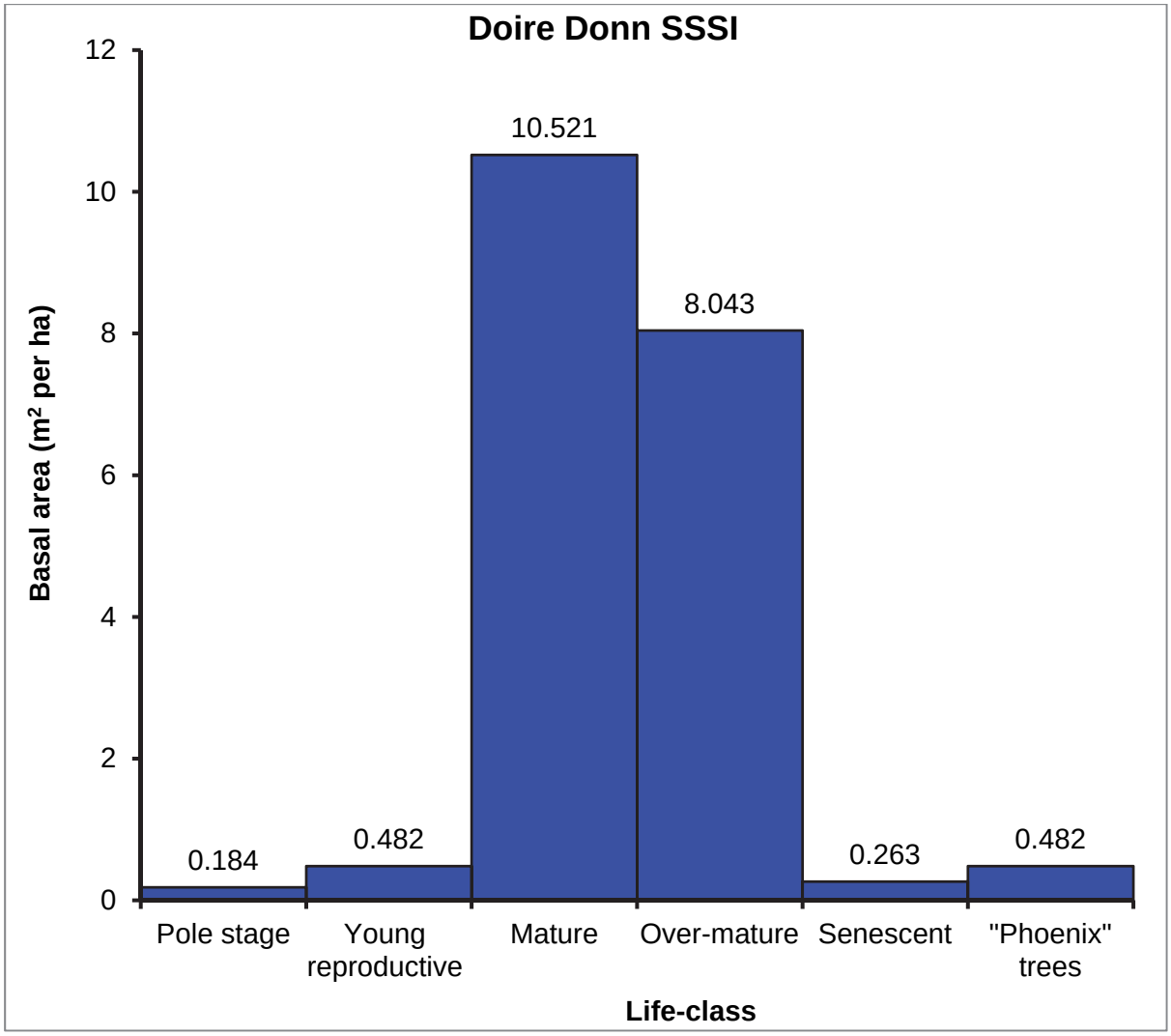

Figure 10. Basal area (m2 per ha) of trees in different life-classes within the Doire Donn SSSI.

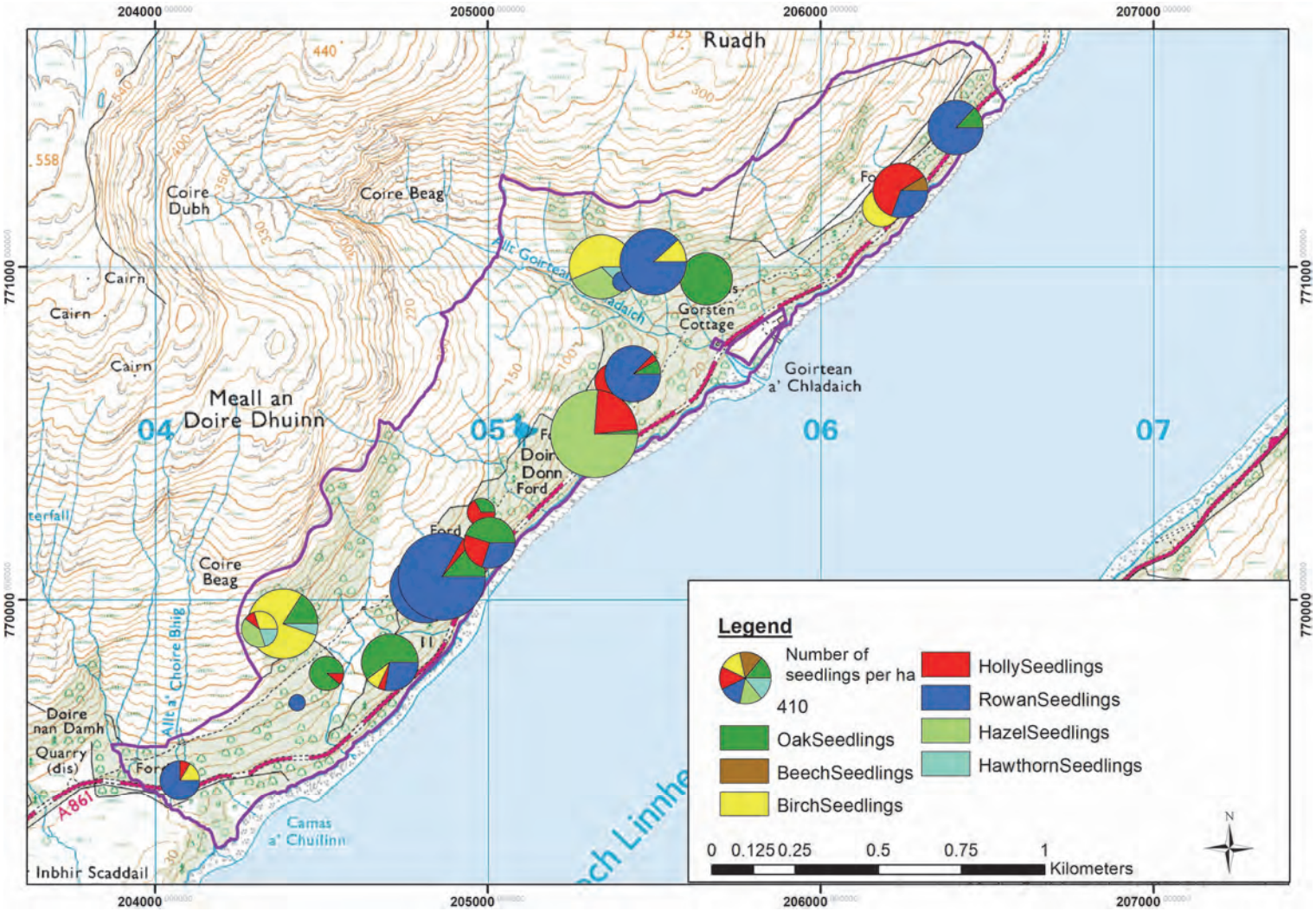

Figure 11. The density of seedlings of each species of tree in each of the plots surveyed across the Doire Donn SSSI. The area of the pie charts is proportional to the total seedling density (per ha). © Crown copyright and database right 2018. Ordnance Survey 100017908.

