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A review of the vascular plant flora of the Cairngorms Connect project area, Scotland, and some possible implications of forest expansion to the natural tree line

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Abstract
Cairngorms Connect, a partnership of four adjoining land owners, is committed to a 200-year vision to enhance and restore habitats, species and ecological processes across a 592 km^2 area within the Cairngorms National Park. This will be achieved by, *inter alia*, expanding woodland to its natural altitudinal limit, including high altitude sub-alpine scrub. All or parts of six native Caledonian pinewoods occur here, *c.*26% of the national total. Ancient, semi-natural woodland within the Cairngorms Connect area is 43% of the National Park total. Modelling of the extent of *potential-natural* woodland (*sensu* Peterken, 1981, 1996) indicates that below 600 m all terrestrial habitats are potentially capable of supporting some degree of tree and scrub cover.

899 vascular plant taxa have been recorded here, of which 693 are native to the area. 7.6% of native taxa are endemic to Great Britain (and Ireland) or to Scotland; these are mainly *Hieracia* (Hawkweeds). Of the native taxa, 23% are of national, and 11% of regional conservation concern. Few native taxa are widespread within the Cairngorms Connect area, most are local or rare. 40% of native taxa have been recorded in five or less monads (1 km squares), with 16% recorded from just a single monad.

12% of native taxa are associated with shaded locations or semi-shade (Ellenberg Light values 3-5). 51% of taxa are found in partial shade to well lit locations (values 6 and 7) and 37% of taxa in well lit to fully lit locations (values 8 and 9). Native taxa with Light values of 6-7 are the most frequent in 92% of monads with more than 10 recorded taxa. 65% of taxa of national conservation concern favour well lit to fully lit locations (Light values 8-9).

Shading of plants, at altitudes below the potential tree line, is strongly influenced by the extent of woodland and scrub and its structure, and by herbivore grazing levels determining height and structure of the field layer. To achieve forest expansion to the natural tree line by natural regeneration will require sustained low levels of grazing and browsing, for decades, or longer. This is already leading to a taller field layer and an increased density of tree regeneration. 40% of native taxa may be negatively impacted, if existing and new woodland becomes dense with a high level of shading. Of these 'at risk' taxa, 50% have maximum height less than 50 cm and may be especially at risk from sustained periods of low grazing. Limited disturbance and lack of open sites and bare ground for seedling recruitment is another potential constraint on vascular plants. The issue of vegetation succession

and shading, leading to possible loss of plant diversity is likely to be much less of an issue at altitudes around and above the tree line. Here there are likely to be benefits, with possible expansion of tall herb communities.

Keywords: altitudinal range; browsing and grazing; Ellenberg values; natural processes; shade tolerance; rewilding

Introduction

The Cairngorms National Park in northern Scotland is of exceptional importance, nationally and internationally, for its habitats and species, and for outdoor recreation (Nethersole-Thomson & Watson, 1981; Gimmingham, 2002; Shaw & Thomson, 2006). Here, extensive tracts of land, including the Cairngorms Connect project area (A.1 below) and the adjoining National Trust for Scotland's Mar Lodge Estate are undergoing ecological restoration. Issues of land ownership and land management are of high public interest, especially in Scotland. Rewilding (in its all-embracing sense), including the expansion of native woodland and the facilitation of natural processes to deliver biodiversity and societal benefits, has both caught the collective public imagination (e.g. Scotland: The Big Picture, Rewilding Britain), and been a source of controversy (IUCN, 2021).

For practical and pragmatic reasons, and for scientific rigour, it is often suggested that the focus of surveys and monitoring should be on a narrow range of target organisms e.g. conservation priority, umbrella and keystone species, and that representative sampling schemes be employed (Summers, 2018). However, most taxa are local or rare, and sample survey and monitoring schemes will record the widespread species and, at best, only a sub-sample of rarer taxa. Illustrative of an alternative approach, this paper seeks to interpret 200 years of accumulated knowledge of the whole vascular plant flora of the Cairngorms Connect project area, and using this as a case study, highlight some key considerations for management.

To be informed, land managers require a clear understanding of the habitats and species present: an ecological audit. Even if the stated objective is nature led rewilding, with no human defined optimal point or end state, it is surely worthwhile understanding the assemblage of species and habitats we begin with.

This paper is in four sections:

A) An outline of Cairngorms Connect, its location, ownership and long-term vision.
B) An outline of the vegetation history, current and potential habitats.
C) A high-level overview of the vascular plant flora of the Cairngorms Connect project area.
D) An investigation of some possible implications for the vascular plant interest of forest expansion to the natural, climate determined tree line.

A.1 Cairngorms Connect

Cairngorms Connect http://cairngormsconnect.org.uk/ is a partnership of four adjoining land owners: Wildland Ltd. (privately owned), RSPB Scotland (a conservation NGO) and two Scottish government agencies, Forestry and Land Scotland and NatureScot (Table 1). The project partnership is committed to a 200-year vision to enhance and restore habitats, species and ecological processes across a 592 km^2 area within the Cairngorms National Park (Figs. 1 and 2). This will be achieved by: expanding woodland to its natural altitudinal limit, including high altitude sub-alpine scrub; restructuring of plantations; restoring blanket and forest bogs; restoring watercourses and floodplains to a more natural state. This is described as the largest habitat restoration project in the UK. The project area is entirely within the Cairngorms National Park and comprises 13% of the National Park area.

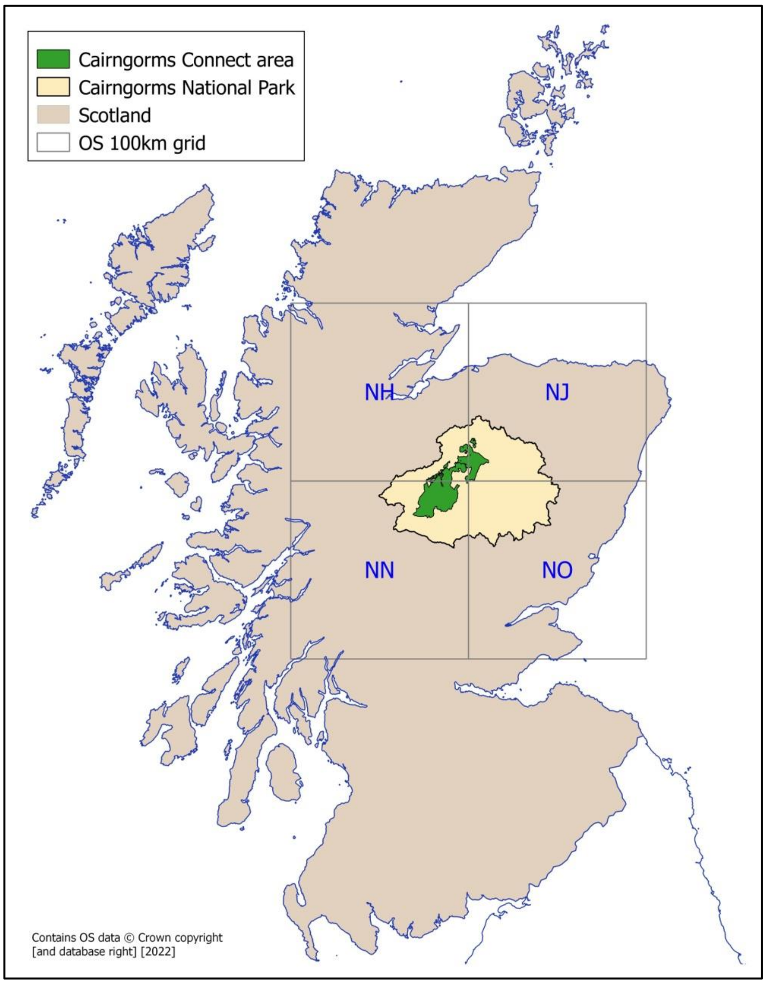

Figure 1. Cairngorms Connect location

Table 1. Cairngorms Connect project area ownerships

Land owner / manager	% of Cairngorms Connect area
Wildland Ltd	54
RSPB Scotland	25
Forestry & Land Scotland	16
NatureScot	5

A map showing place names mentioned in the text without OS grid references, is in Appendix 4. The Cairngorms Connect project area falls within three botanical vice-counties - https://en.wikipedia.org/wiki/Vice-county; v.c.94 (Banffshire), v.c.95 (Moray) and v.c.96 (East Inverness-shire). Further details of the boundary are in Appendix 5.

There is no single unified management plan for the whole Cairngorms Connect area. The four individual land owners develop and implement their own management plans, commensurate with the project's overarching aims. The 'Strathspey Land Management Plan 2021 - 2031' (Forestry and Land Scotland, 2021) includes the whole area owned by Forestry and Land Scotland, and is taken as illustrative of the long-term vision. This plan describes the 200 Year Vision as "*the pinewood is in a near natural state with diverse tree species and age class. Gaps in the canopy are created naturally through wind, snow, wildfire and landslides which will regenerate with a mixture of Scots pine and native broadleaves. Forest has extended to its natural altitudinal limit with montane scrub woodland at the highest elevation. Management interventions are minimal to maintain browsing pressure at a level that allows tree regeneration to occur. The water table in peatlands is at a natural level which now supports the full wetland ecosystem of plants and animals and is actively laying down Sphagnum and storing carbon*".

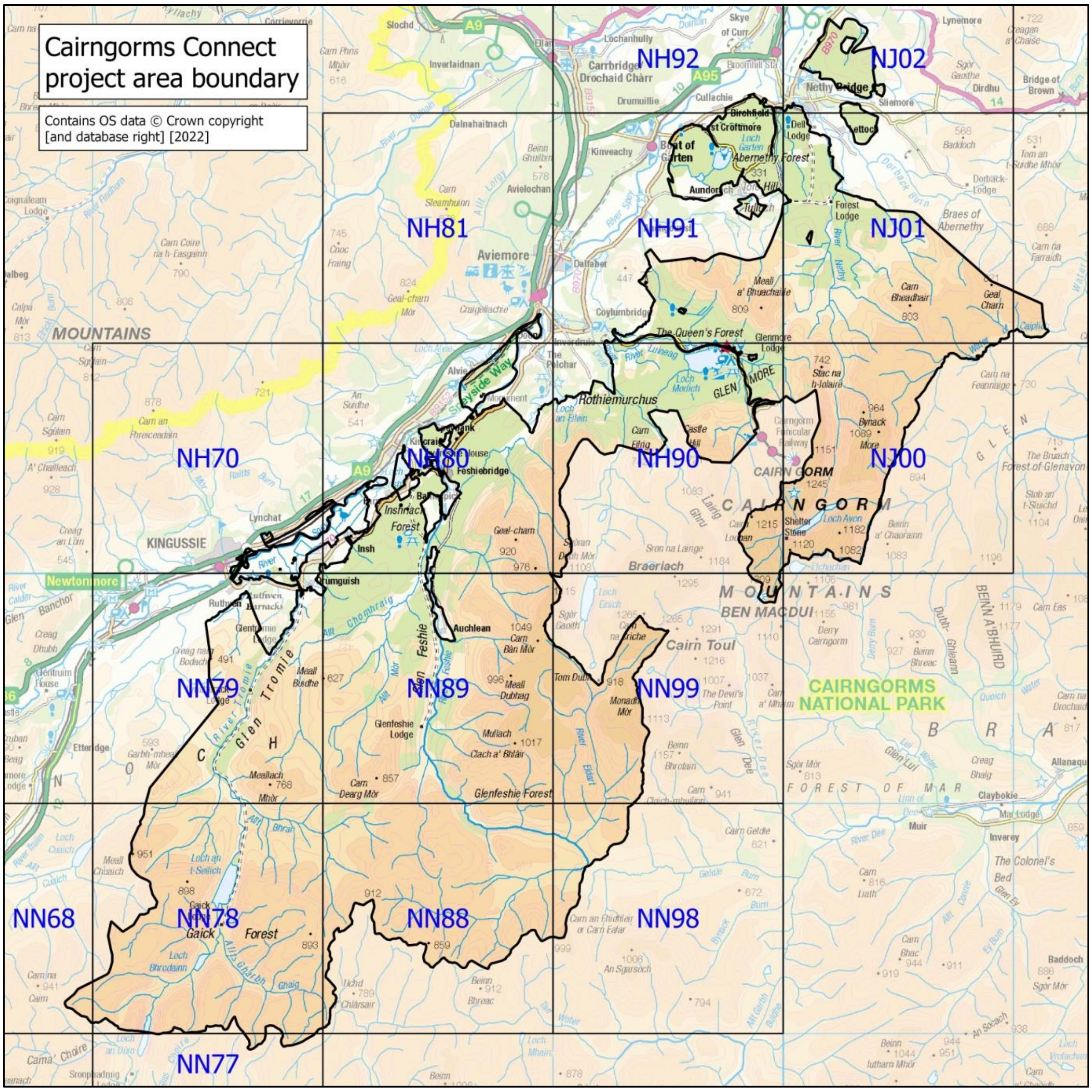

Figure 2. Cairngorms Connect project area

A.2 Altitudinal range

The Cairngorms Connect area ranges in altitude from 200 m (at Mondhuie, by Nethybridge) to 1309 m at the summit of Ben Macdui. The median altitude of the area is 567 m, derived from the Ordnance Survey Terrain 50 raster dataset, which estimates altitudes at 236,720 points on a 50 m grid. Areas in 100 m altitude bands are shown in Fig. 3.

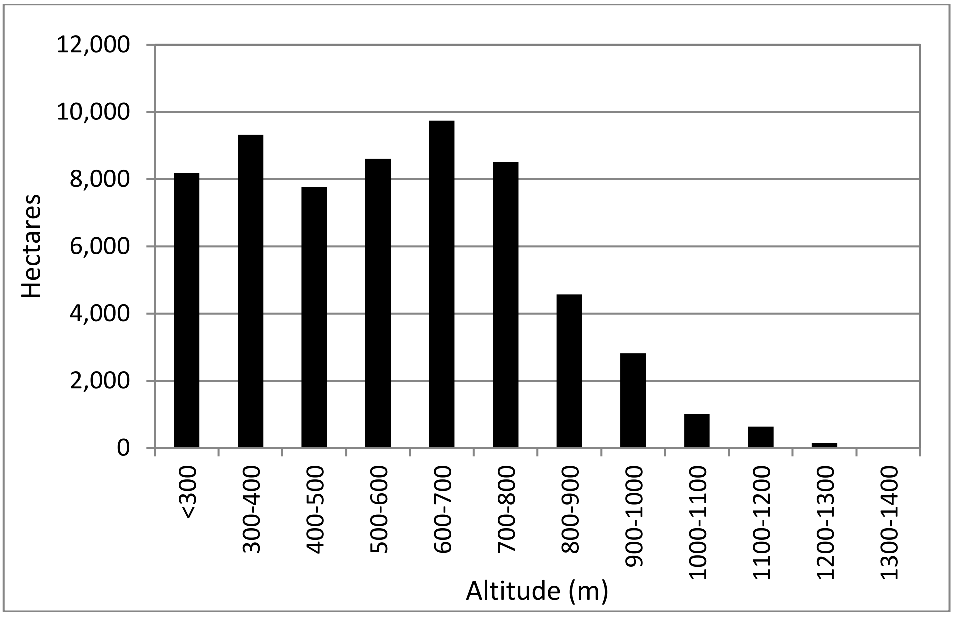

Figure 3. Area in 100 m altitudinal bands

B.1 Woodland History

Summers (2018) summarises the history of Abernethy Forest from the early post glacial to modern times. Smout *et al*. (2005) describe the history of Rothiemurchus Forest from 1650-1900. Steven & Carlisle (1959) give details of the other native pinewoods within the Cairngorms Connect area. Dunlop (1997) discusses the woods of Strathspey in the nineteenth and twentieth centuries.

In brief (dates are calendar years before 1950). *Pinus sylvestris* (Scots Pine) colonised the Cairngorms Connect area between 9000-8500BP, having been preceded by *Juniperus communis* (Juniper), the three *Betula* (Birch) species, *Populus tremula* (Aspen) and *Corylus avellana* (Hazel). *Alnus glutinosa* (Alder) arrived later, from *c*.6700 BP. Pine dominated woodland was at its maximum extent from *c*.8000-5500 BP.

Pratt (2006) used a modelling approach to reconstruct past vegetation over a 15 x 15 km area, centred on Abernethy Forest. Having demonstrated that models of pollen dispersal and deposition can be used to simulate modern pollen rain for the major taxa and land cover types within present day Caledonian pine forest landscapes, she reconstructed the most likely percentage land cover of different woodland types and of open space for 6400, 4260 and 2150 BP, based on dated tephra layers. In summary, this study showed that total forest area declined from >99% of the study area in 6400 BP, to 94% in 4260 BP, then to 41% in 2150 BP. The current forest area in her study area is *c*.14%. The area of mixed Scots Pine –

broadleaf woodland and broadleaf woodland (as a percentage of the total woodland area), varied between 20 and 37% over a 4250-year period, prior to 2150 BP. Currently the figure is <4%.

Woodland losses have been due to anthropogenic (conversion to agricultural land and heathland) and climatic reasons (lowering of the potential tree line, and expansion of bogs). The earliest evidence of forest clearance in Abernethy Forest is *c.*3900 BP (O'Sullivan, 1977). Much of the heathland below the current tree line, to the south of Abernethy Forest, was probably already an open landscape by 2150 BP. O'Sullivan (1977) suggested there was much additional creation of open heathland in the period 500-1000 AD. By the time the first maps were drawn in the late 16th century, the remnant forests of Abernethy and Rothiemurchus were embedded in a settled, cultural landscape, with many place names, not the *original-natural* wild wood (*sensu* Peterken, 1981, 1996). That was long gone. The woodland we see today has been much modified and impacted by human management over recent centuries.