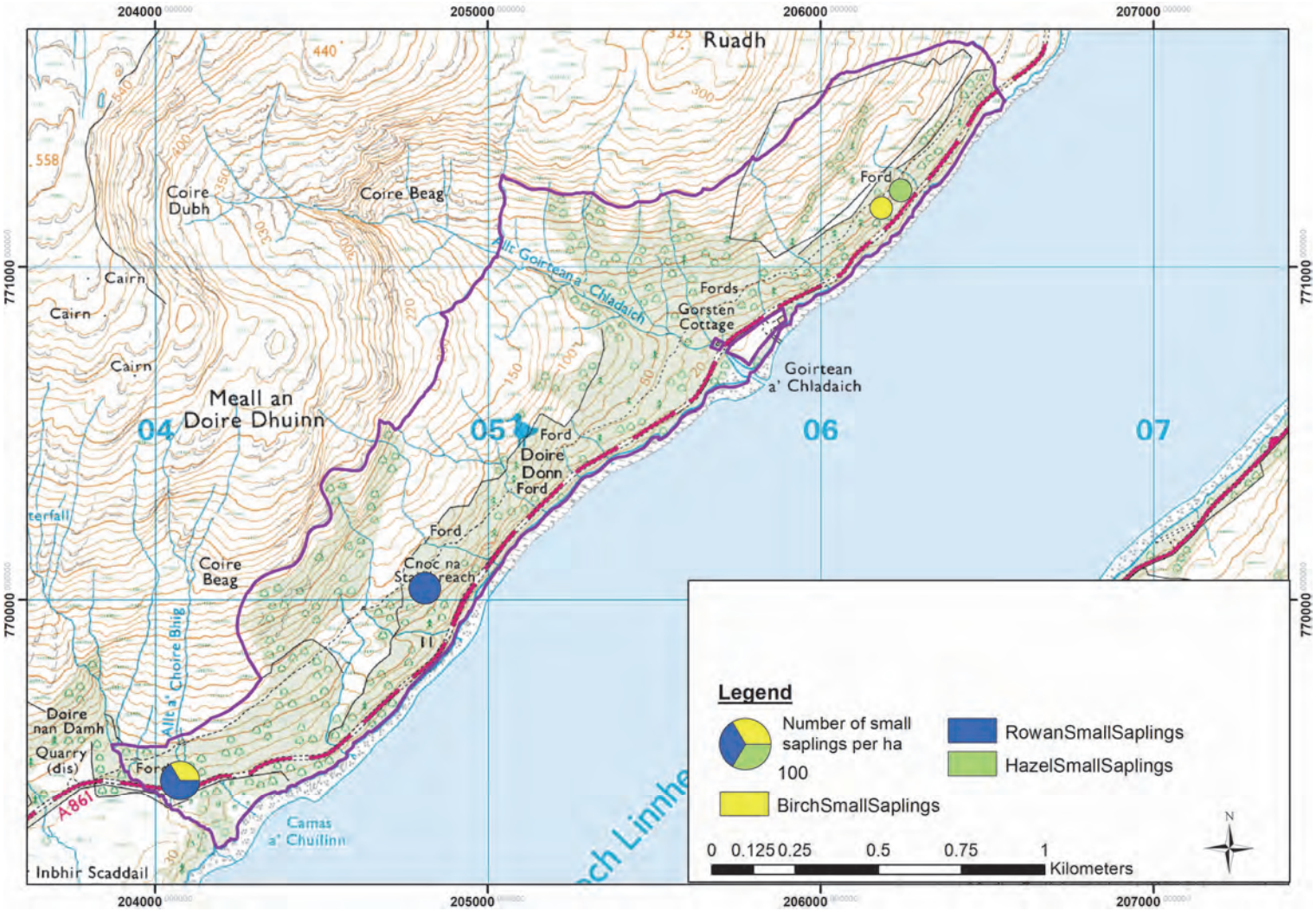

Figure 12. The densities of small saplings of each species (birch, rowan and hazel) in the plots surveyed across the Doire Donn SSSI. The area of the pie charts is proportional to the cumulative density (per ha) of all the saplings. © Crown copyright and database right 2018. Ordnance Survey 100017908.

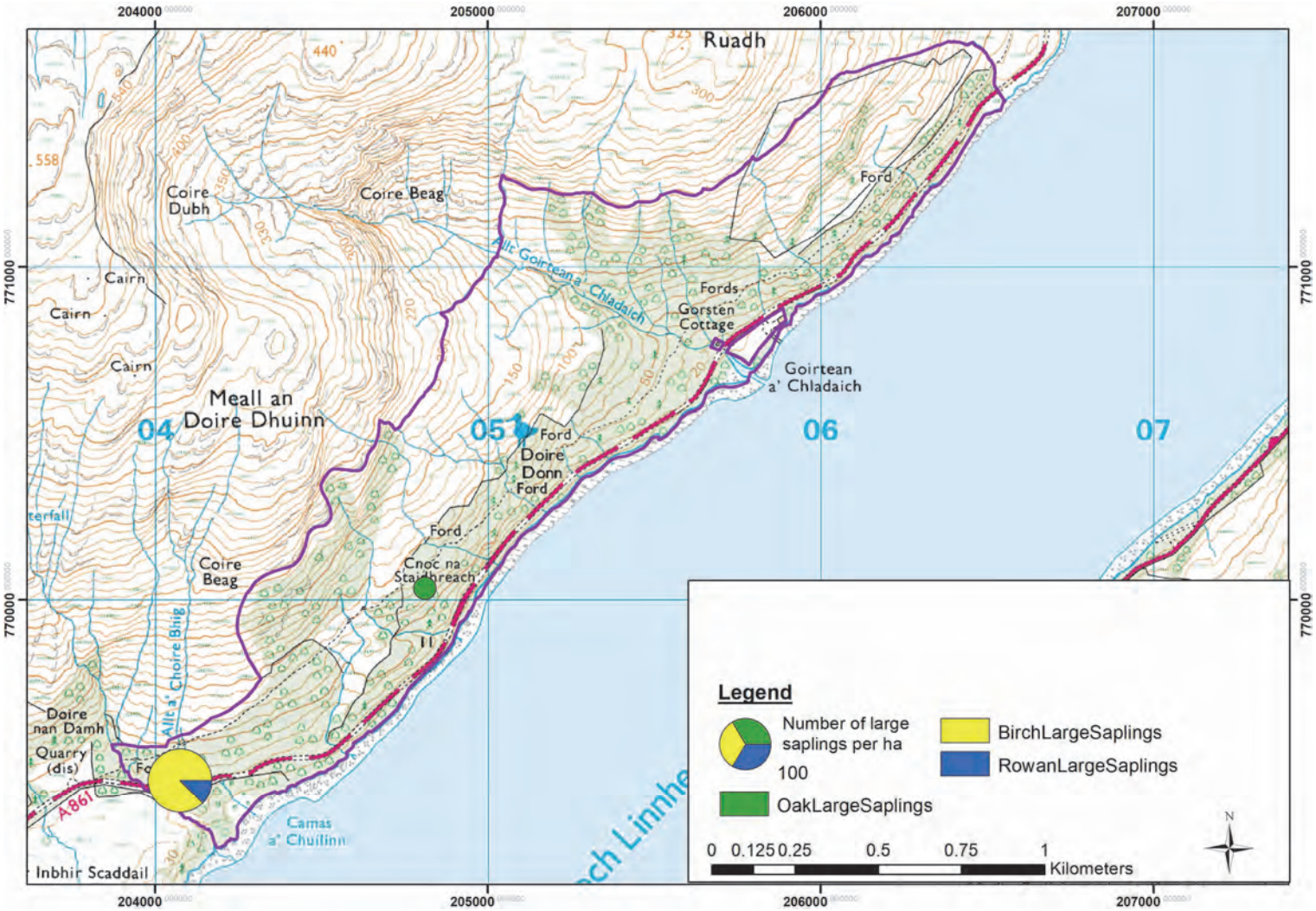

Figure 13. The densities of large saplings of all species (oak, birch and rowan) in the plots surveyed across the Doire Donn SSSI. The area of the pie charts is proportional to the cumulative density (per ha) of all the saplings. © Crown copyright and database right 2018. Ordnance Survey 100017908.

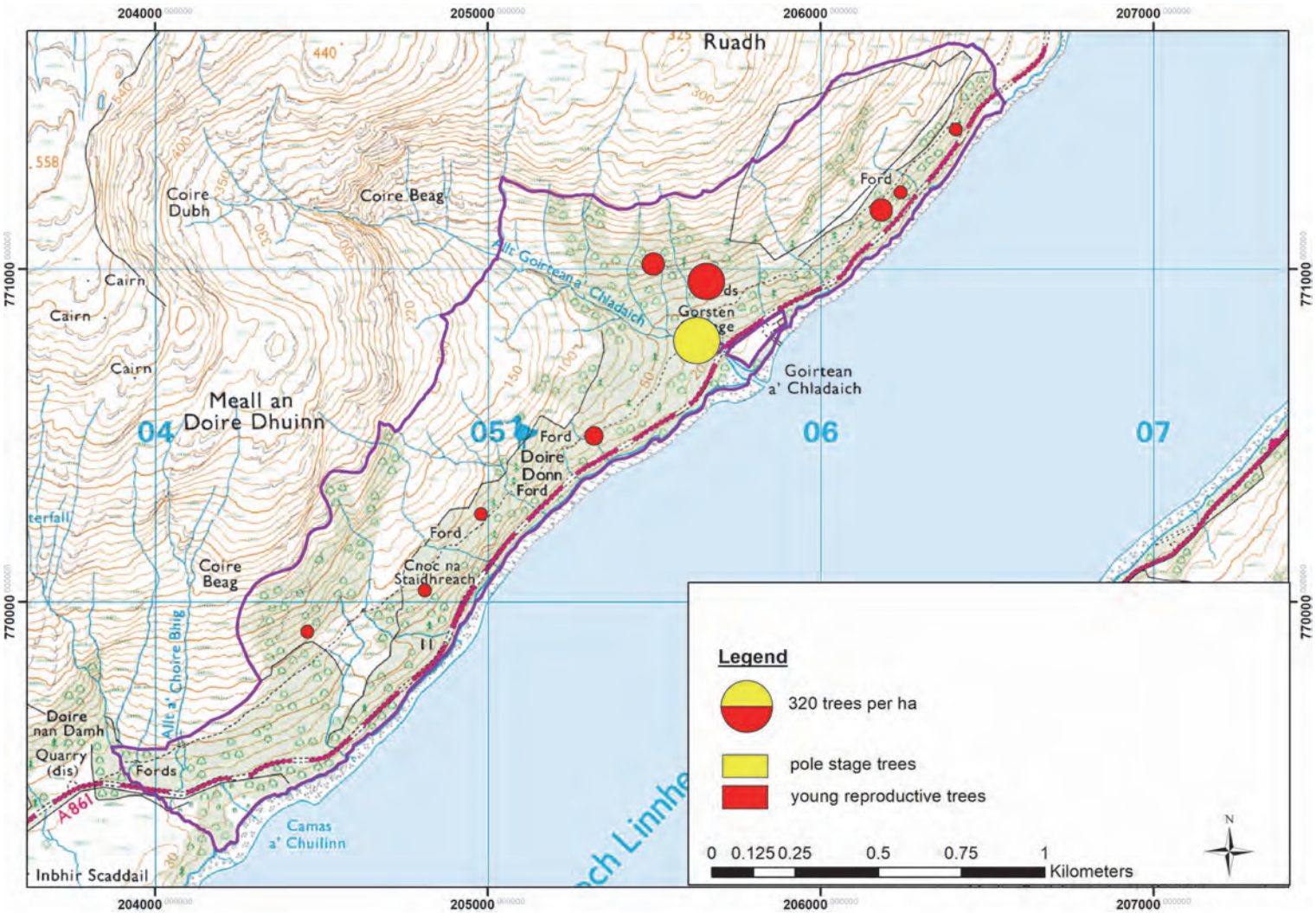

Figure 14. The density of pole and young reproductive trees of all species in the plots surveyed across the Doire Donn SSSI. © Crown copyright and database right 2018. Ordnance Survey 100017908.