B.2 Current Habitats

A broad overview of habitats within the Cairngorms Connect project area is given in Fig. 4.

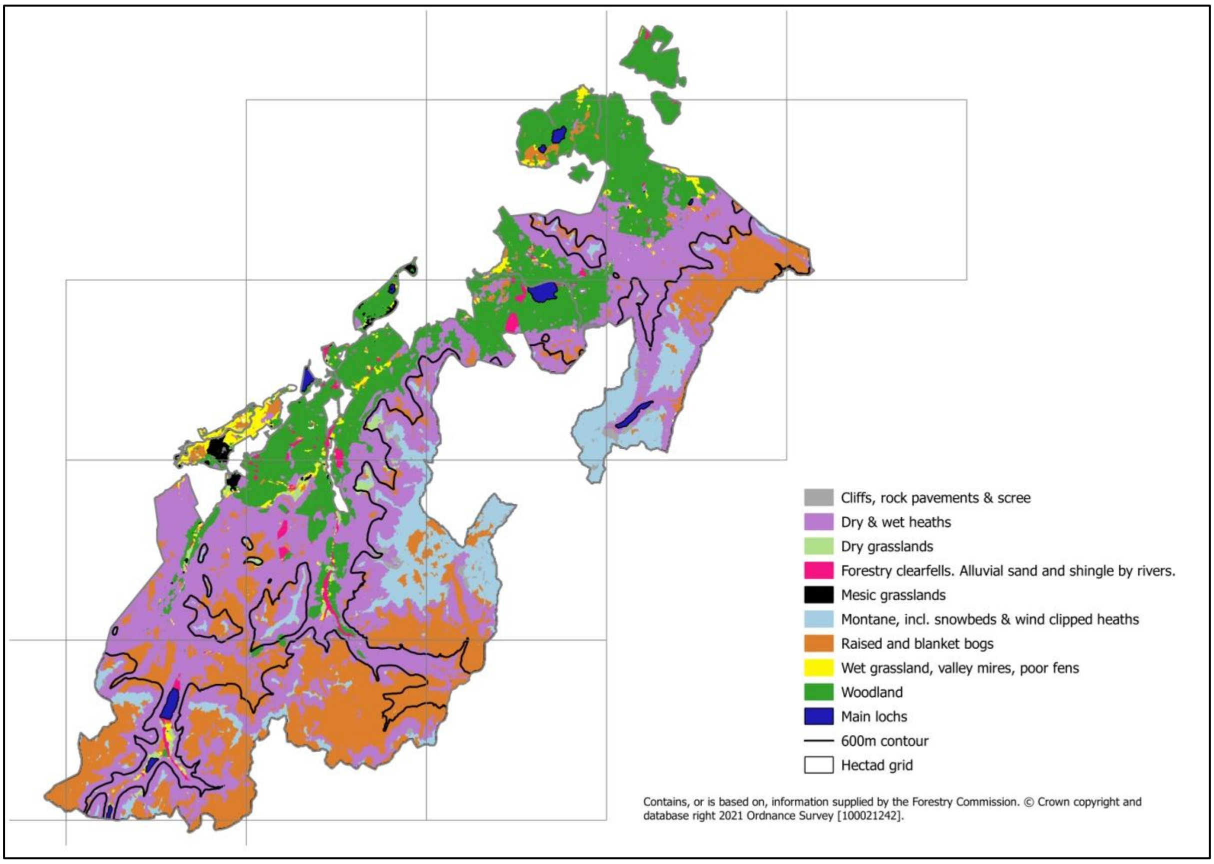

Figure 4. Simplified habitat map of the Cairngorms Connect project area. Maps and data created by Space Intelligence with input and support from NatureScot, © SNH (see: https://spatialdata.gov.scot/geonetwork/srv/api/records/88cea3bd-8679-48d8-8ffb-7d2f1182c175)

The map is based on satellite images, at 20 m resolution, using AI methods (Space Intelligence, 2021). The habitat classification is EUNIS level 2 (Moss, 2008; Strachan, 2017). This Scotland wide mapping, classified habitats into 22 different classes, and an independent assessment of accuracy suggested pixels are placed in the correct class over 90% of the time.

The Space Intelligence land cover mapping was viewed in QGIS as an overlay over air photos. The woodland area is slightly underestimated, as the classification algorithm tended to treat scattered mature trees as heath or bog. The area of heathland is slightly over-estimated, as areas of bog with a high cover of *Calluna vulgaris* (Heather) is mapped as heath. However, as a broad overview of habitats the mapping is sufficiently accurate. To simplify the habitat map, the Eunis level 2 categories were, in some instances, combined (Table 2).

Table 2. Mapping categories with Eunis level 2 codes, as used in Figure 4

EUNIS CODE	Total area (ha)	Area (ha) below 600 m altitude	Mapping category
H2, H3	880	121	Cliffs, rock pavements & scree
F4	21,476	12,546	Dry & wet heaths
E1	752	481	Dry grasslands
J, O	708	702	Forestry clear fells. Alluvial sand and shingle by rivers.
I1, E2	317	314	Mesic grasslands
E4, F2	5,974	14	Montane, including snowbeds & wind clipped heaths
D1	14,783	4,300	Raised and blanket bogs
D2, E3	1,079	1,065	Wet grassland, valley mires, poor fens
F3, F9, G1, G3, G4 & G5	12,540	12,524	Woodland.

B.3 Caledonian Pinewood

The Caledonian Pinewood Inventory (Forestry Commission, 1999) maps the current extent of the native pinewoods named by Steven & Carlisle (1959). The total pinewood area included in the Inventory is *c.*17,900 ha, and comprises 84 separate pinewoods of various sizes. In all cases the balance of probability suggests that they are genuinely native, that is, descended from one generation to another by natural seeding.

The area of native pinewood within the Cairngorms Connect project area, as defined in the Inventory, is 4720 ha (Fig. 5), i.e. *c.*26% of the national total. It includes all or parts of six native pinewoods: Abernethy, Carn na Loinne, Glen Feshie, Glenmore, Rothiemurchus and Glen Tromie. Abernethy and Rothiemurchus are the two largest native pinewoods. The Inventory includes as woodland areas with a lower tree density than the Space Intelligence land cover Scotland 2020 mapping (Fig. 7).

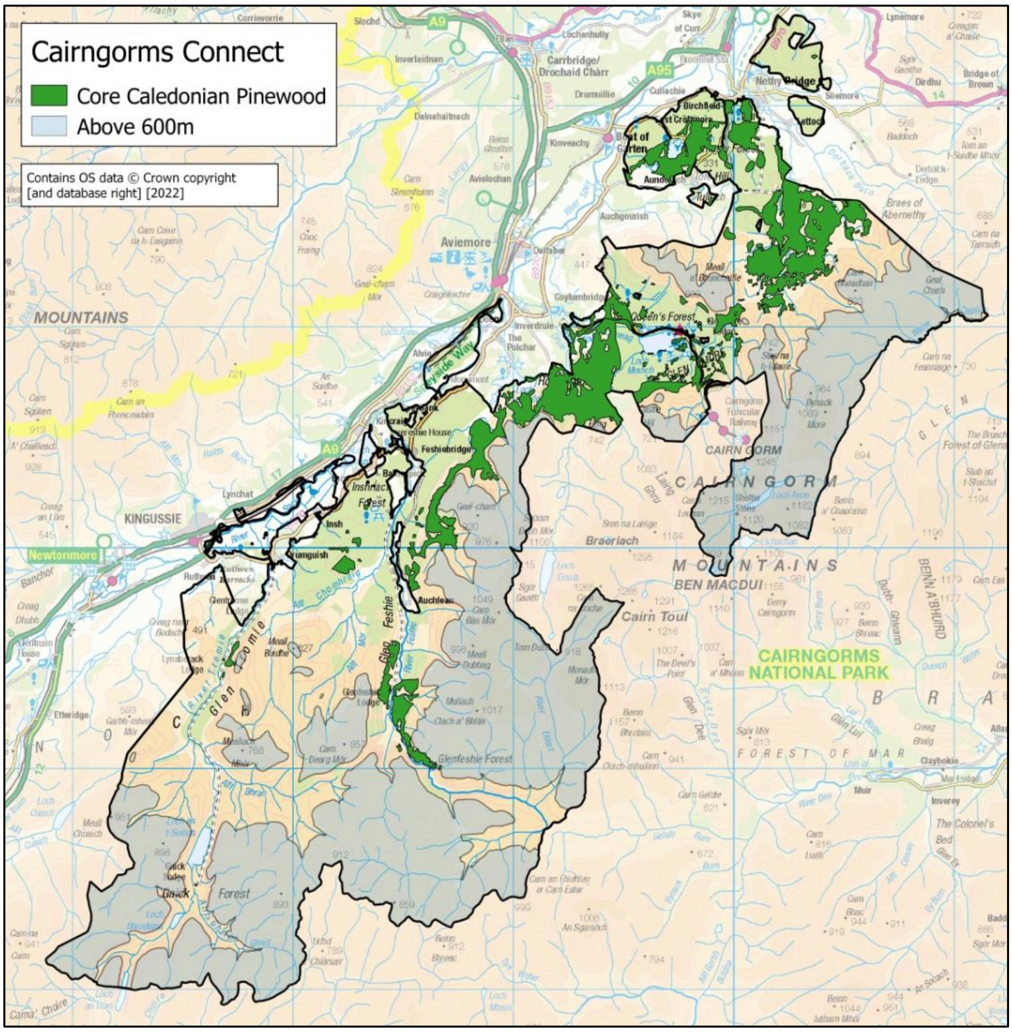

Figure 5. Core Caledonian Pinewood within the Cairngorms Connect project area

B.4 Ancient Woodland Inventory

The Ancient Woodland Inventory (AWI) (NatureScot, 2022) maps as 'Ancient Woodland' all woodlands inferred to have been semi-natural, depicted on the Roy Military maps (*c.*1750) and / or on the Ordnance Survey 1st edition maps (*c.*1860) and continuously wooded to the present day. If planted with non-native species during the 20th century they are referred to as Plantations on Ancient Woodland Sites (PAWS). These ancient woods within the Cairngorms National Park are shown in Fig. 6.

Only 5% of the national park area comprised ancient, semi-natural woodland in the mid-17th to mid-18th centuries. If other woods and long-established plantations shown on the Roy and / or OS maps are included, the total is 7.5%. The extent of this ancient, semi-natural woodland within the Cairngorms Connect area is 42.7% of the National Park total.

However, a high proportion of this woodland area was converted to plantations in the 19th and 20th centuries. Dunlop (1997) found that of all the woodland included in the Ancient Woodland Inventory in Badenoch and Strathspey, 49% had been converted to plantations, of which 85% was planted with non-native conifers.

Dunlop observed that conversion to plantations was the cause of the greatest loss of semi-natural woodland in this area in the 20th century. The last clear fells of old growth ancient woodland (*sensu* the AWI), were in Abernethy Forest as recently as 1982 and 1984.

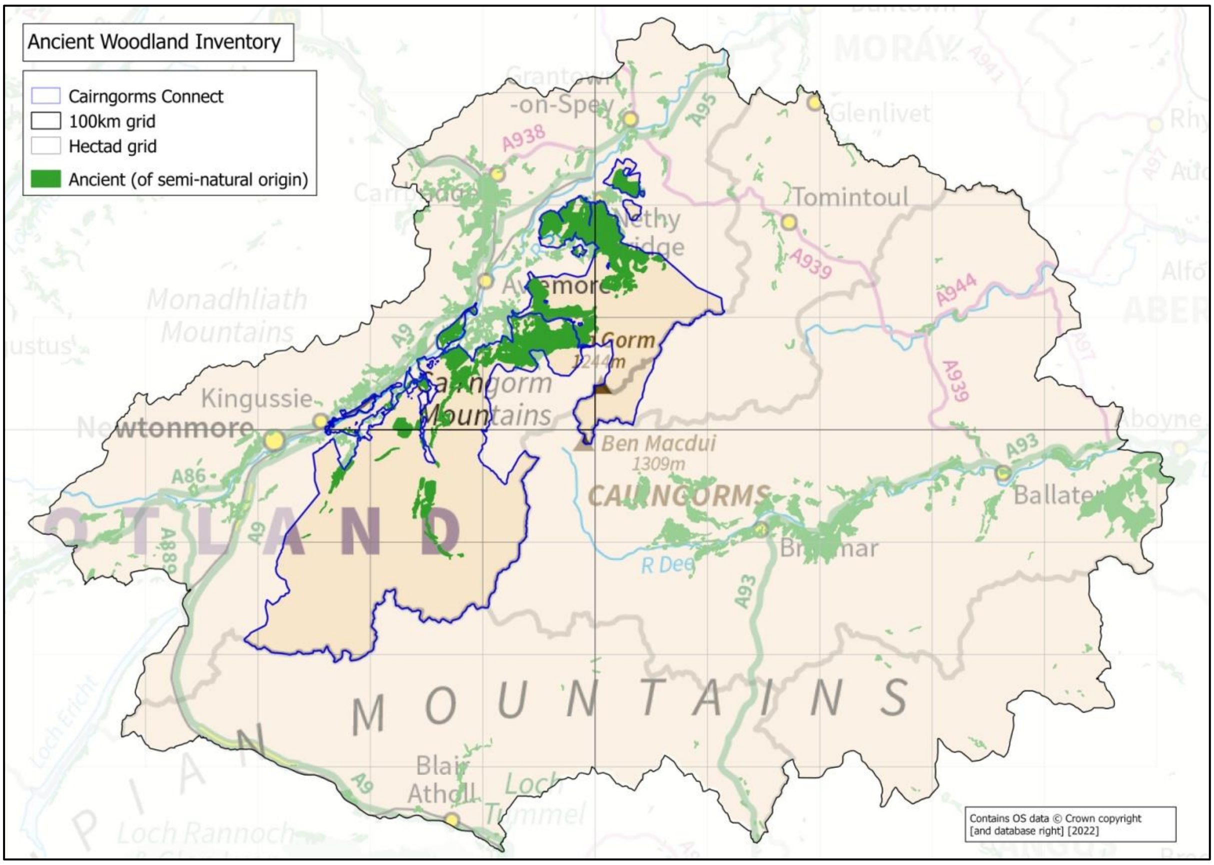

Figure 6. Distribution of 'ancient woodland' as defined by the Ancient Woodland Inventory

B.5 The present extent of woodland and scrub below 600 m

It is surprisingly difficult to accurately estimate the total Cairngorms Connect woodland area. In addition to the current extent of established woodland, 12,540 ha (Table 2), there has been recent (post-2000) grant-aided native woodland planting across 1,586 ha between Glen Feshie and Glen Tromie (Fig. 7). Also, as noted above, the Caledonian Pinewood Inventory includes areas of low-density mature trees (1428 ha), which the Space Intelligence mapping treats as open habitats. There is therefore a minimum of *c.*15,554 ha of woodland below 600 m.

Detailed surveys revealed extensive natural regeneration of (especially) *Pinus sylvestris* around the southern margin of Abernethy Forest. Here natural regeneration has been recorded in *c.*1,400 100 m grid cells between the southern edge of the existing forest (outwith areas mapped as woodland in Fig. 7) and the 600 m contour (RSPB unpublished data). The area of natural regeneration is probably a significant underestimate, as detailed surveys of tree regeneration have only been carried out across a part of the Cairngorms Connect area.

Over the last decade, RSPB have also carried out enrichment planting of under-represented native broadleaf tree species within 129 one ha grid cells around the southern margin of Abernethy Forest. These planting locations are amongst naturally regenerating pines, outwith areas mapped as woodland in Fig. 7.

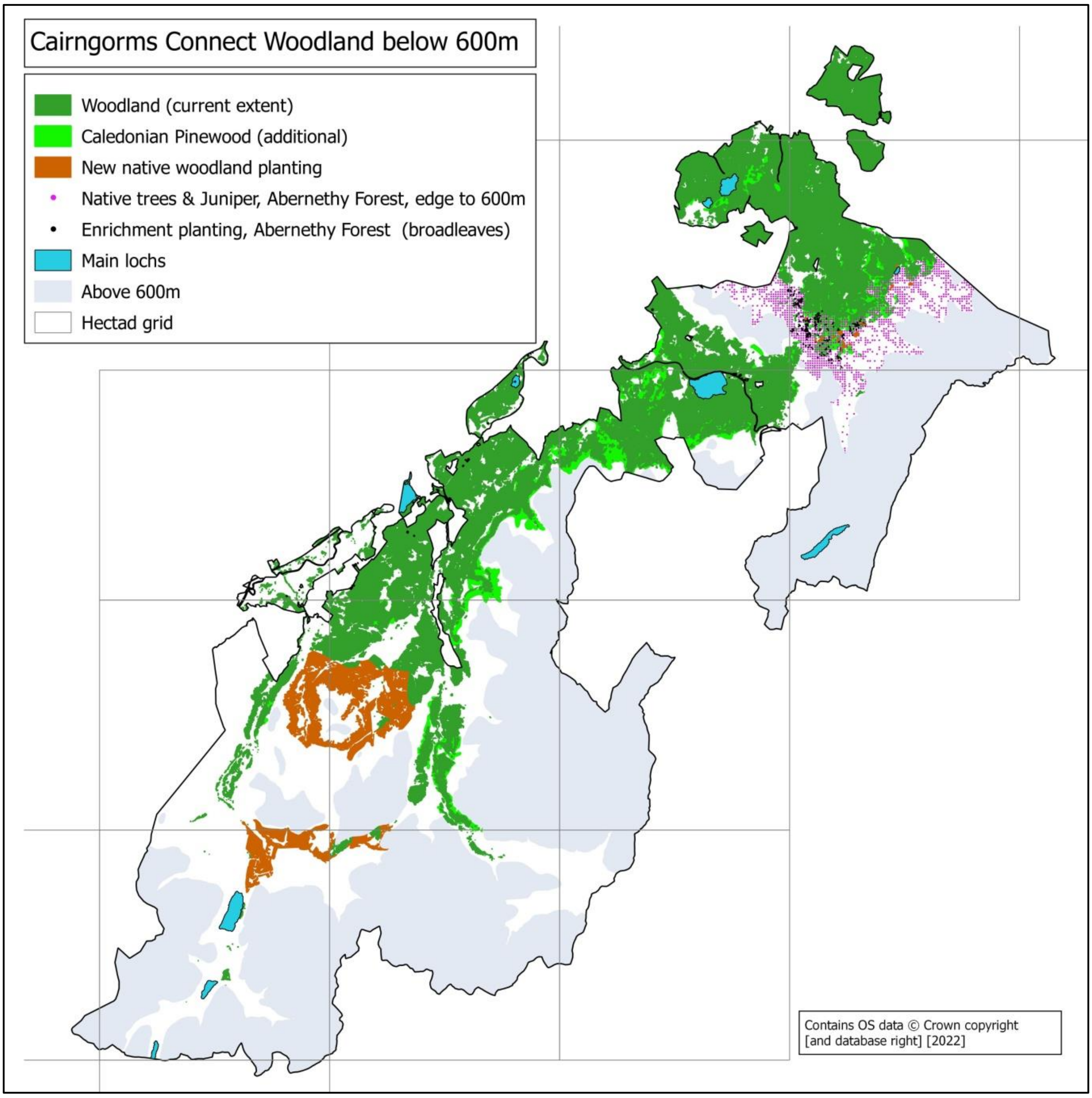

Figure 7. The current extent of woodland below 600 m altitude. Native & non-native species woodland; new native woodland planting; natural regeneration of native trees and shrubs (partial survey only)

B.6 Semi-natural and planted woodland

Approximately 8,758 ha (56%) of the current woodland area (15,554 ha) consists of planted woodland (Fig. 8). Within Abernethy Forest this figure excludes former plantations and under planting on ploughed ground where all planted trees have been felled, and areas where non-native conifers have been removed. As a result of restoration management, in some parts of Abernethy, where trees were flat planted without ground cultivation, e.g. west of Loch Garten, it is now difficult to distinguish areas of planted pines from self-sown woodland.

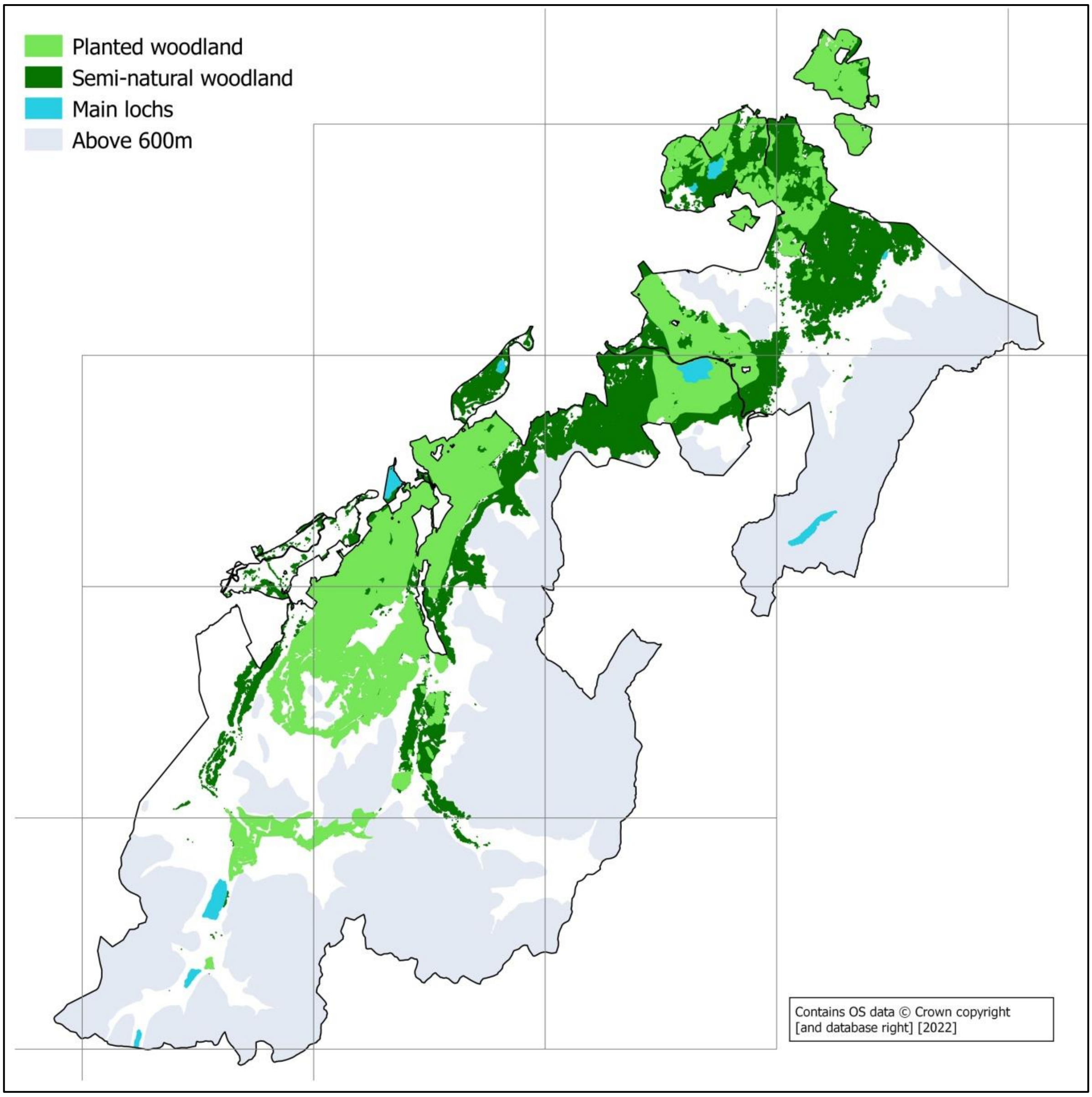

Figure 8. Areas of semi-natural and plantation woodland

Today we are fortunate that even half of the Cairngorm Connect forest area is semi-natural woodland. In 1957, the then owner of Abernethy Forest drew up a plan for a rolling programme of felling and planting, to commence in 1967. If that plan had been adhered to, all the southern half of the forest would have been cleared and replanted over a 70-year period (Summers, 2018).

B.7 Heterogeneity

Three datasets give an impression of the spatial heterogeneity of vegetation communities and forest structure. Vegetation mapping using the National Vegetation Classification (NVC) (Rodwell, 1991-2000) is available for 52% of the Cairngorms Connect area below 600 m altitude (Government Digital Service, 2022). Vegetation composition and structure was mapped as homogenous units of one or more NVC types; results are split into polygons with and without woodland (Table 3). In Abernethy Forest, stands of trees with a homogenous structure were mapped

(Summers *et al.*, 1997) and the pinewood (W18) forest field layer composition and structure was mapped as homogenous units by Nisbet in 2002 (Roberts, 2010, Appendix 10). Mean, median and inter-quartile range of patch sizes from these surveys are similar (Table 3).

Table 3. Vegetation patch size from three surveys

Survey	Mean (ha)	Median (IQ range) (ha)
NVC below 600 m (with woodland)	6.30	0.82 (0.26-3.05)
NVC below 600 m (non-woodland)	4.84	0.68 (0.19-2.57)
Abernethy forest stand structure	4.86	1.69 (0.75-4.25)
Abernethy W18 field layer	4.68	1.42 (0.64-4.45)

B.8 Potential tree line

The term 'tree line' often appears in the literature, however its meaning is ambiguous. It is more informative to use the terms 'timber line' and 'scrub line'. The 'timber line' is the upper limit of the 'forest zone', and is the altitudinal limit of erect tree growth above which trees become wind-pruned and increasingly stunted (often referred to as Krummholz, 'crooked wood' in German). Trees growing above the timber line show a number of characteristic features including: 'flagging' (branches mainly found on the lee side of the trunk); presence of a low 'skirt' of branches, hugging the ground, and protected from abrasion by lying snow; twisted trunks and branches; and reduced height. The 'scrub line' is the altitudinal limit of tree growth, above which montane (middle alpine zone) vegetation occurs. The zone of montane scrub potentially occurs between the timber and scrub lines.

The tree line at Creag Fhiaclach (NH8905) is considered the most natural in the UK (Shaw & Thompson, 2006). It has remained at the current elevation for the last 1000 years (Nagy *et al.*, 2013). *Pinus sylvestris* is, by far, the dominant native tree in the Cairngorms Connect area. Field observations of *P. sylvestris* in the Rothiemurchus, Glenmore & Abernethy area of the north-west Cairngorms (Amphlett, 2003), demonstrated that the average current potential timber line, on north-west facing slopes is at about 560 m altitude. On sites with a south to south-west aspect, the potential timber line is a little higher at about 590 m. On isolated hilltops, eg. Carn na Chnuic (506 m) and Carn na Loinne (498 m), both in Abernethy Forest, or on locally exposed sites, the timber line can be lowered to less than 500 m. *Pinus* scrub at a density of several hundred trees ha^{-1} can extend above the timber line to at least 650 m, with greater than 100 ha^{-1} up to 690 m (Fig. 9). Current average potential timber and scrub lines, in this area, for *P. sylvestris* are therefore at *c.*560m and *c.*650 m respectively.

An additional desk-based search for high elevation trees was made. 10 m interval contours were created in QGIS using the Ordnance Survey Terrain 50 raster dataset (which uses a 50 m sampling grid). These were displayed as an overlay over current (March 2020) Bing air photos, and a search was made for additional high-altitude mature trees within the Cairngorm Connect area (Table 4). These were identified as casting a shadow in the photographs.

The instances of high-altitude mature trees in Table 4, were outwith the area surveyed in 2003. These additional locations contain mature trees at a mean of 563 m (range 515-615 m), similar to the earlier findings.

Table 4. High altitude mature trees (timber line)

Locality	OS Grid reference	Altitude (m)
Creag Follais	NH890048	520
Creag Bheag	NN872891	515
Creag nan Caillich	NN852901	580
Creag na Gaibhre	NN857908	615
Alt nam Bo (W. of)	NH869014	560
Creag Fhiaclach (NE of) / Coire Buidhe	NH899057	585

The highest altitude dense natural regeneration of *P. sylvestris* in the Cairngorms Connect area is on the south facing slope of Meall a' Bhuachaille (OS grid reference NH9910, Fig. 9). Here, dense *P. sylvestris* occurs to at least 650 m, gradually petering out above.

Figure 9. Developing natural *Pinus sylvestris* timber and scrub lines. South facing slope of Meall a' Bhuachaille, NH9910. Contours at 50 m intervals. Near natural pinewood on boulder scree on right of photo. © Google 2022

On the south-east facing slope of Carn Dearg (NN818903) established plantation woodland extends to just over 650 m altitude. Above that point, the boundary of a more recent planting scheme extends to 760 m, though it is unclear if trees have been planted to that altitude. An experimental forestry plot, now felled, on a south-west facing slope above Glenmore extended up to 670 m (NJ011080).

Juniperus communis occurs both within the forest zone (as subsp. *communis*) and at high altitude in montane communities. Within the forest zone good examples are in Ryvoan Pass (NH9910 and NJ0010) where dense stands of *Juniperus* grow in species rich pinewood on south-east facing slopes, and on west facing slopes in Glen Feshie, east and south-east of Ruigh Aiteachain bothy (NN8492).

The maximum recorded altitude for *Juniperus* within the Cairngorms Connect area is *c.*1100 m in Coire Raibeirt, Cairn Gorm. Some of the high-altitude plants are referable to subsp. *nana*. *Juniperus communis* is locally frequent at and above the *P. sylvestris* timber line in a form intermediate between the two subspecies. It is especially frequent on the slopes above Loch Avon, in upper Strath Nethy & along the Lairig an Laoigh (Fig. 10). Surveys by RSPB in 2001 and 2016/17 recorded *J. communis* in 622 out of 818 100 m OS grid cells between 680-900 m altitude (76%). Frequency of *J. communis* was highest (86%) between 750-800 m. The terrain here is difficult to survey, so the percentage frequencies are minima.

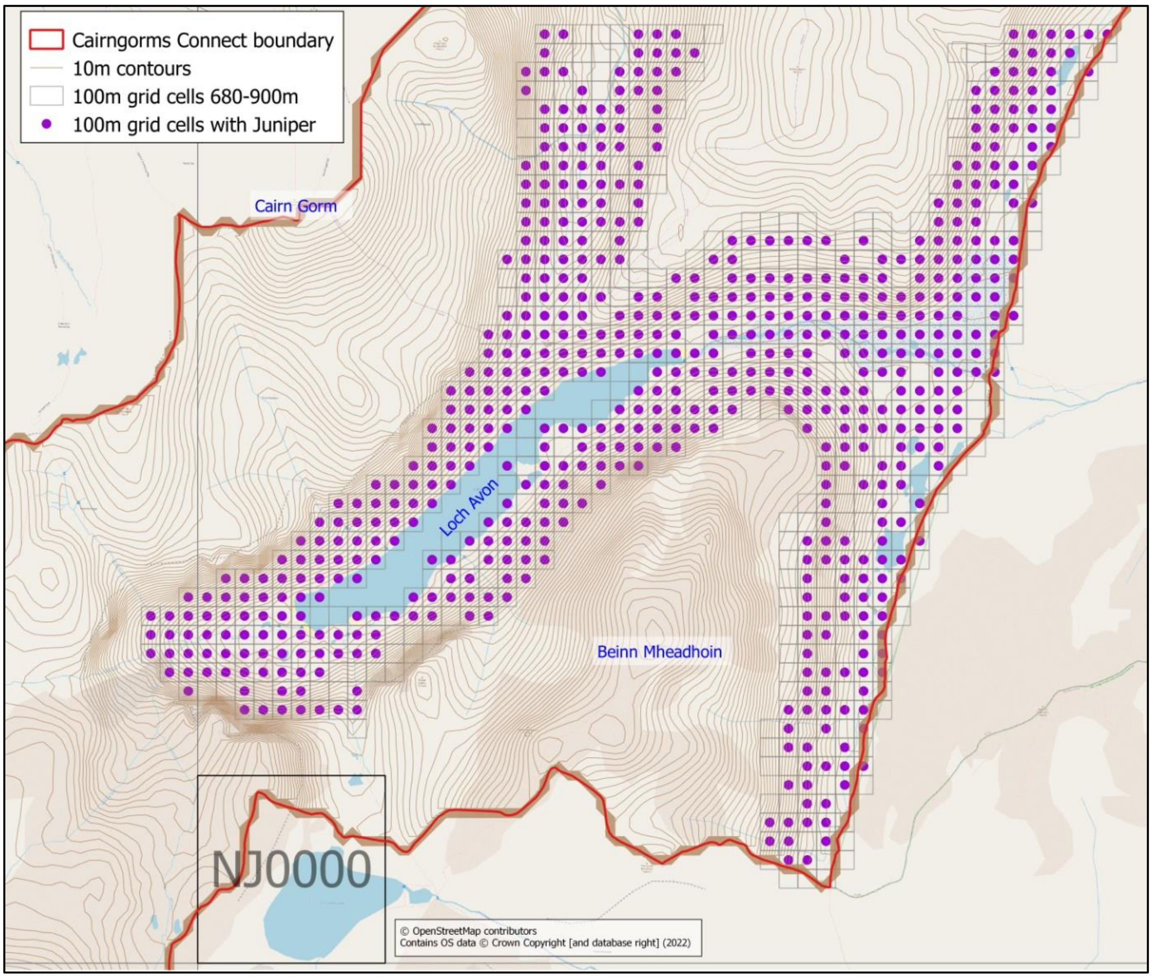

Figure 10. Distribution of *Juniperus communis* (Juniper) in 100m OS grid cells between 680-900 m altitude, Loch Avon, upper Strath Nethy & Lairig an Laoigh. Survey data by RSPB Scotland

Within the same survey area, albeit remote from seed sources, other shrub and tree species are infrequent or rare. *Sorbus aucuparia* (Rowan) is recorded from 10.0% of grid cells; *P. sylvestris* from 7.7% of cells; *Salix* (Willows) from 2.6% of cells; and *Betula* from 0.1% of cells. Again, these frequencies are minima, but the records were mostly collected at the same time as *J. communis* was recorded, and the relative frequencies are considered reliable.

Therefore the 'scrub line' for *J. communis* is much higher than that for *P. sylvestris*, and certainly has the potential to exceed 800 m in favourable locations. Here it typically grows as groups, or isolated bushes within a matrix of dwarf shrub heath, and is most luxuriant in sheltered locations e.g. amongst boulders or in hollows.

In Scandinavia a form of *Betula pubescens* is dominant in the subalpine zone, often referred to as 'mountain birch (Jonsell, 2000). This northern form of *B. pubescens* is thought to be derived from adaptive selection of *B. pubescens* and introgression from *B. nana* (Ashburner and McAllister, 2013). In recent literature, this is referred to as *B. pubescens* subsp*. czerepanovii* (Orlova) Hämet-Ahti, or *B. pubescens* var. *pumila* (L.) Govaerts (Ashburner and McAllister, 2013), or is not given taxonomic recognition (Jonsell, 2000). It was formerly often incorrectly named *tortuosa* at species or subspecies rank (Amphlett, 2021). The adoption of the subspecies name *tortuosa* in the New Flora (Stace, 2019), wrongly indicates a close similarity of the small-leaved *B. pubescens* in the Highlands of Scotland, and the Scandinavian 'mountain birch'. In Scotland, the widespread small-leaved variant of *B. pubescens* is var. *fragrans* Ashburner & McAll., (a British and possibly Irish endemic), which shows no signs of morphological influence from *B. nana.*

However, not all examples of small-leaved *B. pubescens* in Scotland are var. *fragrans*. It is probable that some herbarium specimens collected in the late 19th and early 20th centuries, referred to by Marshall (1914) as '*x B. intermedia*', including from locations in the Cairngorms, are referable to var. *pumila*. See discussion and illustrations in Amphlett (2021).