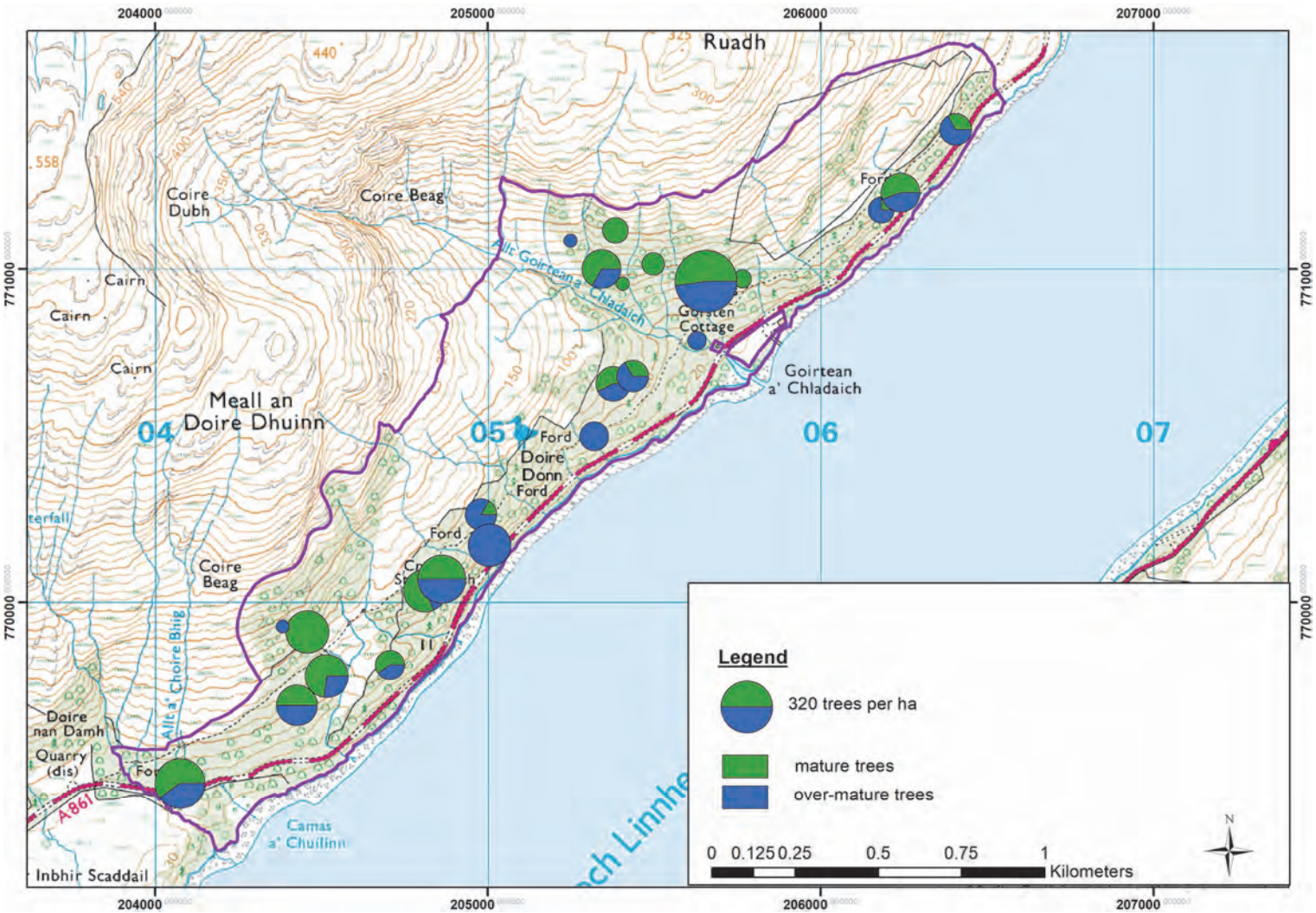

Figure 15. The density of mature and over-mature trees in the plots surveyed across the Doire Donn SSSI. The area of the circles is proportional to the cumulative densities. © Crown copyright and database right 2018. Ordnance Survey 100017908.

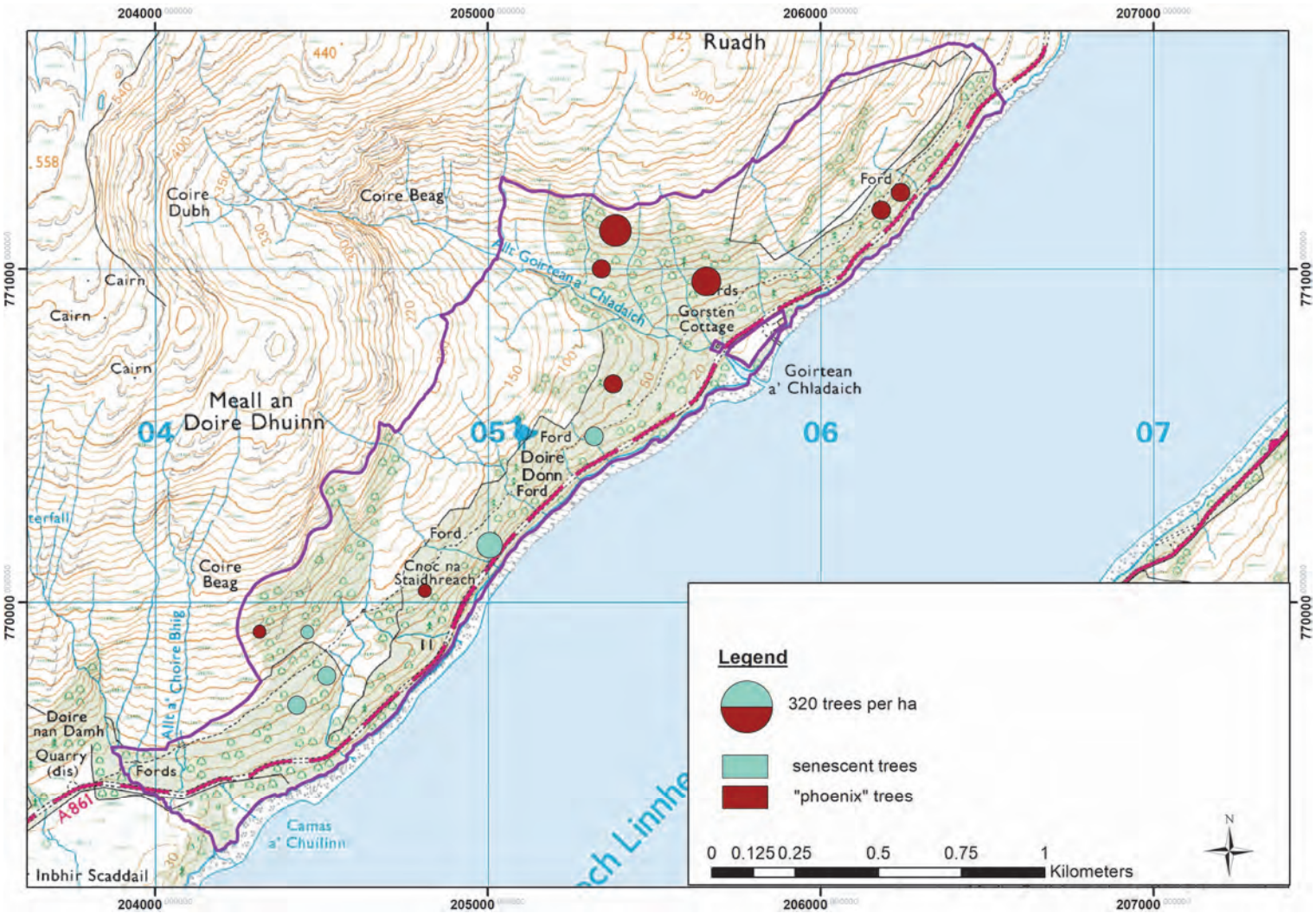

Figure 16. The densities of senescent and "phoenix" trees in the plots surveyed across the Doire Donn SSSI. The diameter of the circle is proportional to the cumulative density (per ha) of each species. © Crown copyright and database right 2018. Ordnance Survey 100017908.

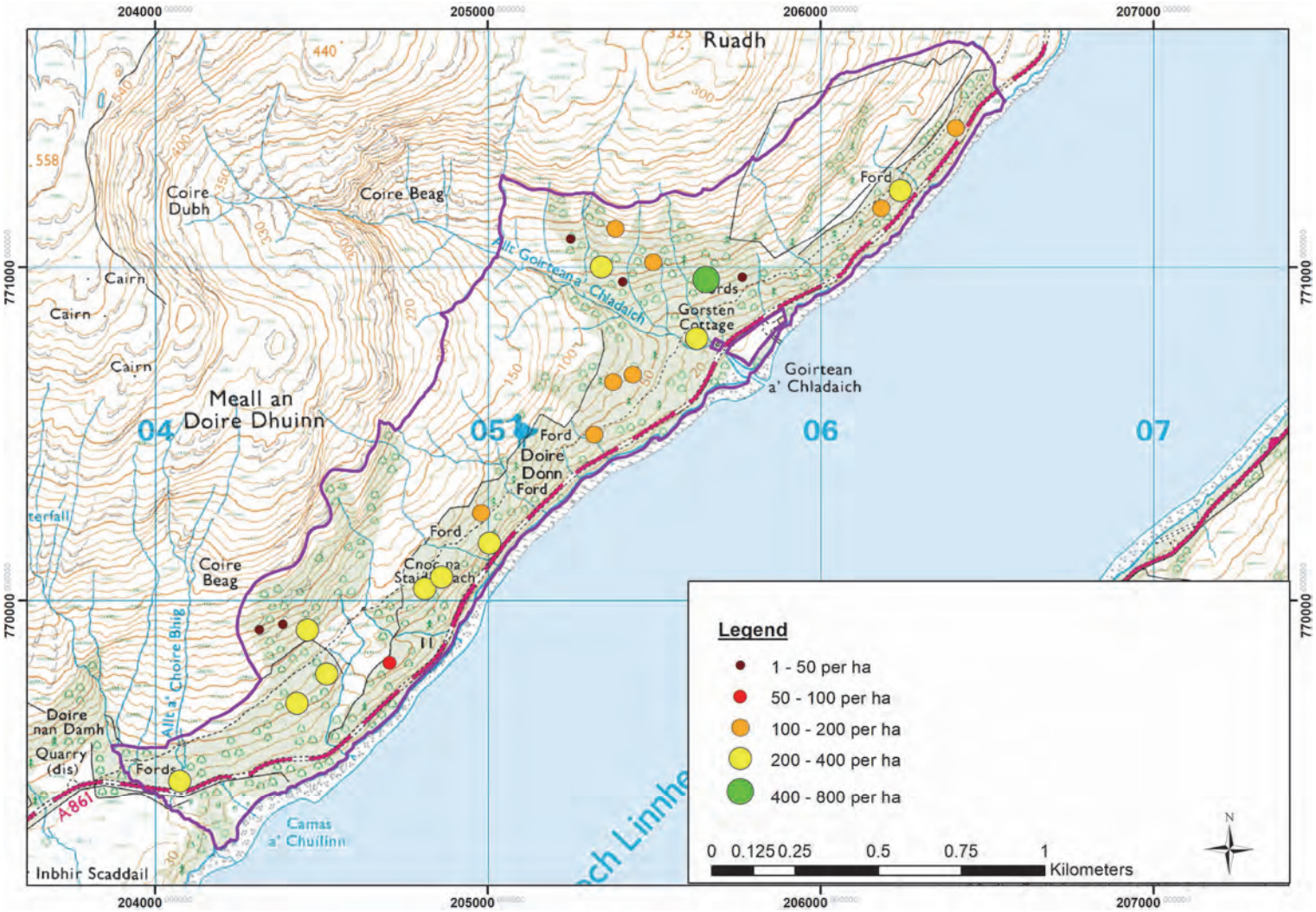

Figure 17. The density of all live trees in the plots surveyed within the Doire Donn SSSI. © Crown copyright and database right 2018. Ordnance Survey 100017908.

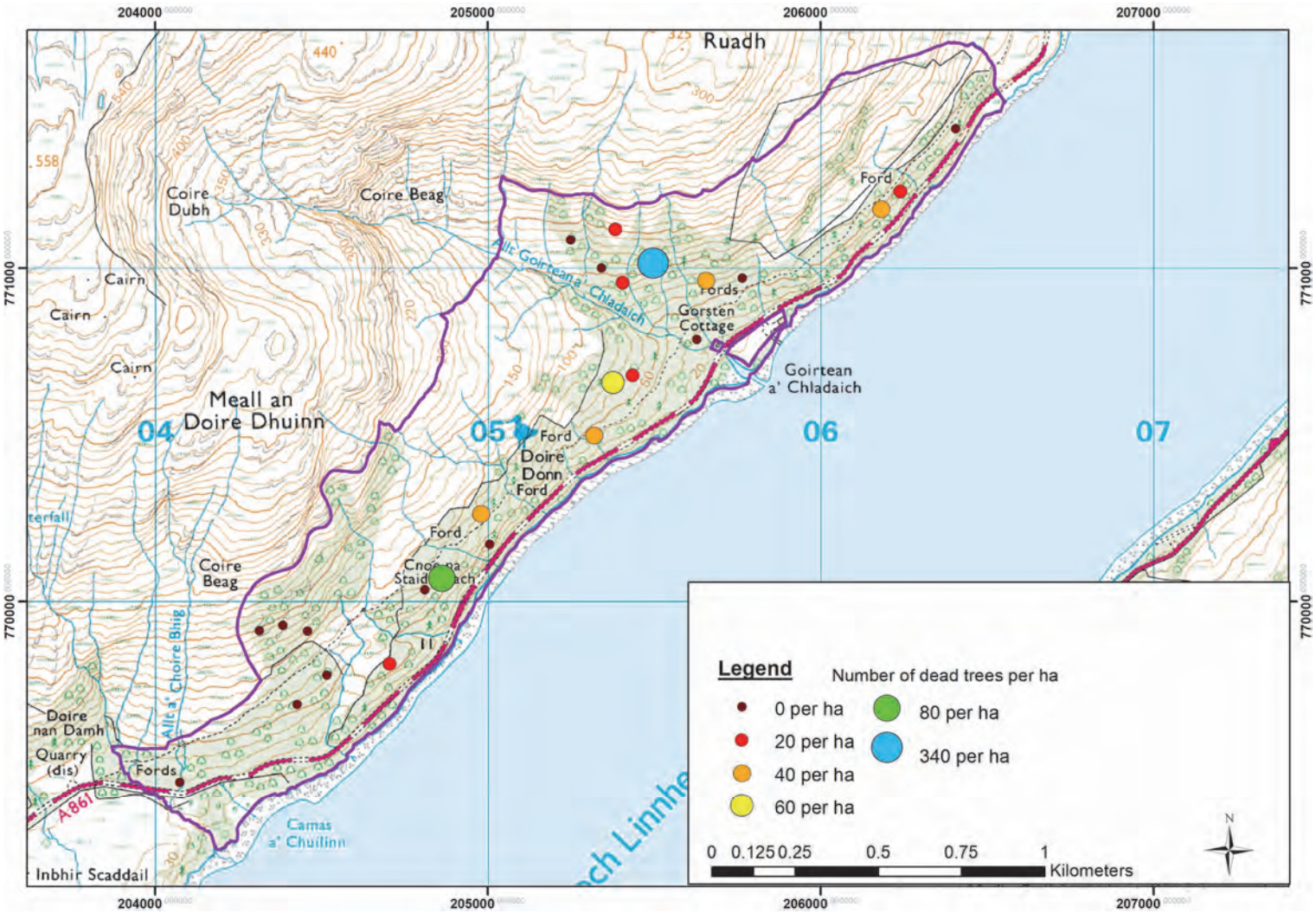

Figure 18. The density of all dead trees (standing, fallen and stumps) within the Doire Donn SSSI. © Crown copyright and database right 2018. Ordnance Survey 100017908.