B.9 Potential Habitats

The Native Woodland Model (Towers *et al*., 2004), combines two digital datasets within a GIS model. These are the 1:250 000 scale national soils map (Macaulay Institute for Soil Research, 1982) and the 1:25 000 scale Land Cover of Scotland 1988 (LCS88) dataset (Macaulay Land Use Research Institute, 1993). Because of the scales of these datasets, the authors advise that the model should not be used at scales more detailed than 1:50 000. The NWM enables the prediction of woodland types which could (hypothetically) develop under current climate and soil conditions, if there were no additional constraints. This would be described as *potential-natural* woodland, *sensu* Peterken (1981, 1996), and see below (B.10).

The model predictions (in shapefile format) were extracted for the Cairngorms Connect area, and split into two altitudinal zones; above and below 600 m (Table 5). Below 600 m all terrestrial habitats are potentially capable of supporting some degree of tree and scrub cover, although 26% of that area is predicted to only support scattered trees and scrub. Above 600 m the model suggests 75% of terrestrial habitats could support some degree of tree and scrub cover, of which 58% would be scattered trees and scrub.

Table 5. Native Woodland Model predicted potential vegetation communities

Code	NVC / Habitat Description	Area (ha) <600 m	Area (ha) >600 m	Total (ha)
Sc6	Basin Bog woodland/scrub	1,507	791	2,297
Sc3	Birch/Willow	643	1,711	2,354
Sc1	Juniper	2,025	2,340	4,365
Sc7	Mixed montane scrub	1,454	2,795	4,249
Sc5	Peatland with scattered trees/scrub	2,295	5,391	7,686
Sc5/W18	Peatland with scattered trees/scrub + W18 Mosiac	572	366	939
Sc5/W4/W17/ W18	Peatland with scattered trees/scrub + W4 Birch with purple moor-grass and open ground + W17/W18 Mosaic	0	37	37
Sc5/W4	Peatland with scattered trees/scrub Mosaic + W4 Birch with purple moor-grass and open ground	543	1,256	1,799
Sc4	Scattered Birch/Willow	46	2,811	2,857
Sc2	Scattered Juniper	104	549	653
Sc8	Scattered mixed montane scrub	21	737	758
W11/W7	W11 + W7 Mosaic	353	0	353
W11	W11 Upland Oak-Birch	581	0	581
W11/W17	W11/W17	175	0	175
W17	W17 Upland Oak-Birch with blaeberry	310	0	310
W17/W11	W17/W11	172	0	172
W17/W18	W17/W18	2,360	22	2,382
W17/W18/W4	W17/W18 & W4 Birch (with open ground) Mosaic	30	0	30
W18/Sc5	W18 + Peatland with scattered trees/scrub Mosaic	4,349	505	4,854
W18/W4	W18 + W4 Mosaic	12	0	12
W18	W18 Scots Pine with heather	7,954	515	8,469
W18/W17	W18/W17	5,072	9	5,081
W4/W18	W4 + W18 Mosaic	5	0	5
W4/W17/W18	W4 Birch (with open ground) + W17/W18 Mosaic	79	26	104
W4/Sc5	W4 Birch (with open ground) + Peatland with scattered trees/scrub	345	4	349
W4	W4 Birch with purple moor-grass & open ground	298	73	370
W6	W6 Alder with stinging nettle	501	0	501
W7	W7 Alder-ash with yellow pimpernel	80	0	80
BU	Built-up land	5	0	5
DR	Developed rural land	7	0	7
Water	Inland Water	479	65	544
U	Unsuitable for tree/scrub growth	168	6,633	6,802
TOTAL		32,547	26,636	59,183

It must be stressed that the model's outputs are entirely hypothetical predictions. The model assumes that the only constraints are soils and climate and it makes no allowance for availability of seed or impacts of wild or domestic herbivores.

B.10 The near natural vision

Cairngorms Connect does not describe itself as a rewilding project, yet it does have a long term (200 year) vision of the component habitats being in a near natural state. What might that mean? Peterken (1981) deconstructed the term 'natural' as it applied to woodland naturalness:

- *original-naturalness*, the (actual) state which existed before people became a significant ecological factor. In Britain, the pre-Neolithic forests are generally recognised as original-natural.
- *present-naturalness*, the (hypothetical) state which would prevail now if people had never become a significant ecological factor. Such forests would have continued to develop in response to climatic change, long-term soil maturation and continued migration of species. Therefore, they would be different in many ways from the former original-natural forest.
- *potential-naturalness*, the (hypothetical) state that would develop now if human influence were removed completely, and the resultant succession took place in an instant. This describes our understanding of the current potential of species on a site, under prevailing conditions of climate and soils. Such forest would be different again, because soils have changed due to the removal of forest cover and subsequent land-use, and they may also have been affected by eutrophication and other forms of pollution.
- *future-naturalness*, the (potential) state that would eventually develop if people's influence were completely and permanently removed. The available range of species may have been altered by past extinctions and introductions, additional species may colonise, soils will change as succession occurs and climate will continue to change.

In 'Natural Woodland' (Peterken, 1996) he added a fifth quality of *'past-naturalness'*. This is the (actual) quality which attaches to woods whose components have been inherited directly from the *original-natural* forests. Less utilitarian, and more evocative, though echoing the same sentiment is the famous phrase of Steven & Carlisle (1959) that "*to stand in them is to feel the past*". The full complement of native taxa (or all taxonomic groups) gives rise to the quality of *'past-naturalness'*. Their distribution, relative frequency and abundance will have changed over the millennia, but these native taxa are the direct descendants from the *original-natural* habitats.

Peterken (1996) considered what actions were required to restore an *original-natural* forest. He concluded that the "*complete restoration of original-natural woodland would be very expensive, quite impracticable and socially unacceptable*." He went on to point out that any specific target time period was an arbitrary choice, and that there would also be a substantial loss of species as open spaces became covered in trees.

Future-naturalness is very close to some current ideas of rewilding, and of non-intervention, primacy of natural processes, and self-willed land. Taken literally, the *future-natural* option requires the landowner, manager and wider society to have no objectives for the area in question. All future outcomes will be equally valued, as long as they are the outcome of non-intervention. It requires acceptance of all native, naturalised and planted species now on site, and others that might colonise by natural regeneration in the future, coupled with acceptance of existing, artificially modified land forms and soils. This approach would be in contradiction to existing site conservation designations and none of the Cairngorms Connect landowners and managers share this vision.

Peterken's qualities of naturalness can be applied to all habitats, not just woodland. Habitat restoration as envisaged by Cairngorms Connect primarily draws on the idea of *present-naturalness* informed by insights from *potential-naturalness*.

C.1 Extraction of records for the Cairngorms Connect area

The Cairngorms Connect project area has a complex boundary, 397 km in length, hence with an area of 592 km^2, it actually intersects 751 monads (1 km grid squares). Vascular plant records with grid references intersecting the project area have grid reference precision varying from 1 m to 10 km. Hence it is not appropriate to simply extract and analyse all intersecting records (Table 6). In January 2022, the Botanical Society of Britain and Ireland (BSBI) database (DDb) held more than 108,000 plant records that intersected the Cairngorms Connect boundary.

A shapefile of the Cairngorms Connect boundary was uploaded to the DDb, and used to run a series of spatial queries to select and download records that were from within, or for which the site grid reference intersected, the boundary. Rejected records, and those considered doubtful or that require further checking were excluded. All the records included in this analysis have been confirmed through processes of verification and validation. 86% of the records were verified and validated within the DDb, primarily by BSBI vice-county recorders, and these have been especially thoroughly checked.

Table 6. Plant records precision

Precision	Number of grid squares within or intersecting Cairngorms Connect boundary	Percentage grid squares intersecting the Cairngorms Connect boundary	Percentage records in analysed dataset
Hectad (10 km)	18	100.0	8.7
Quadrant (5 km)	48	91.7	5.4
Tetrad (2 km)	222	66.2	10.8
Monad (1 km)	751	45.4	23.0
100 m (or better)	61,308	7.4	52.1

Records with grid references that intersected the Cairngorms Connect boundary were assessed as to the likelihood whether the record referred to the Cairngorms Connect area or not. The percentage of the grid reference square of each record that fell within the Cairngorms Connect boundary was calculated using GIS. That figure, along with the site name, vice-county, taxon, and local knowledge were used to make the assessment. Records that intersected the boundary at 100 m grid reference precision (or better) were, for the most part, assumed to be from within the boundary; a few records that were obviously from outwith the boundary were excluded. Records at 1 km, 2 km, 5 km or 10 km precision were placed in one of three categories: outwith the Cairngorms Connect boundary (hence removed from the dataset), probably or possibly within the boundary. Records that intersected the boundary at 5 km or 10 km grid reference precision and lacking a locality name, were removed from the dataset. Genus only records were also removed. Finally, any taxa for which the only records had been assessed as only possibly within the boundary were also removed. The final dataset for analysis held 71,191 records, of which 75% were at monad or better precision (Table 6). Records assessed were those on the DDb in January 2022.

C.2 Summary of the dataset

The final dataset included 1038 taxon names. These names were rationalised to remove naming inconsistencies. Most subspecies and all varieties were subsumed within the nominate species name. Inconsistently identified species were grouped under an aggregate name. Hence, the list of taxon names used in the analyses was reduced to 899 taxa (Table 7).

Table 7. Summary of taxa in analysed dataset

Rank	Total
Species	803
Hybrid	56
Subsp.	6
Aggregate	34
Total	899

The records are of vascular plants (clubmosses, horsetails, ferns, conifers and flowering plants), and are from the period 1821 to 2021. Scientific names follow Stace (2019).

In Fig. 11, records with a date range (of more than a single year) are assigned to the decade of the starting year. 136 records lacked a start year for a range, and are not included. 62% of the records are from post 1999; 79% are post 1989; 94% are post 1969.

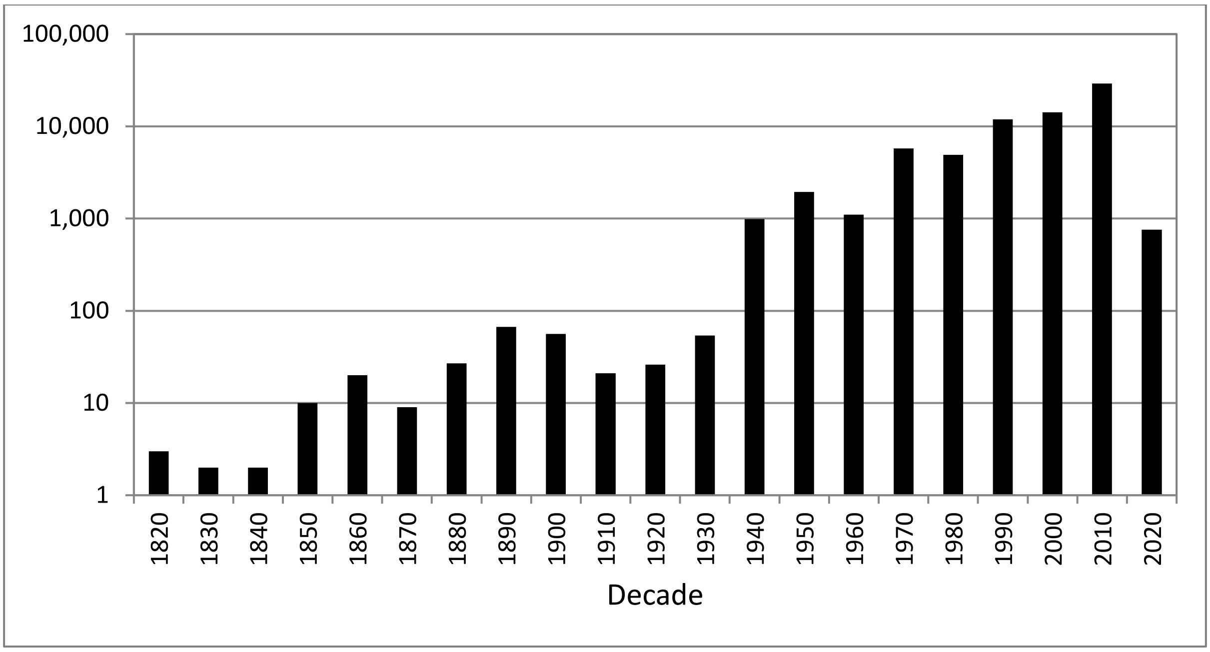

Figure 11. Cairngorms Connect. Number of records of vascular plants per decade (y-axis uses a log scale). The 2020 decade only includes records from the first two years

C.3 Discovery of the flora

The earliest plant record for the Cairngorms Connect area is that of *Lycopodium annotinum* (Interrupted Clubmoss) (Hooker, 1821). Other species recorded in the 1820s by Hooker were *Luzula arcuata* (Curved Wood-rush) and *Deschampsia cespitosa* subsp. *alpina* (Alpine Hair-grass). Almost all the earliest records (pre-1860) are of montane species. A notable, and intriguing exception is that of the Nationally Scarce *Melampyrum sylvaticum* (Small Cow-wheat), recorded by W.A. Stables in 1843 at Kinrara; it has not been recorded there since.

Knowledge of the flora gradually increased (Fig. 12), such that by the end of the 1930s, 152 taxa are known to have been recorded. There was a marked increase in discoveries in the 1940s, consolidated in the 1950s, with fieldwork being undertaken for the first *Atlas of the British Flora* (Perring & Walters, 1962), in particular by Mary McCallum Webster. By the end of the 1950s the known flora of the Cairngorms Connect area stood at 559 taxa.

Post-1959, the total of native taxa has increased by a further 39% (to 693 taxa). Over the same period total recorded alien taxa has increased by 235%, so more than trebled, to 209 taxa. In each of the three decades from 1990 more than 50% of newly recorded taxa were of aliens. This reflects the actual expansion of alien taxa, as well as a greater enthusiasm for recording all plant taxa 'in the wild'.

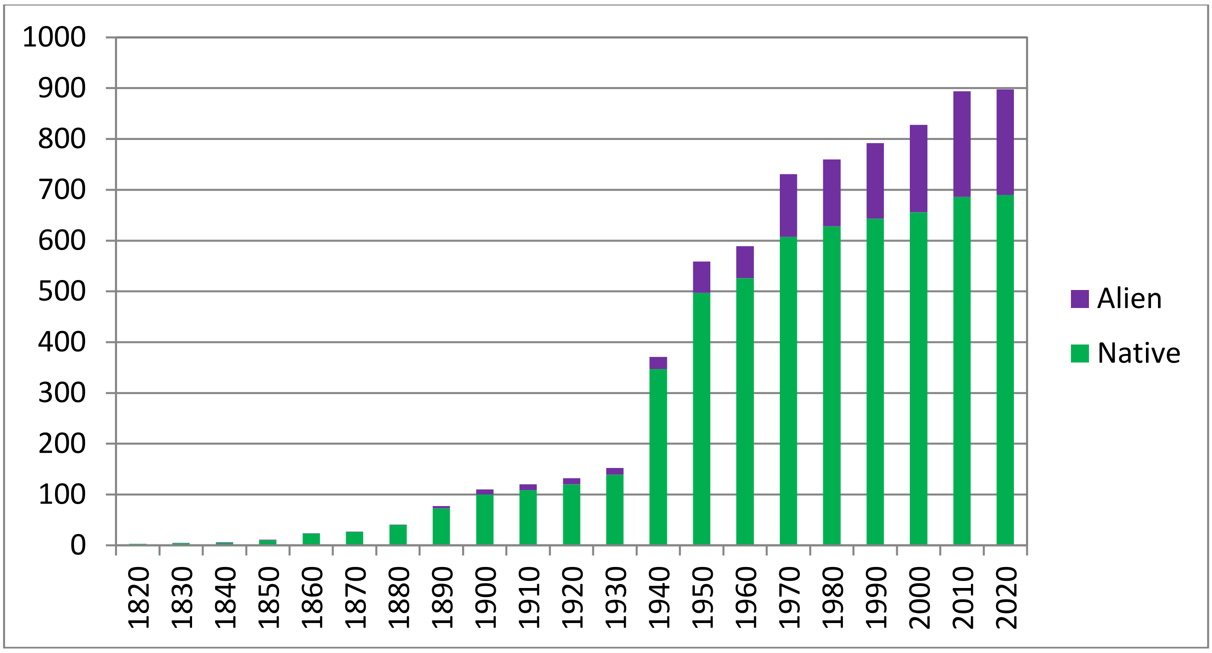

Figure 12. Taxon accumulation, by decade

Post-1999, an additional 47 native plant taxa have been recorded. These are a mixture of:

- previously overlooked taxa, eg. the Nationally Rare *Calamagrostis stricta* (Narrow Small-reed) and the Nationally Scarce *Juncus castaneus* (Chestnut Rush);
- new taxonomic treatments, eg. the Nationally Scarce *Trichophorum cespitosum* (Northern Deergrass);
- recording of taxonomically difficult groups, eg. *Taraxacum* (Dandelions);
- greater recording of hybrids, eg. *Salix myrsinifolia x phylicifolia = S. x tetrapla*, *Equisetum pratense x sylvaticum = E. x mildeanum, Carex bigelowii x nigra = C. x decolorans* and *Dactylorhiza maculata x Gymnadenia borealis = X Dactylodenia evansii*;
- new arrivals, eg. *Crassula tillaea* (Mossy Stonecrop) which is being dispersed on the tyres of vehicles, and *Puccinellia distans* (Reflexed S
- altmarsh-grass) now found along road verges where salt is applied in winter.

C.4 Floristic elements

The British and Irish flora has been classified (Hill *et al*., 2004) according to two criteria: occurrence in major terrestrial biomes (latitude), and eastern distributional limit (longitude), in the Northern Hemisphere. The native Cairngorms Connect flora is compared to that for the whole of Great Britain and Ireland (Table 8). Only those taxa listed by Hill *et al*., (2004) are included in this analysis. These taxa are mostly at species rank and exclude most micro-species.

Table 8. Percentage of native species in major biome (latitude) and eastern limit (longitude) categories, comparing Cairngorms Connect to Great Britain and Ireland

	GB & Ireland %	Cairngorms Connect %	Ratio of CC%:GB & Ireland %
1. Arctic-montane	5.7	8.8	1.55
2. Boreo-arctic montane	2.7	4.6	1.70
3. Wide-boreal	1.5	2.5	1.62
4. Boreal-montane	8.0	10.9	1.37
5. Boreo-temperate	16.3	28.2	1.73
6. Wide-temperate	2.9	3.7	1.27
7. Temperate	38.2	31.7	0.83
8. Southern-temperate	16.6	9.0	0.54
9. Mediterranean-atlantic	8.2	0.7	0.09
0. Hyperoceanic	1.2	0.2	0.15
1. Oceanic	13.3	3.9	0.29
2. Suboceanic	9.4	6.1	0.65
3. European	33.9	33.7	0.99
4. Eurosiberian	17.4	17.7	1.02
5. Eurasian	7.0	9.3	1.33
6. Circumpolar	17.8	29.1	1.63

When compared to the native flora of the whole of Great Britain and Ireland, the native flora of the Cairngorms Connect area is characterised by:

- a greater representation of Arctic-montane, Boreal-montane and Boreal species;
- a reduced representation of Temperate, Southern-temperate and Mediterranean-Atlantic species;
- a greater representation of species with Eurasian and Circumpolar distributions;
- a reduced representation of Suboceanic, and especially Oceanic and Hyperoceanic species.

However, it should be noted that examples of all the major biomes and eastern distributional limit categories are to be found in the Cairngorms Connect flora. Indeed, although the Cairngorms Connect native flora has strong affinities with species of Arctic, Boreal and more continental distributions, numerically the most frequent categories are actually Temperate and European.

The rarest of the Floristic Elements (i.e. hyperoceanic), is only represented by a single species, *Hymenophyllum wilsonii* (Wilson's Filmy-fern) discovered in 2012, growing on a moss-covered boulder in native pinewood at 400 m altitude, on a sheltered north-west facing slope. In 2018 the population was found to extend to several boulders at the same location.

From a Eurasian perspective, Worrell (1996) concluded that the Scots Pine and pine-birch forests in the Scottish Highlands have sufficient affinities with many Eurasian boreal forests for the term boreal forest to be valid. However, they are growing in a climate which is more strongly oceanic than other regions where boreal forests occur.

C.5 Endemic taxa

38 native taxa are endemic to Scotland, including 7 which are endemic to the Cairngorms. In addition, there are 15 taxa endemic to Great Britain, or GB and Ireland (Table 9). Of the 693 native taxa, 7.6% are endemics. The majority (47) of these are microspecies of *Hieracium* (Hawkweeds).

Table 9. Endemic taxa

Taxon	Cairngorms endemic	Scottish endemic	GB & Ireland Endemic	Total
Athyrium distentifolium var. *flexile*		1		1
Betula pubescens var. *fragrans*			1	1
Cochlearia micacea		1		1
Hieracium spp.	7	28	12	47
Taraxacum spp.		1	2	3
Total	7	31	15	53

C.6 Native cf alien taxa

Although 23% of the recorded taxa are alien, this overemphasises their abundance and range. The distribution of alien plant records is shown in Fig. 13, and of native taxa in Fig. 14.

Areas remote from seed sources of alien taxa, and higher altitude areas, have few alien taxa recorded as compared to native taxa, as can be seen by comparing Fig. 13 and Fig. 14. For example, hectad NN78 (Gaick) has 328 taxa recorded of which 99.4% are natives. In contrast, hectad NH80 has the greatest number of recorded taxa (611), of which 80.4% are natives. This hectad includes rural habitation, eg. Insh and Feshiebridge, a B classification road, and the River Spey running through it, all of which may be the source of, or facilitate the spread of, alien taxa.

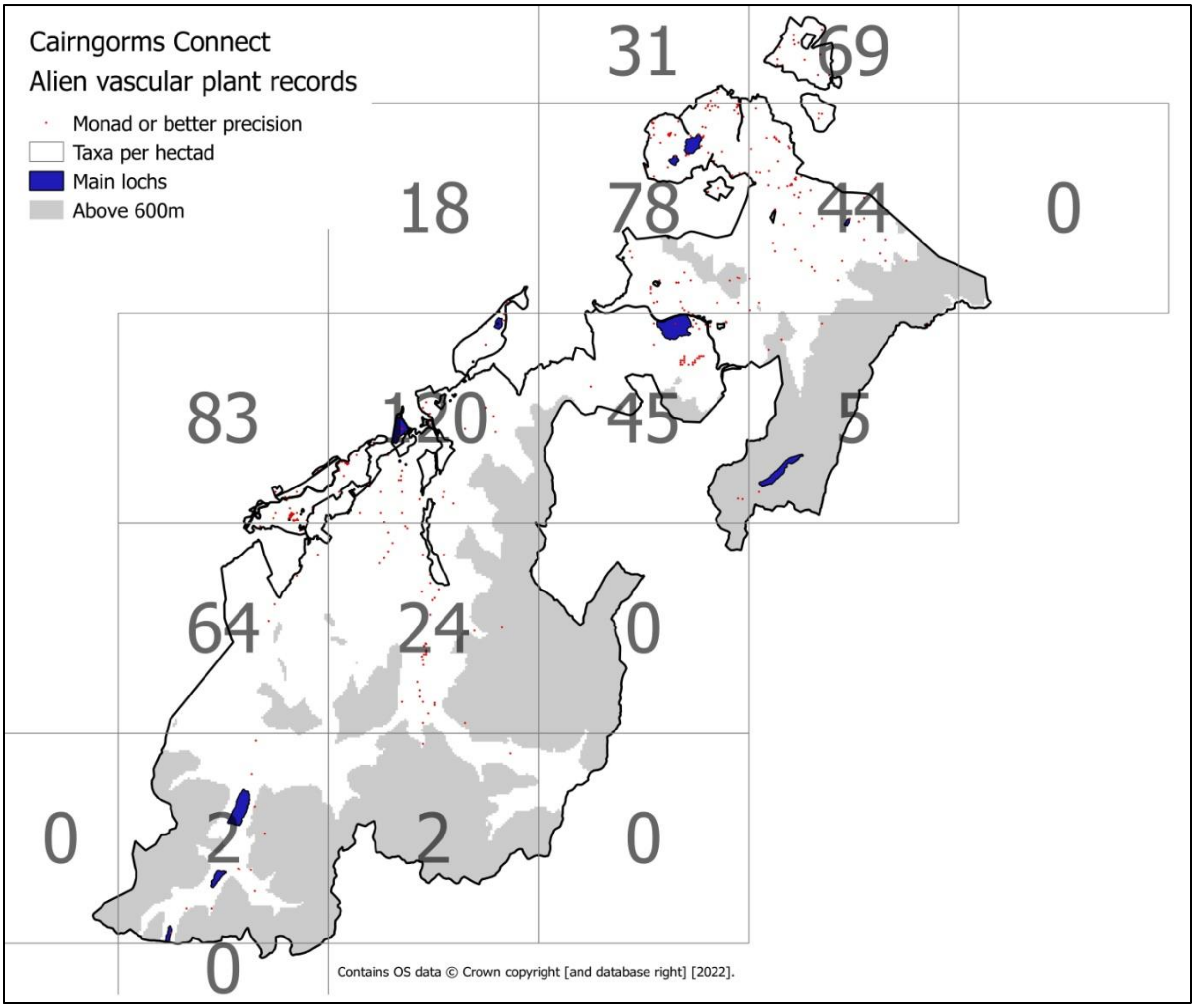

Figure 13. Distribution of records of non-native species

C.7 Altitudinal distribution of taxa

The number of native and alien taxa per 100 m altitude class, based on the mean altitude of grid references at monad or better precision, are shown in Fig. 15. Most taxa (72%) are recorded from more than one altitude band. The number of native taxa declines linearly with altitude (r^2 = 0.97). Areas per 100 m altitude band are approximately equal up to 800 m (Fig. 3) but diminish rapidly at higher altitudes. In Fig. 15a areas and taxa above 800 m are grouped, so that all altitude bands are approximately similar in area. A quadratic function is the best fit (r^2 - 0.94). While it is likely that altitude is the primary driver of species diversity, it should be borne in mind that recording intensity (Fig. 16) is lowest between 500-800 m. Number of native taxa in the band 5-600 m is slightly lower, and between 6-700 m is slightly higher than the quadratic best fit line. This most likely reflects the different number of monads with records in each band (Fig. 16).

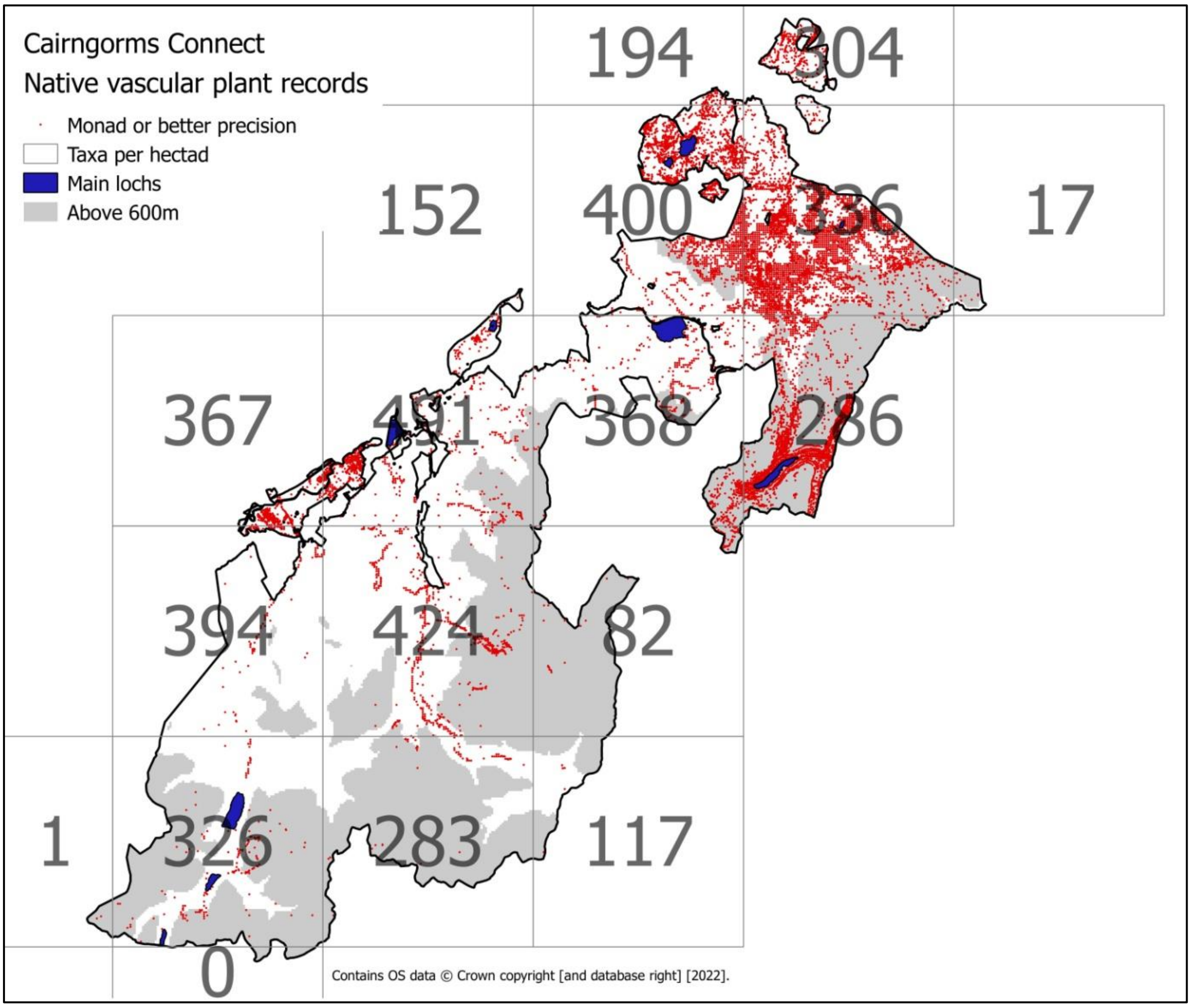

Figure 14. Distribution of records of native species

Alien taxa are largely found below 400 m, and especially below 300 m. Of the 209 alien taxa, only 12 have been recorded from locations greater than 400 m altitude. Of these, only two species are at all widespread, *Epilobium brunnescens* (New Zealand Willowherb) in 32 monads above 400 m, and *Picea sitchensis* (Sitka Spruce) in 12 monads above 400 m. Above 400 m, 97% of recorded taxa are natives.

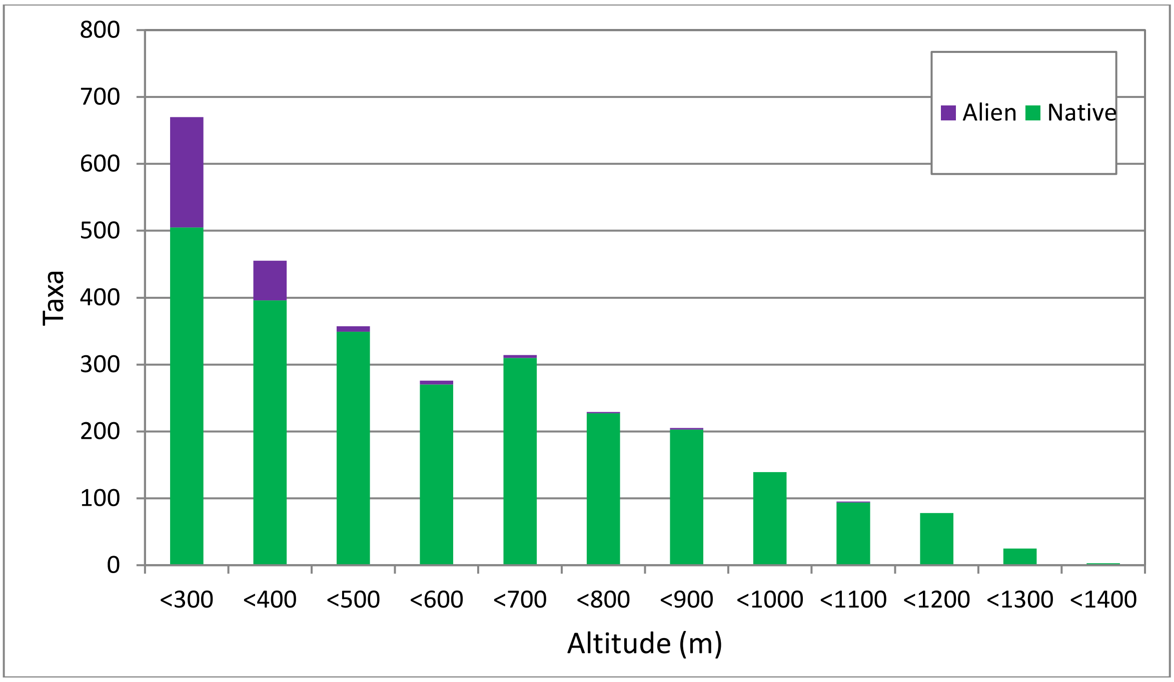

Figure 15. Native and alien taxa per 100 m altitude class

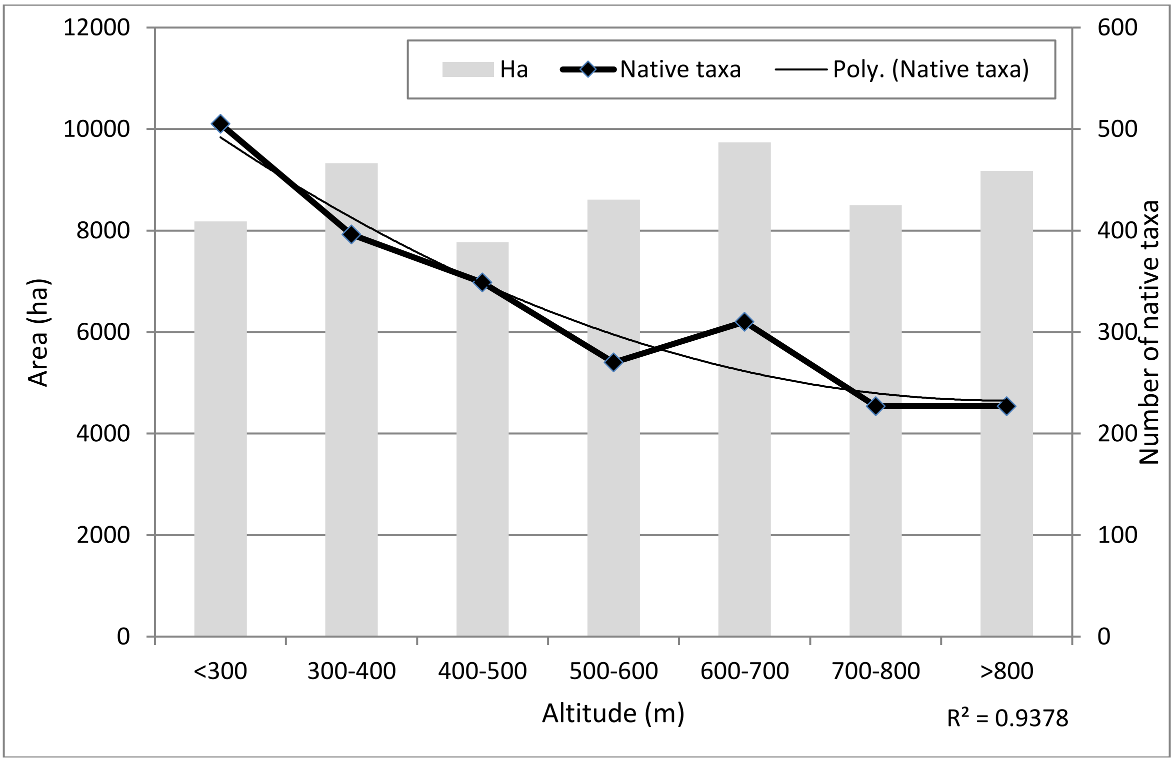

Figure 15a. Native taxa per 100 m altitude class (bands above 800 m grouped). Smooth line shows a fitted quadratic function.