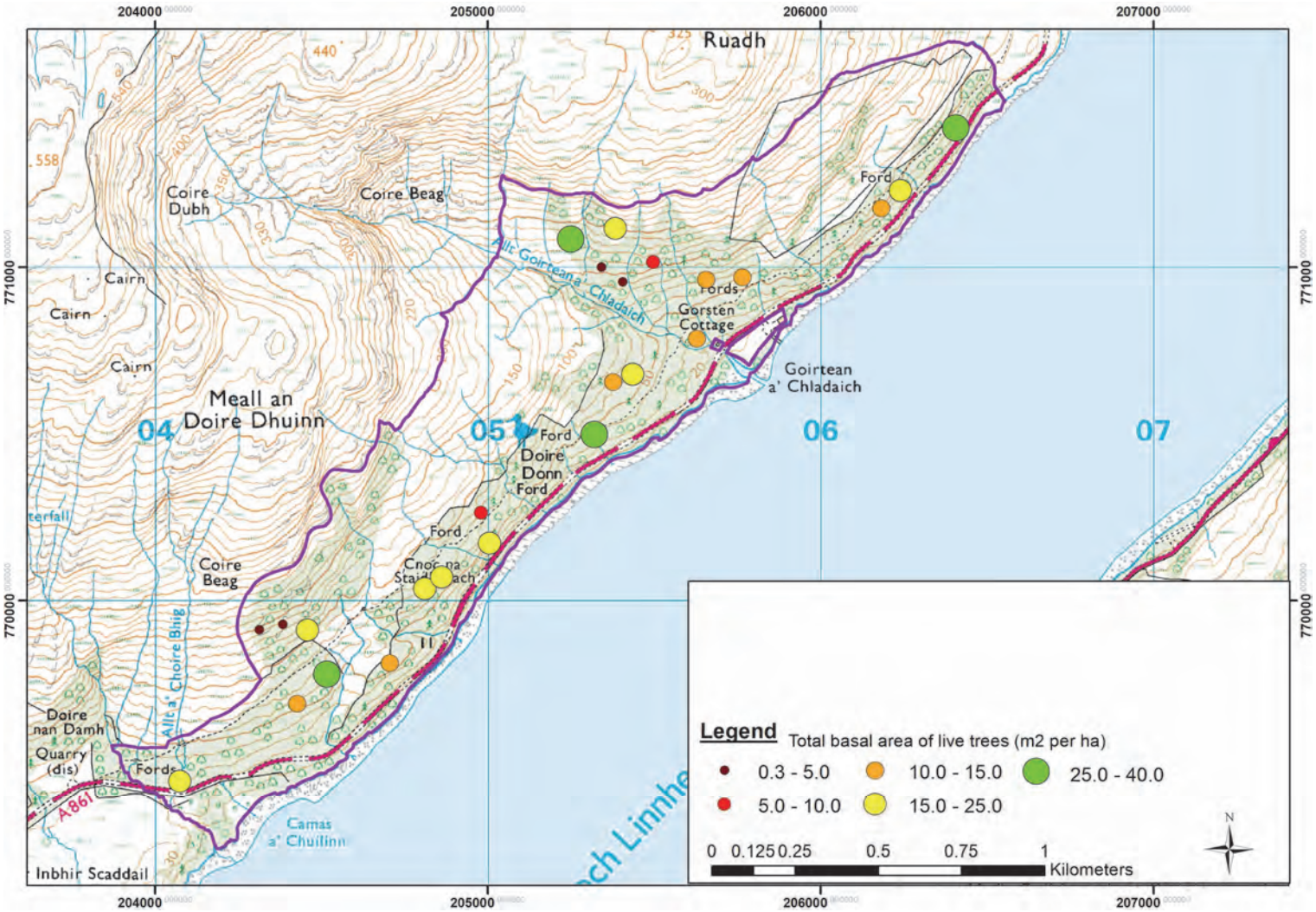

Figure 19. The basal area (m² per ha) of live trees in the different plots across the Doire Donn SSSI. © Crown copyright and database right 2018. Ordnance Survey 100017908.

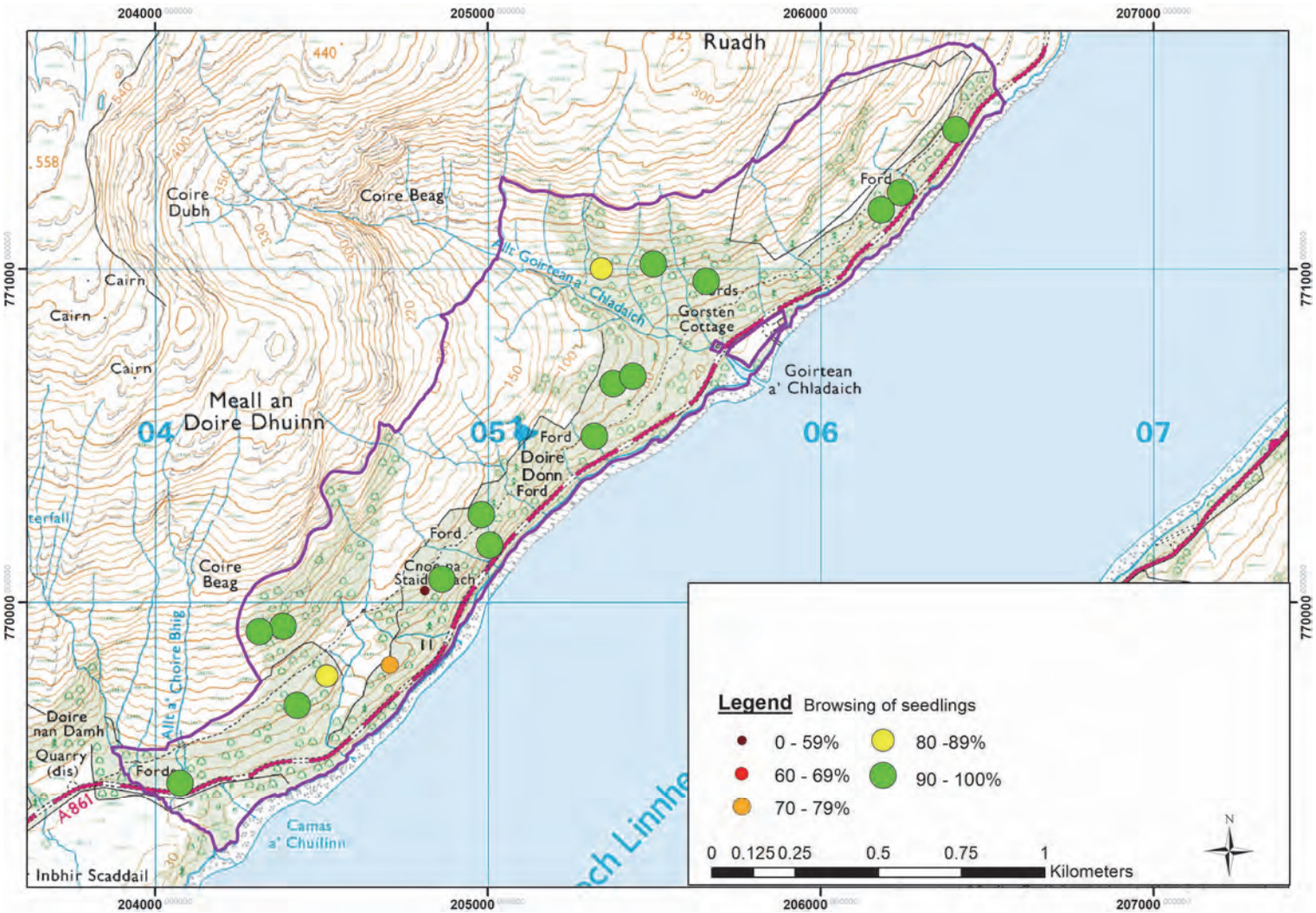

Figure 20. The percentage of seedlings where the leading shoot was browsed for all species present in each plot surveyed across the Doire Donn SSSI. © Crown copyright and database right 2018. Ordnance Survey 100017908.