C.8 Altitudinal recording bias

The available records show distributional (Figs. 13 and 14) and altitudinal biases (Fig. 16).

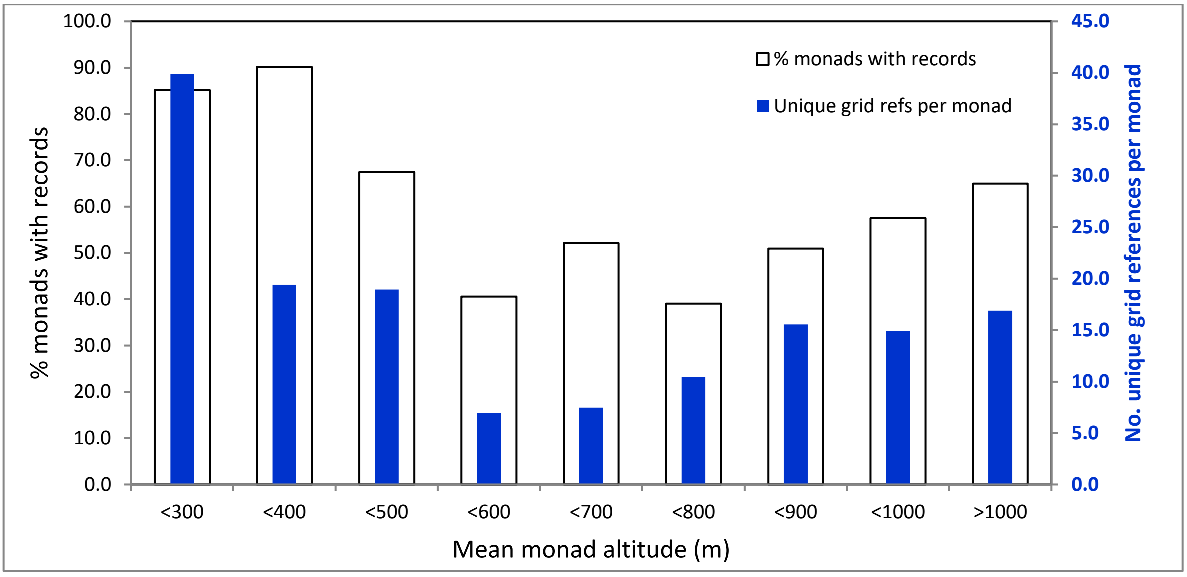

Figure 16. Percentage monads with records and number of unique grid references per monad, in 100 m altitude classes

Below 400 m altitude, 87% of monads have records, whereas at 5-600 m and 7-800 m the average is only 40%. Above 800 m 56% of monads have records.

The bias towards lower altitude areas reflects proximity to where recorders live, points of access and easier access routes within the site. Much recording has been undertaken by volunteers, and at a minimum, BSBI vice-county recorders have collected and / or collated 70% of these records. Targeted surveys for site condition monitoring of designated areas, have been undertaken by staff and contractors for NatureScot. RSPB Scotland have carried out extensive surveys of their nature reserves, adding considerably to recording coverage.

This analysis of recording bias can be used to identify taxa that may be under recorded, relative to other taxa. 48 native taxa have >50% of their Cairngorms Connect records between 500-800 m altitude. Amongst these, taxa that grow in widespread habitats, e.g. heaths and blanket bogs, may very well be under recorded. Examples include *Betula nana* (Dwarf Birch, Nationally Scarce) (100%); *Diphasiastrum x issleri* (Issler's Clubmoss, Near Threatened, Nationally Scarce) (95%); *Cornus suecica* (Dwarf Cornel, Near Threatened) (84%); *Rubus chamaemorus* (Cloudberry) (79%); *Vaccinium uliginosum* (Bog Bilberry) (57%); *Lycopodium annotinum* (Interrupted Clubmoss, Nationally Scarce) (51%).

C.9 Taxa of Conservation Concern

Of the 693 native taxa, a remarkable 161 (23%) are of national conservation concern (Appendix 1). These are taxa included on the GB Red List (above Least Concern) (Cheffings & Farrell, 2005, with updates), GB Nationally Rare or Nationally Scarce. Appendix 1 includes additional *Hieracium*, *Taraxacum* (Dandelion) and hybrid species, qualifying under the same criteria.

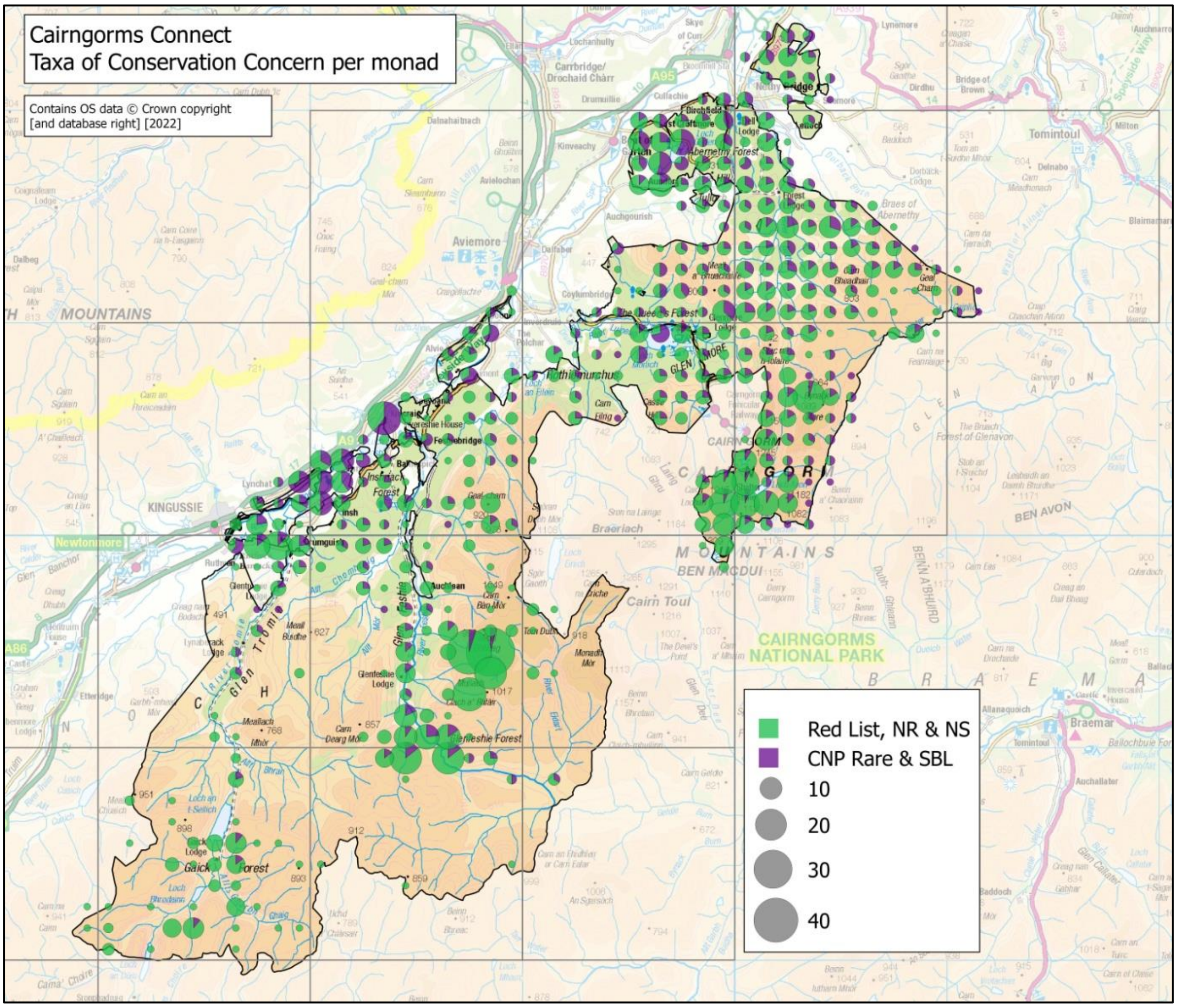

Figure 17. Taxa of Conservation Concern per monad. National: Red List (above Least Concern), Nationally Rare and Nationally Scarce. Regional: Very Rare or Rare in Cairngorms National Park and Scottish Biodiversity List

There are also an additional 76 native taxa (11%) which are included on the Scottish Biodiversity List, or are Very Rare or Rare in the Cairngorms National Park area (Appendix 2). The latter two categories are here defined as taxa with 1-3, or 4-10 recorded tetrads post-1986 within or intersecting the National Park boundary. (There are 1020 tetrads fully contained within the CNP boundary and an additional 234 tetrads intersect the boundary). Therefore 34% of native taxa in the Cairngorms Connect area are of national or regional conservation concern (Fig. 17).

The greatest concentration of taxa of Conservation Concern is in Coire Garbhlach, where monad NN8894 has 49, and NN8794 has 41 taxa. Other monads with >20 taxa of Conservation Concern are at Druim nam Bo and Slochd Beag, in Glen Feshie; upper Glen Feshie itself; Coire Dearg, in Strath Nethy; and the Loch Insh / Kincraig Bridge area.

C.10 Frequency of native taxa

Few native taxa are widespread, most are local or rare (Fig. 18). Just under 8% of native taxa have been recorded in more than 100 monads. Not surprisingly the most widely recorded is *Calluna vulgaris* (Heather), in 266 monads. Conversely, 40% of native taxa have been recorded in five or less monads, with 16% recorded from just a single monad. With further recording, the number of apparently rare or scarce taxa will inevitably be reduced. However, it is likely that additional taxa will be recorded for the first time, and many of these will be recorded in few monads.

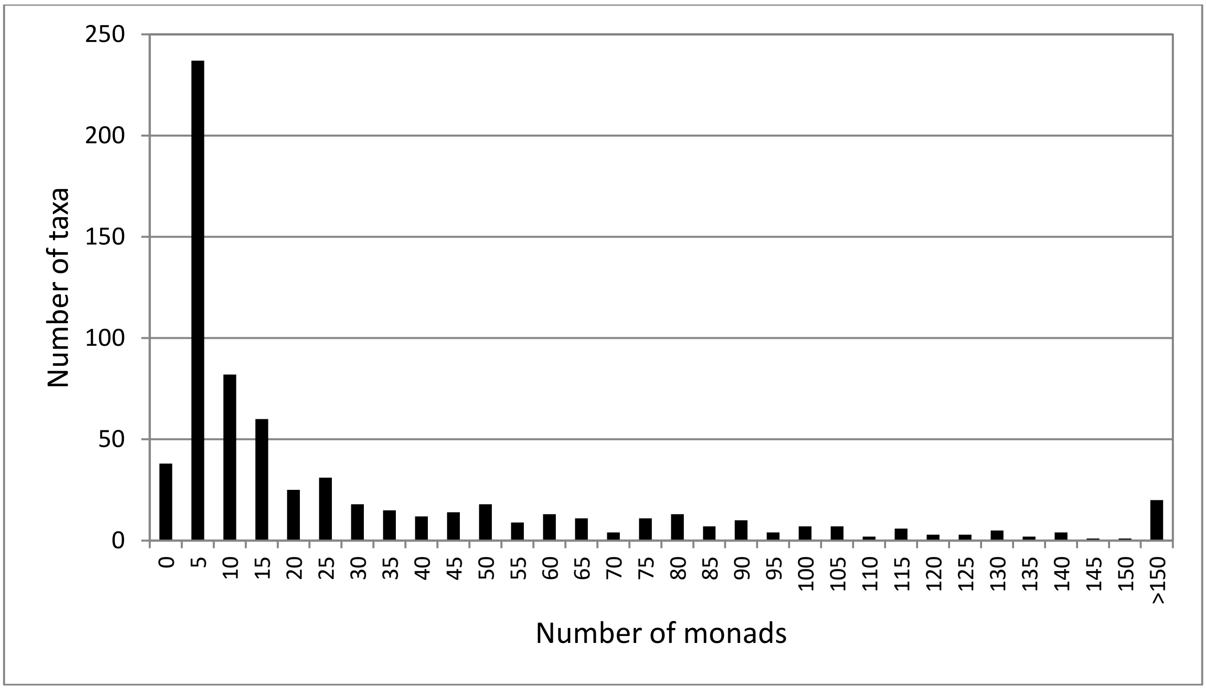

Figure 18. Frequency of native taxa (number of monads with records)

C.11 Ellenberg Values

The basis of Ellenberg indicator values is the realised ecological niche (Hill *et al.*, 1999). Hill *et al.* (1999, 2004) recalculated Ellenberg's indicator values (which were for central Europe) for Great Britain. The values are intended as typical values for GB, and where a species' ecological niche varies across the country, an intermediate value is used. Hill *et al.* provide indicator values for Light, Moisture, Reaction (soil or water pH), Nitrogen (a general indicator of soil fertility), and Salt. The indicator values are arbitrary scales.

Some taxa, i.e. micro species of *Hieracium* and *Taraxacum*, some hybrids and taxa newly elevated to species rank had no Ellenberg values. Indicator values were estimated for these taxa based on expert knowledge and a range of literature sources.

The following analyses (Fig. 19) are restricted to taxa native to the Cairngorms Connect area.

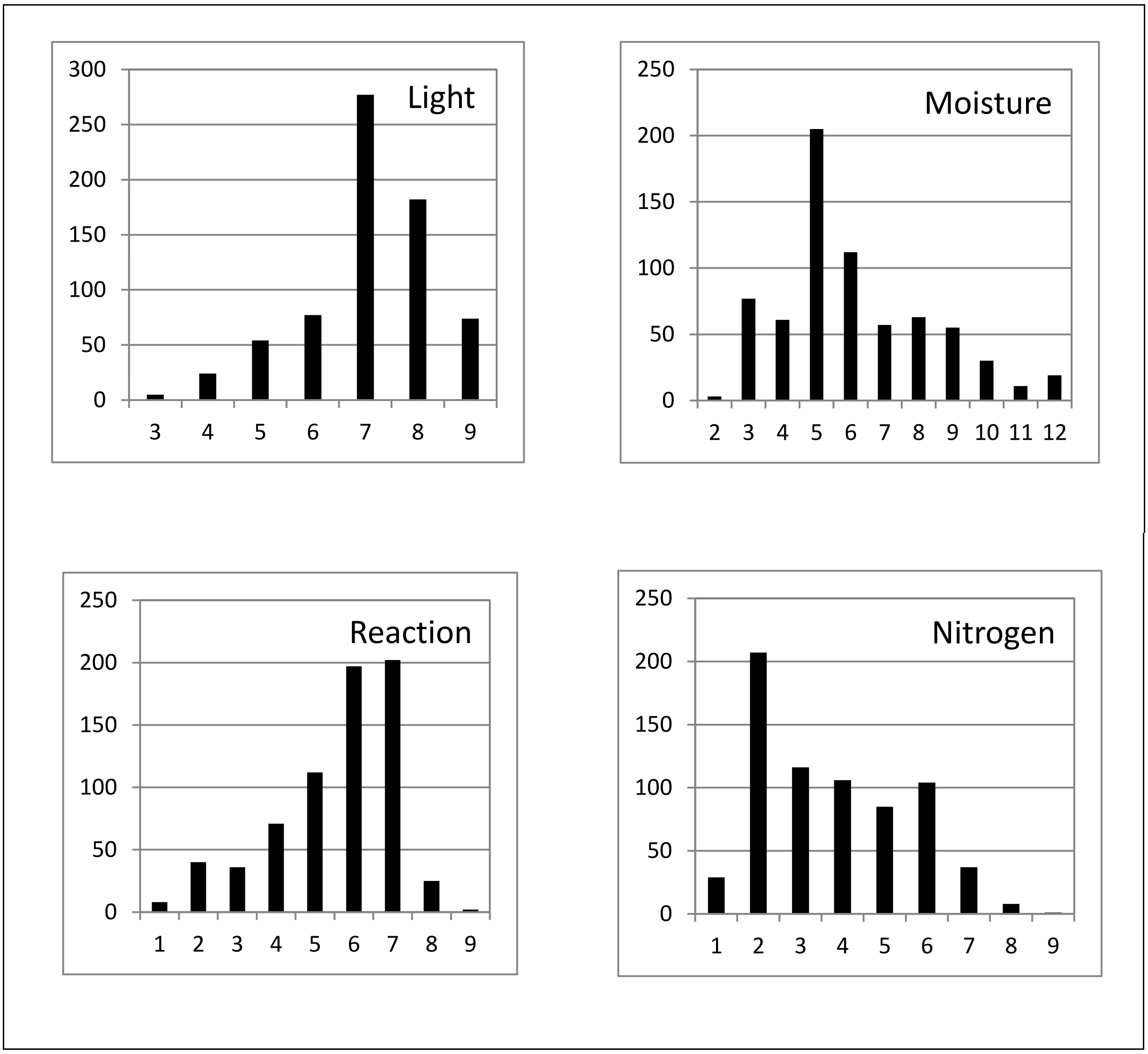

Figure 19. Ellenberg indicator values (X axis) of taxa native to Cairngorms Connect area. Y axis (number of taxa)

Ellenberg Light

There are no taxa with Light values of 1 or 2, plants of deep shade. 12% of taxa are associated with shaded locations (values 3 and 4) or semi-shade (value 5). 51% of taxa are found in partial shade to well lit locations (values 6 and 7). 37% of taxa are in well-lit to fully-lit locations (values 8 and 9).

Ellenberg Moisture

There are no taxa with a Moisture value of 1. 12% of taxa are associated with dry ground (values 2 and 3). 55% of taxa are associated with moist ground of average dampness (values 4, 5 and 6). 17% of taxa are associated with consistently damp ground (not waterlogged) (values 7 and 8). 17% of taxa are found on saturated or seasonally flooded ground, or are aquatics (values 9, 10, 11 and 12).

Ellenberg Reaction
12% of taxa are associated with markedly acid soils (values 1, 2 and 3). 26% of taxa are associated with moderately acid soils (values 4 and 5). 58% of taxa are associated with circum-neutral soils (values 6 and 7). Finally, just 4% of taxa are associated with basic, high pH soils (values 8 and 9).

Ellenberg Nitrogen
51% of taxa are associated with infertile sites (values 1, 2 and 3). 43% of taxa are associated with intermediate fertility (vales 4, 5 and 6). 7% of taxa are associated with richly fertile or eutrophic sites (values 7, 8 and 9).

D.1 Ellenberg Light values: altitude and distribution
Water levels, acidity and fertility are to a great extent determined by topography, soils and geology. However, shading of plants, at altitudes below the potential tree line, is strongly influenced by the extent of woodland and scrub and its structure, and by herbivore grazing levels (both wild and domestic animals) determining height and structure of the field layer.

The percentage of taxa, in 100 m altitude bands, in the same three Light value groupings as used above, is shown in Fig. 20. Only records at 1 km or better grid reference precision were used. Altitudes of individual records are the mean altitude of the location grid square, calculated within the BSBI database, using the SRTM 90 m DEM Digital Elevation Database. This raster dataset is not quite as accurate as the Ordnance Survey Terrain 50 dataset (which uses a 50 m sampling grid). For the 751 monads that intersect the Cairngorms Connect area, the mean altitude estimates from the two datasets are similar; 90% of monad means are within ±9 m of each other.

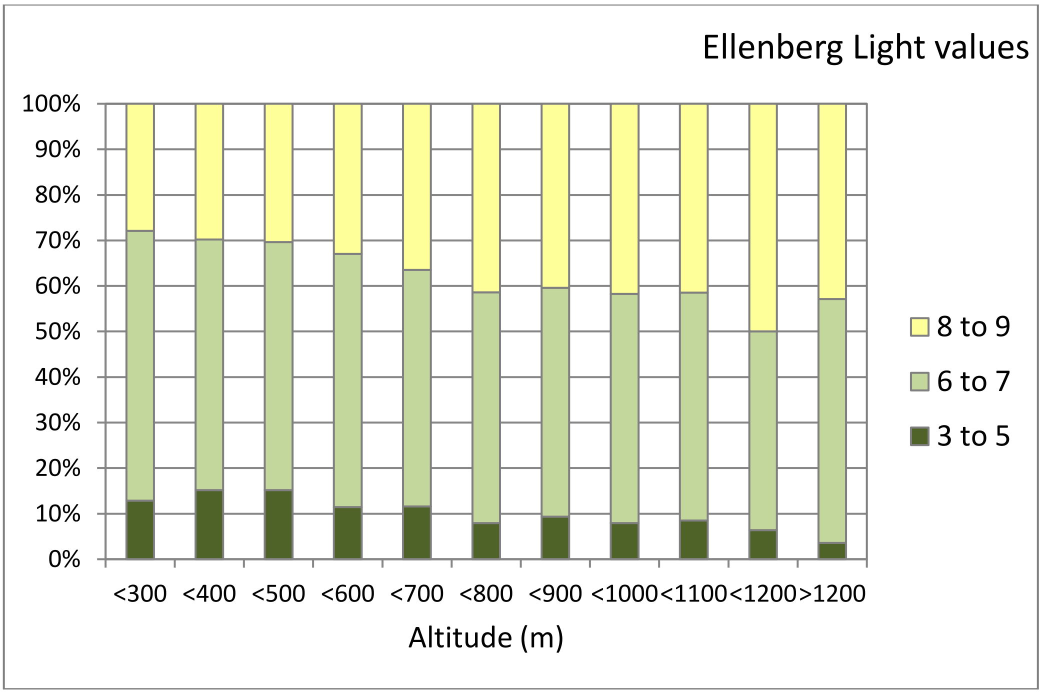

Figure 20. Percentage native taxa in three classes of Ellenberg Light values in 100 m altitude bands

As discussed, above, the current average potential timber and scrub lines, in this area, for *P. sylvestris* are at *c.*560 m and *c.*650 m respectively. For analysis purposes, land below 600 m is considered to fall within the potential 'forest zone'.

Below 600 m, taxa associated with shaded locations (Light values 3, 4 and 5), vary from 11 to 15% of the 100 m band taxon totals. Examples of these taxa (all woodland species) include the following:

Anemone nemorosa (Wood Anemone)
Athyrium filix-femina (Lady-fern)
Circaea alpina x *lutetiana* = *C.* x *intermedia* (Upland Enchanter's-nightshade)
Corallorhiza trifida (Coralroot Orchid)
Dryopteris affinis agg. (Scaly Male-fern)
Dryopteris dilatata (Broad Buckler-fern)
Dryopteris filix-mas (Male-fern)
Equisetum sylvaticum (Wood Horsetail)
Goodyera repens (Creeping Lady's-tresses)
Gymnocarpium dryopteris (Oak Fern)
Linnaea borealis (Twinflower)
Luzula pilosa (Hairy Wood-rush)
Lysimachia nemorum (Yellow Pimpernel)
Melampyrum pratense (Common Cow-wheat)
Mercurialis perennis (Dog's Mercury)
Moneses uniflora (One-flowered Wintergreen)
Neottia cordata (Lesser Twayblade)
Orthilia secunda (Serrated Wintergreen)
Oxalis acetosella (Wood-sorrel)
Phegopteris connectilis (Beech Fern)
Pyrola media (Intermediate Wintergreen)
Pyrola minor (Common Wintergreen)
Trientalis europaea (Chickweed-wintergreen)

Below 600 m, just over half (54-59%) of the 100 m taxon totals have Light values of 6 or 7; i.e. in partial shade to well-lit locations. None of these taxa are restricted to woodland and very few, e.g. *Vaccinium myrtillus* (Bilberry) and *V. vitis-idaea* (Cowberry), are found within closed canopy woodland. Again, below 600 m, between 28-33% of the 100 m taxon totals have Light values of 8-9 (well-lit to fully lit locations). The number of taxa per monad in these three Light value categories are shown in Fig. 21.

Native taxa that prefer only partial shade or well-lit locations (Light values 6-7) were the most frequent in 80% of monads with records. Only considering monads with more than 10 taxa, and dividing monads into two altitudinal classes, below and above 600 m mean monad altitude, native taxa with Light values of 6-7 were the most frequent in 87-93% of monads (Table 10).

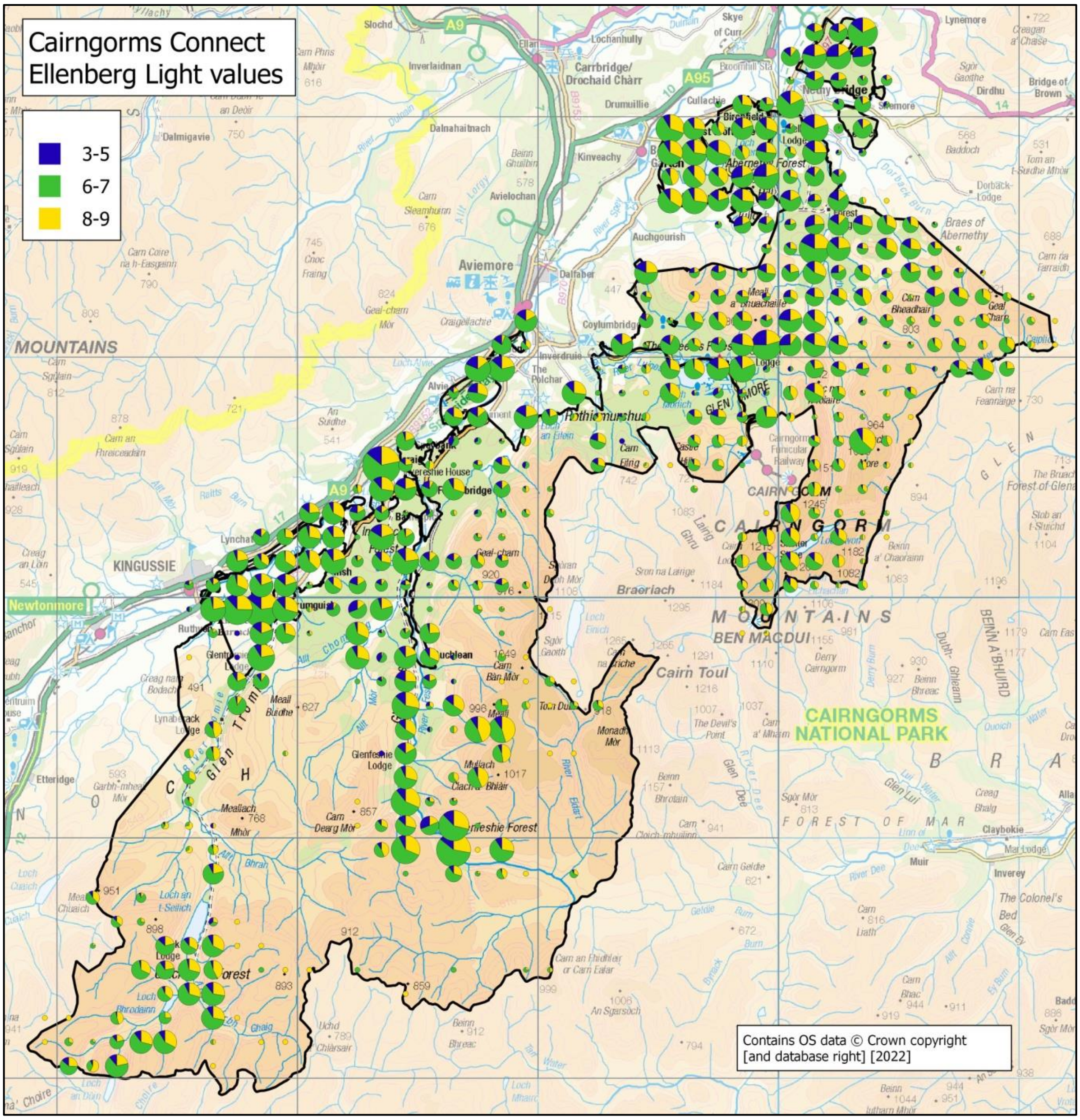

Figure 21. Frequency of native taxa in three categories of Ellenberg Light values. Symbol size proportional to the total number of taxa

Table 10. Number of monads (%) above and below 600 m mean altitude, in which taxa in three Ellenberg Light value classes were the most frequent. Only monads with >10 taxa recorded are included

Ellenberg Light values	<600 m	>600 m
3-5	0	1 (1%)
6-7	235 (93%)	89 (87%)
8-9	17 (7%)	12 (12%)

Considering taxa of national and regional conservation concern (see Section C.9), overall, those favouring well-lit to fully lit locations (Light values 8-9) are the most frequent (Fig. 22, Table 11).

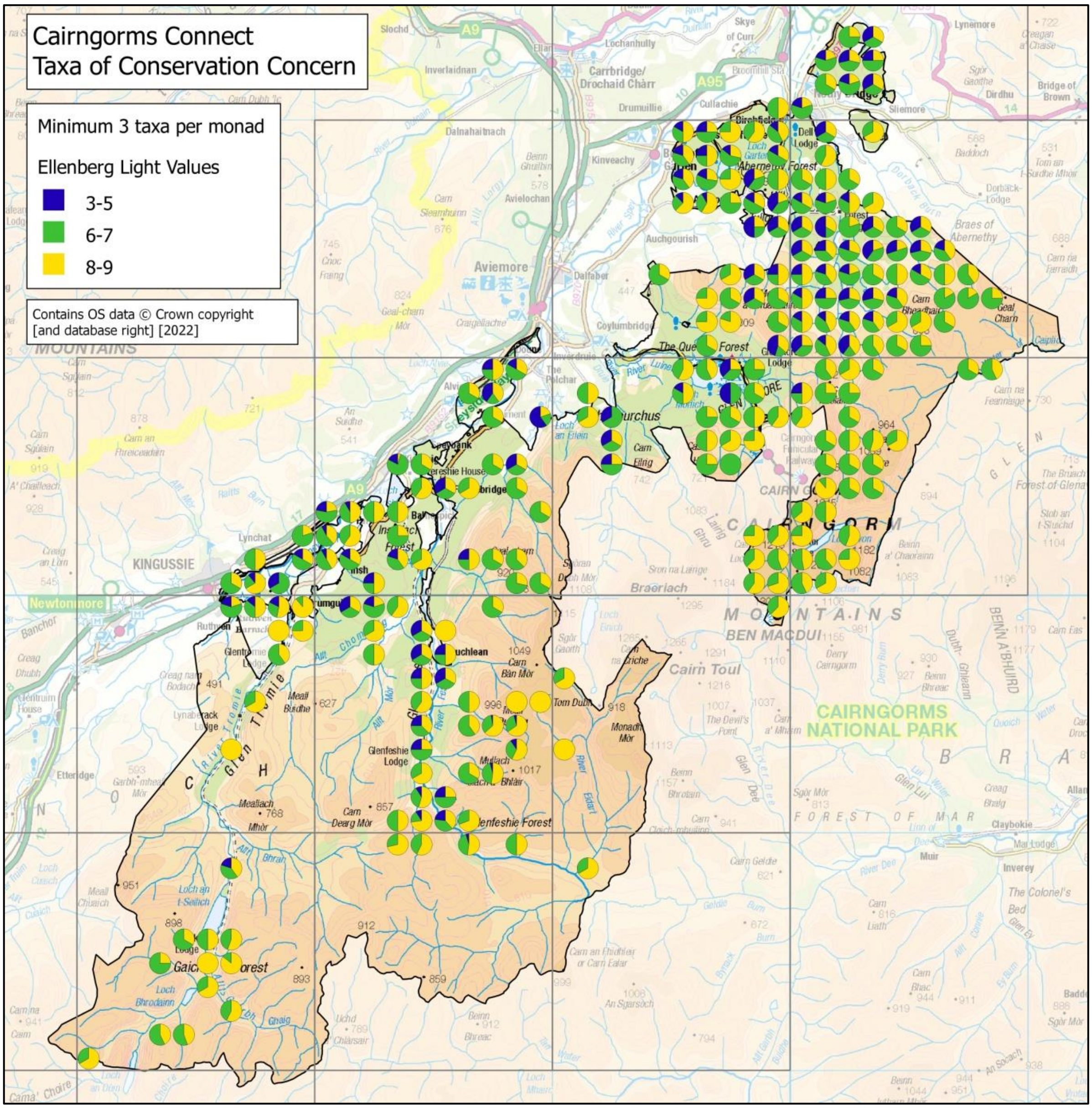

Figure 22. Proportion of taxa of national and regional conservation concern in three categories of Ellenberg Light values. Minimum 3 taxa recorded per monad

Table 11. Number of taxa (%) of national and regional conservation concern in three Ellenberg Light value classes

Ellenberg Light values	National Conservation Concern	Regional Conservation Concern	Total
3-5	10 (6%)	10 (13%)	20 (8%)
6-7	46 (29%)	47 (61%)	93 (39%)
8-9	105 (65%)	20 (26%)	125 (53%)

There are 250 monads in which three or more taxa of national or regional conservation concern have been recorded. Of these, in only four monads are taxa favouring shaded conditions (values 3-5) in the majority. In all the other monads (98%), taxa favouring partial shade to well-lit locations, (values 6 and 7), or well-lit to fully lit locations (values 8 and 9) are in the majority or coequal.

There are 275 native taxa (40% of the Cairngorms Connect total), recorded at monad or better precision, with >90% of records from <600 m altitude, and Ellenberg Light values 6-9 (i.e. occurring in no more than partial shade), and Ellenberg Moisture (F) values 2-8 (i.e. excluding taxa of saturated or seasonally flooded ground, or aquatics) (Appendix 3). These taxa are therefore those considered most at risk from an expansion of the area of shady woodland. An increase in area of occupancy of trees and shrubs is not, in itself, an issue. It is primarily the degree of shading.

D.2 Plant size (height)

Plant height can be used as a general indication of plant size. Maximum height of all native terrestrial or emergent taxa was taken from Plantatt (Hill *et al.*, 2004). For taxa not included in this work, heights were taken from other standard floras, especially Dudman and Richards (1997) for *Taraxacum* species and Sell and Murrell (2006) for *Hieracium* species. In scapose taxa, leaf length was used (Fig. 23).