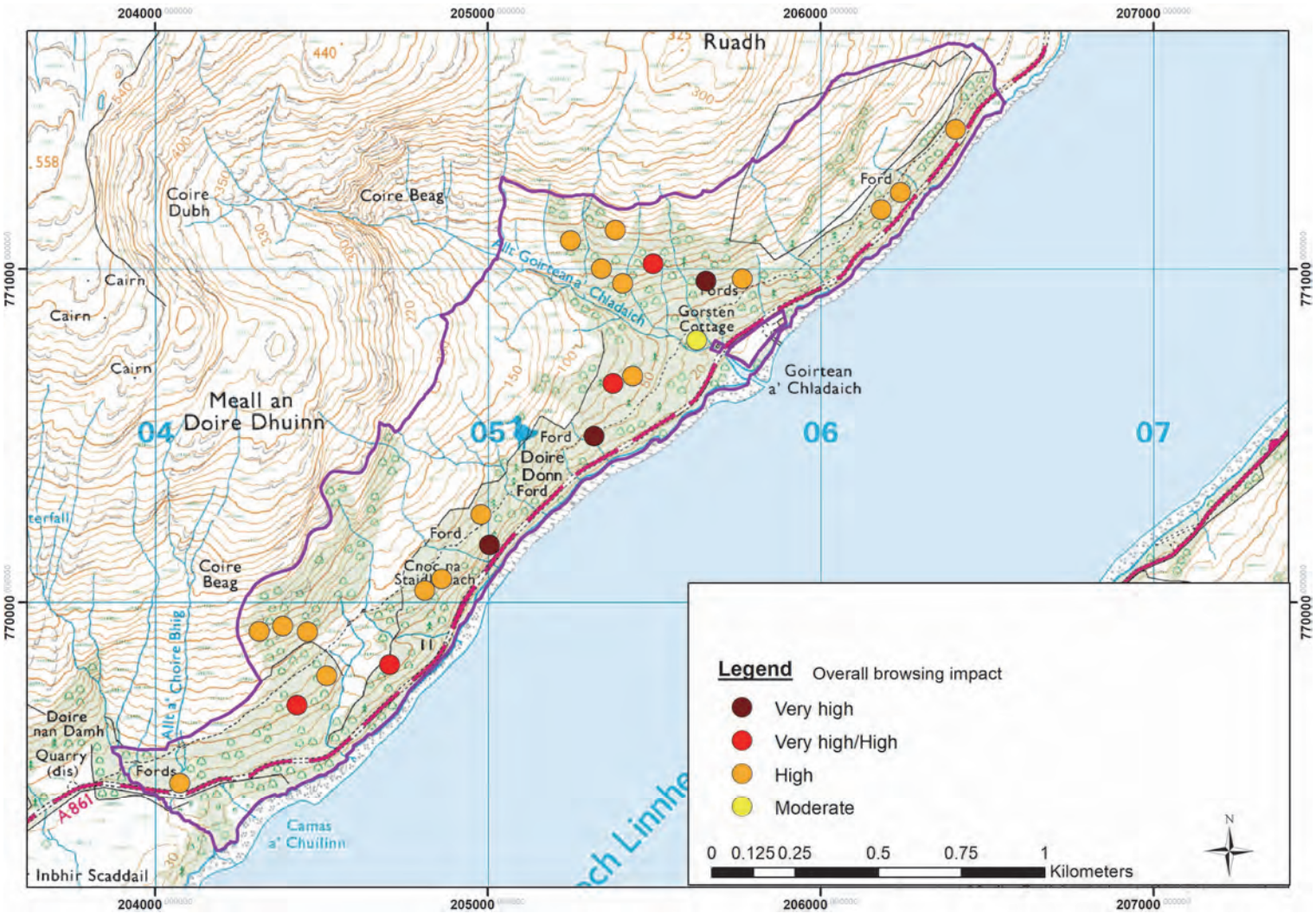

Figure 21. The overall herbivore impacts for each plot surveyed within the Doire Donn SSSI. © Crown copyright and database right 2018. Ordnance Survey 100017908.

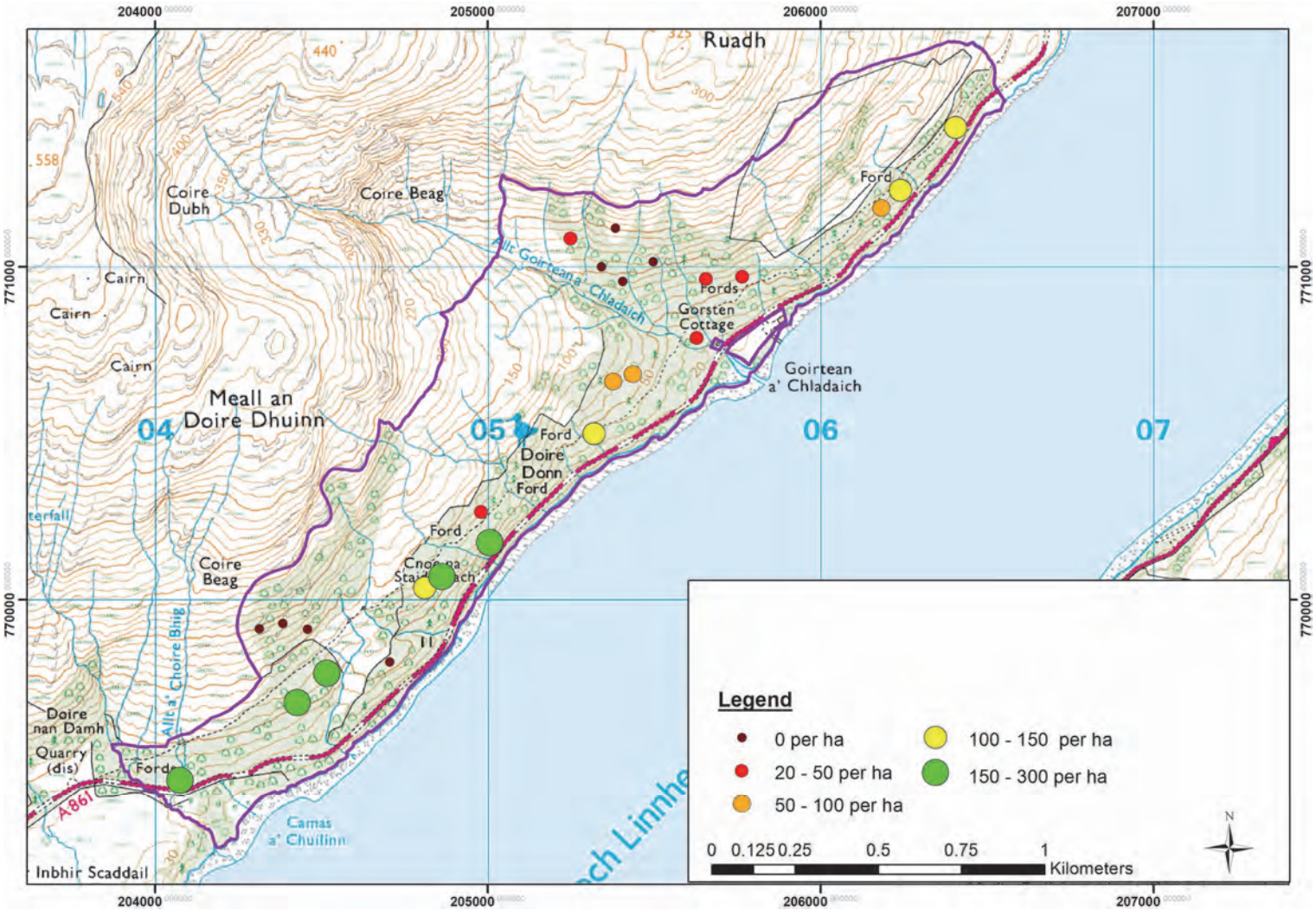

Figure 22. The density of all live sessile oak trees (per ha) more than 5 cm in diameter in the plots surveyed across the Doire Donn SSSI. © Crown copyright and database right 2018. Ordnance Survey 100017908.

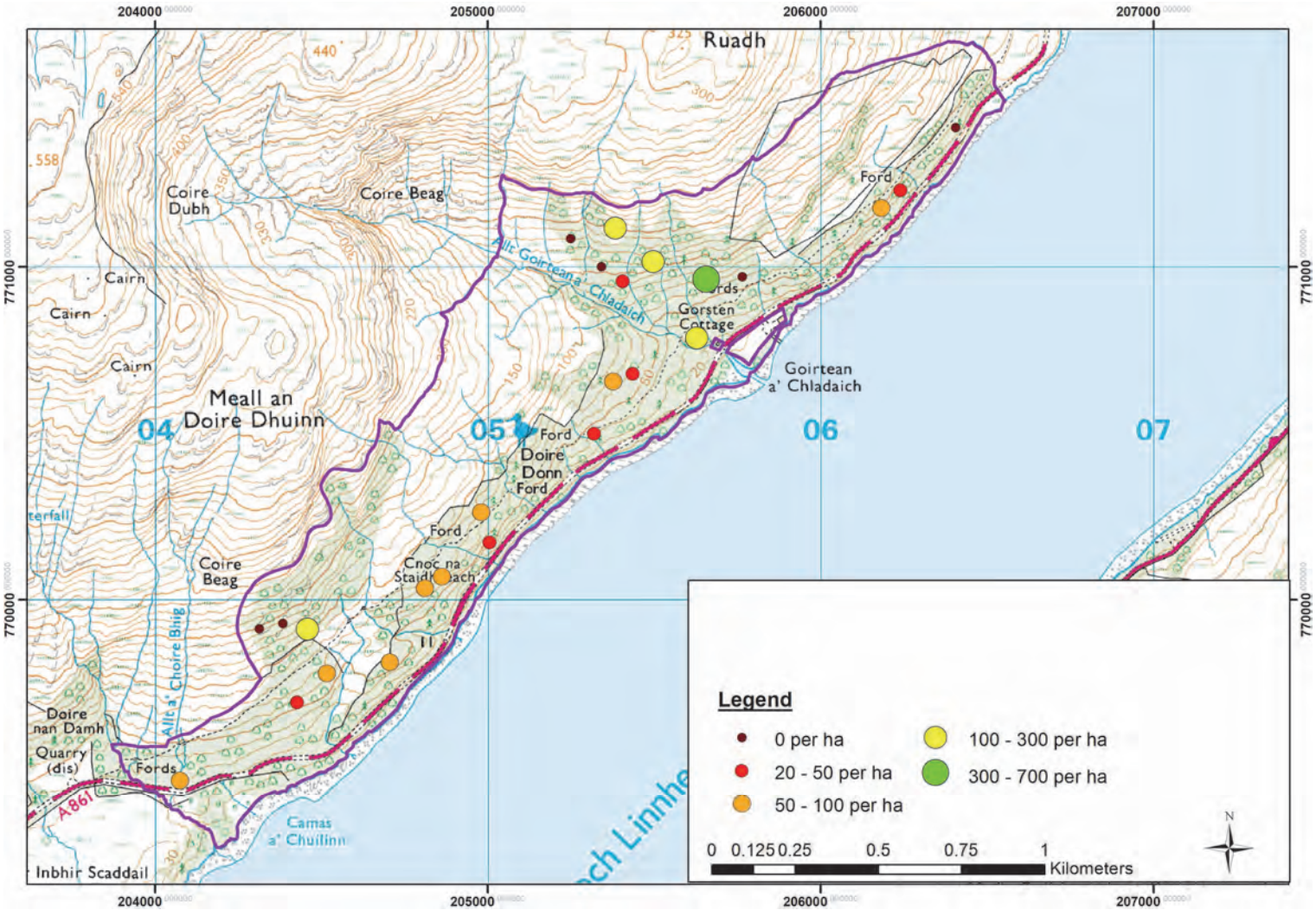

Figure 23. The density of all live downy birch trees (per ha) more than 5 cm in diameter in the plots surveyed across the Doire Donn SSSI. © Crown copyright and database right 2018. Ordnance Survey 100017908.

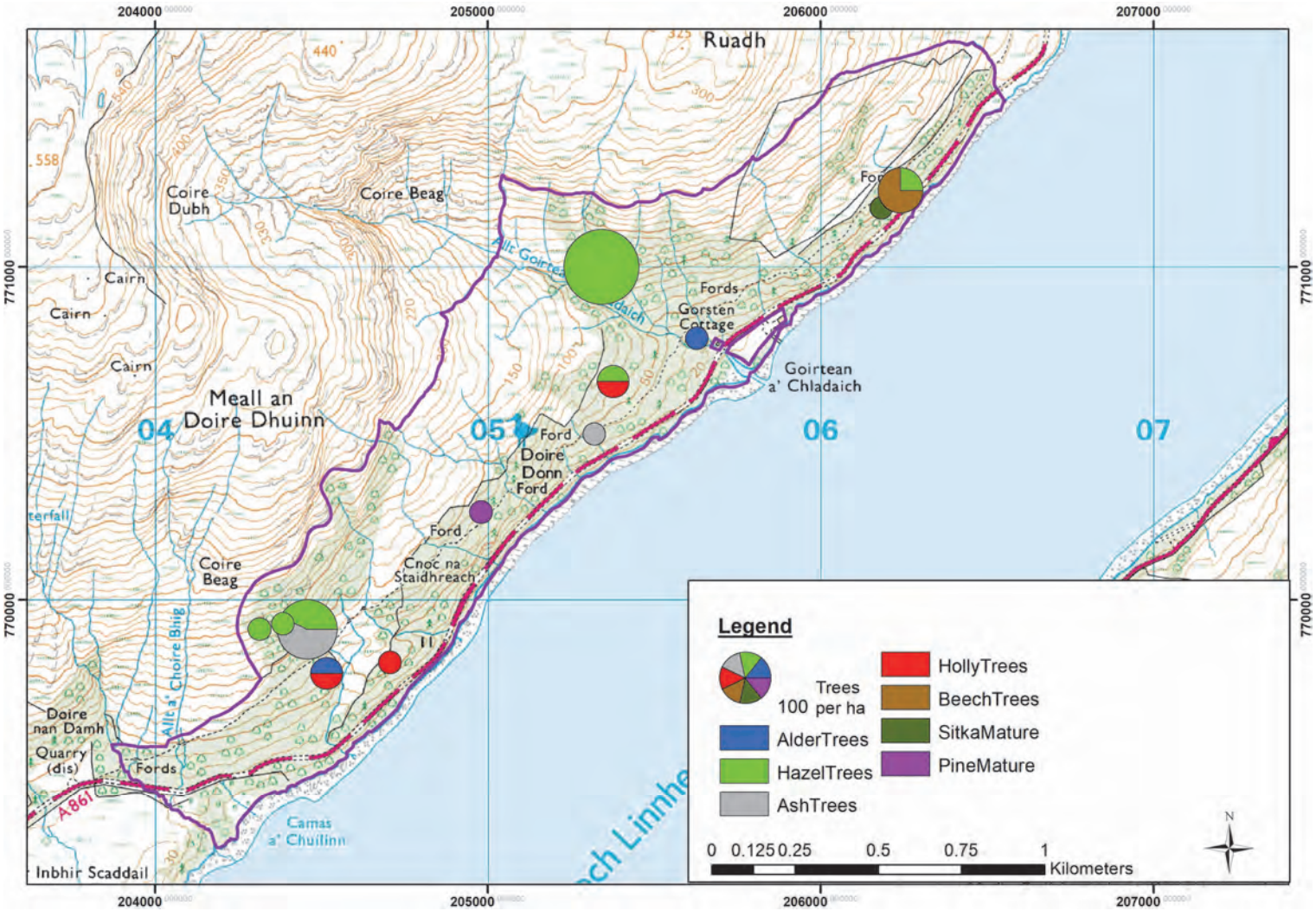

Figure 24. The density of all alder, ash, beech, hazel, holly, Scots pine and Sitka spruce trees more than 5 cm in diameter in the plots surveyed across the Doire Donn SSSI. The area of the pie charts is proportional to the total density of trees per ha. © Crown copyright and database right 2018. Ordnance Survey 100017908.

Figure 25. Photographs of the trees in the following plots: a) DD15; b) DD20; c) DD17; d) DD24.

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

Table 9. 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 10. Life Stage Classes for Scots Pine (After Clifford, 2004).

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

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

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

Table 11. 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 12. 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 13. 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 14. 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 15. 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.

ANNEX 4: RAW DATA AND CALCULATED VALUES FOR EACH SAMPLE PLOT

This annex can be downloaded from the SNH website as a separate document.

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ISBN: 978-1-78391-823-2

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