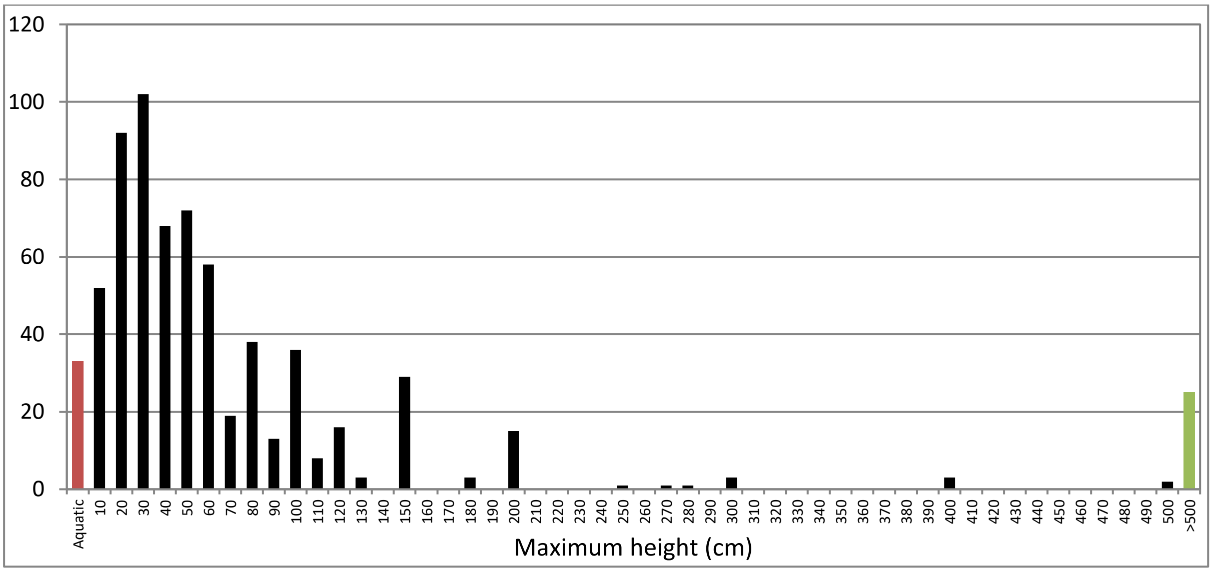

Figure 23. Potential maximum height of native taxa

Of the 693 native taxa, 33 (5%) are aquatics, indicated at the left side of Fig. 23. 48 taxa (7%) are trees or woody shrubs, potentially growing to more than one metre in height. Of the terrestrial and emergent taxa, 80% have maximum height less than one metre, with the modal height class being 21-30 cm.

Of native taxa (excluding aquatics), those less than 30 cm maximum height, comprise about a quarter of the total taxa recorded per monad, median 24.0% (inter-quartile range 17.2-33.3) (Fig. 24).

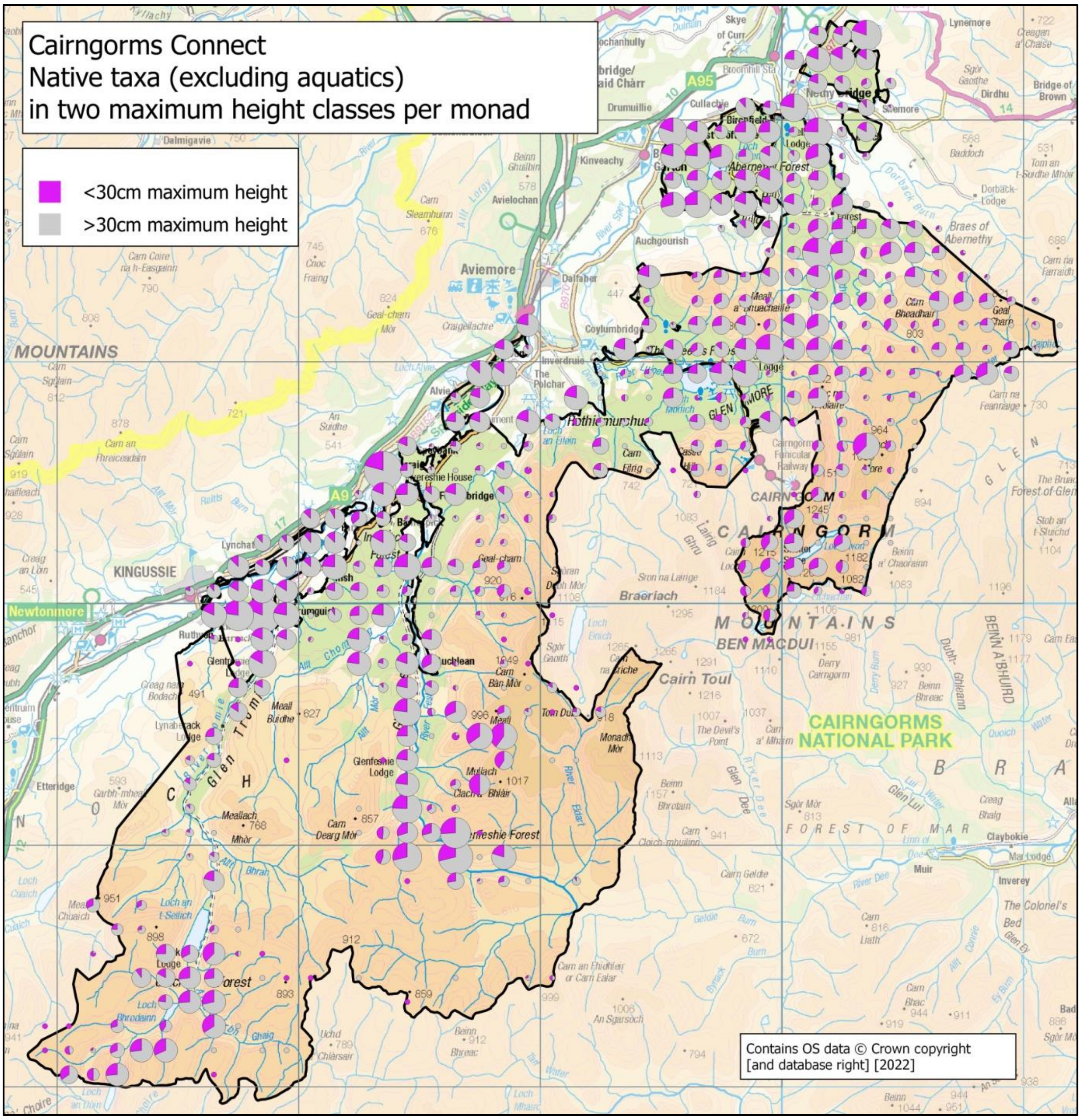

Figure 24. Frequency of native taxa, excluding aquatics, in two height classes per monad

D.3 Taxa indicative of non-W18 woodland

Vegetation mapping using the National Vegetation Classification (NVC) (Rodwell, 1991-2000) is available for 58% of the Cairngorms Connect area (Government Digital Service, 2022). Within the mapped area all woodland on well drained ground comprises four NVC communities (Rodwell, 1991, Table 12).

The floristic tables from the published NVC accounts are available online (JNCC, 2020). These floristic tables list 80 vascular plant taxa, recorded in the W11, W17 and W19 communities, but which are not listed for W18 woodland. Of these 80 taxa, 75 are recorded within the Cairngorms Connect boundary as native species. A coincidence map of the number of these discriminatory taxa (for non W18 woodland) was created (Fig. 25).

Table 12. Woodland NVC communities of dry ground, mapped in Cairngorms Connect area

NVC Code	NVC Community	Percentage of NVC woodland area
W11	*Quercus petraea-Betula pubescens-Oxalis acetosella* woodland	5.3
W17	*Quercus petraea-Betula pubescens-Dicranum majus* woodland	3.2
W18	*Pinus sylvestris-Hylocomium splendens* woodland	89.5
W19	*Juniperus communis* subsp. *communis-Oxalis acetosella* woodland	2.0

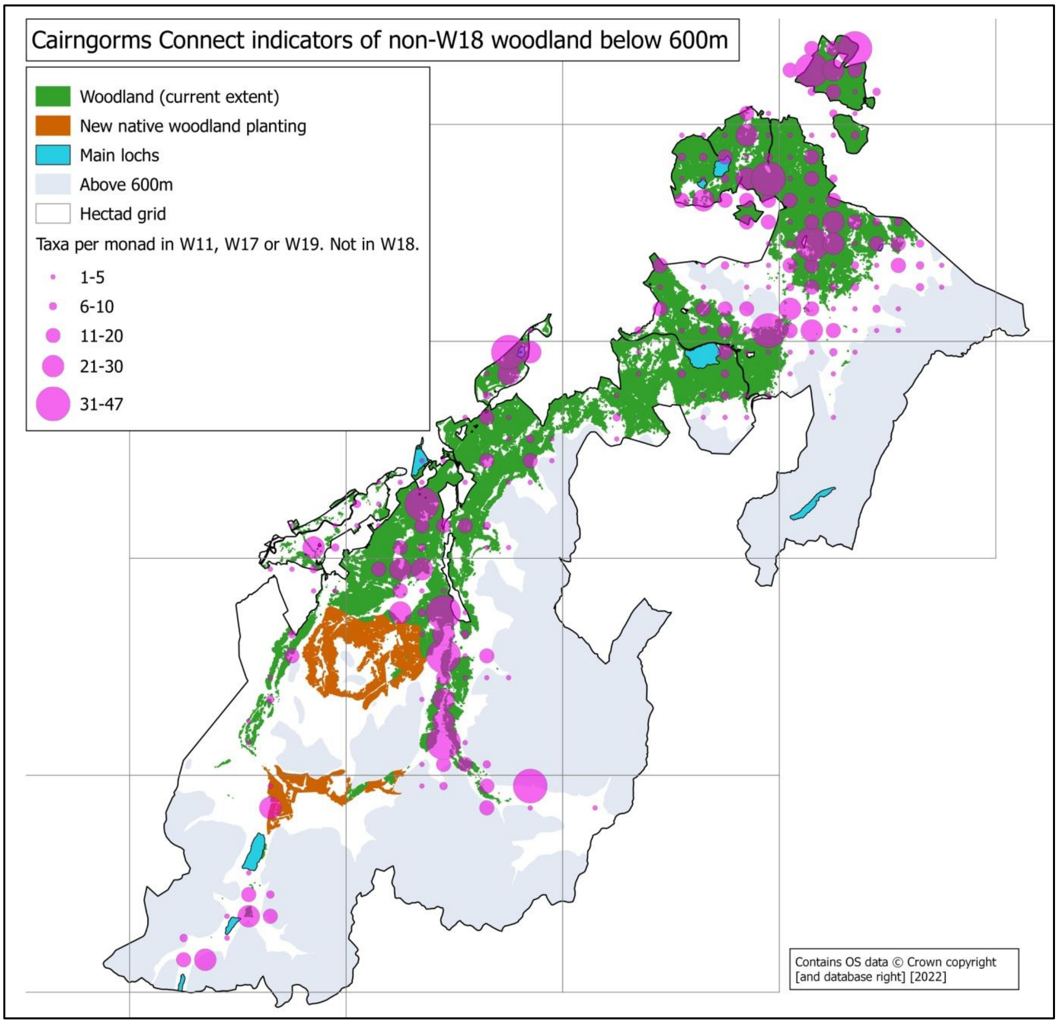

Figure 25. Coincidence map of indicators of non-W18 woodland

The coincidence mapping highlights concentrations of these taxa in *c.*10 locations. These are, from north to south:

- Craigmore Wood, including along the Backharn Burn.
- Tore Hill.
- Tulloch Moor.
- Rynettin area and along the River Nethy, south of Forest Lodge.
- Ryvoan Pass and nearby.
- Kinrara.
- Invertromie and Dell of Killiehuntly.
- Inshriach, north of Uath Lochans.
- Glen Feshie.
- Glens south of Gaick Lodge (where there has only been limited recording at monad or better precision).

D.4 Distribution of taxa of neutral to high pH soils

The proportions of native taxa associated with acid vs. neutral or high pH soils per monad is shown in Fig. 26.

There is wide variation in the proportion of taxa associated with neutral to high pH soils, median 5.0% (inter quartile range 1.0-22.0). Only considering monads with more than 10 taxa recorded, the median is 12.5% (inter quartile range 3.0-30.0). While taxa of acid conditions dominate over wide areas, there are areas where taxa of neutral to high pH conditions comprise a significant minority of the taxa. These areas are similar to those with concentrations of indicators of non-W18 woodland (Fig. 24), but with several additions. These include from north to south:

- Marginal areas of Abernethy Forest, including Garten Wood.
- Coire Dearg (Bynack).
- Insh Marshes and adjacent ground.
- Montane ground on the east side of Glen Feshie, e.g. Coire Gharbhlach.
- Additional monads in the Gaick area.

Peterken (1996) stated that at least three major woodland types have become virtually extinct at a national scale: floodplain forest, tree line forest and pinewoods on dry base-rich soils. All three types occur, and have the potential to be expanded and enhanced, within the Cairngorms Connect area. In Glen Feshie, scattered woodland and tree regeneration occurs on the steep flanks of the upper glen and along the valley floor (Fig. 27). This area of woodland has changed little in extent since the mid-18th century Roy map. 100 m grid cells with trees or regeneration, visible on current air photos were used to query the BSBI database. The area, 241 ha, has records of 154 native taxa at 100 m or better precision. NVC mapping shows that the area supports all four woodland types (W11, W17, W18 and W19). Additionally, there is a mosaic of 11 other NVC communities, including CG10 (*Festuca ovina* - *Agrostis capillaris* - *Thymus praecox* grassland) and CG11 (*Festuca ovina* - *Agrostis capillaris* - *Alchemilla alpina* grass-heath).

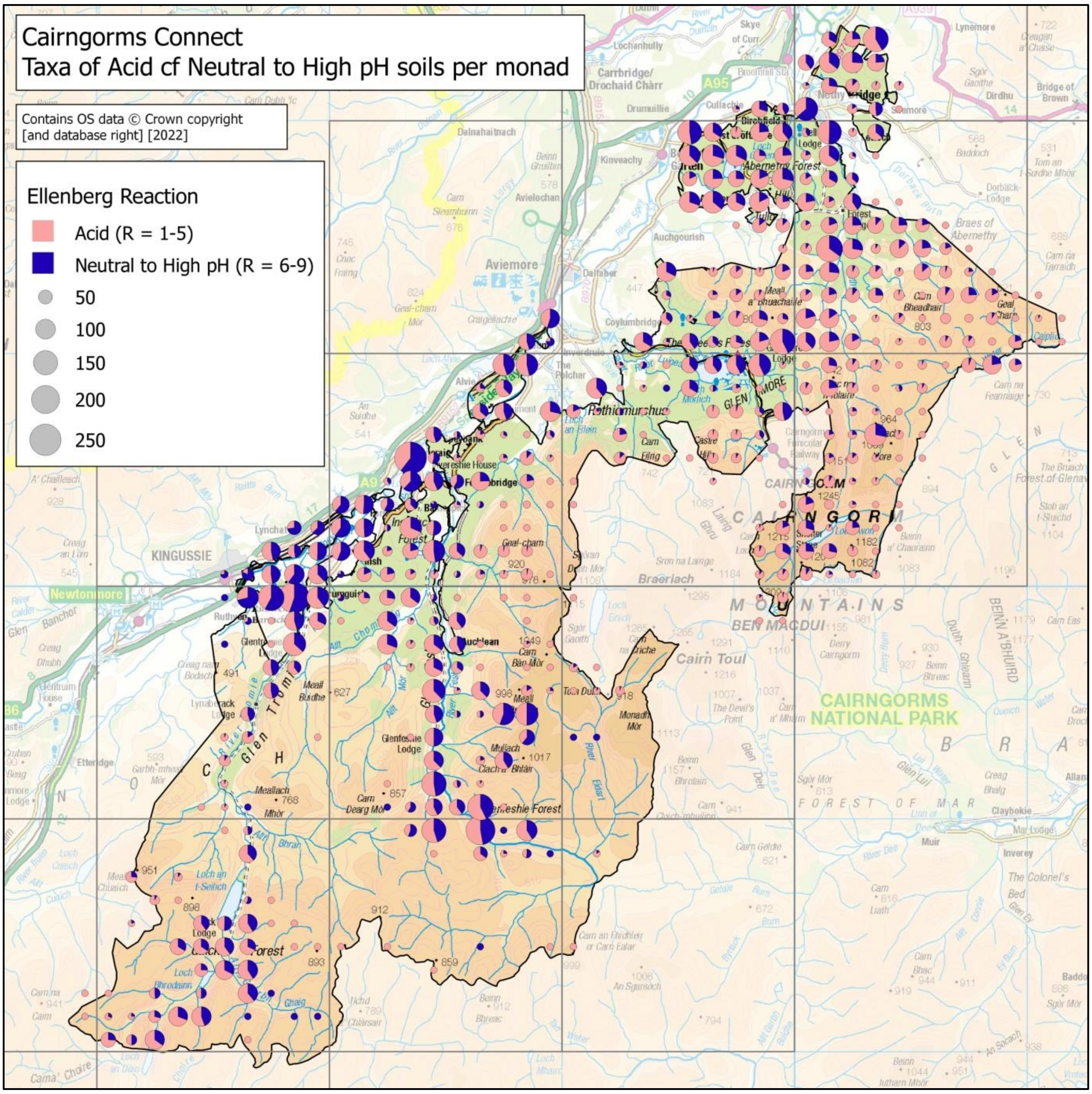

Figure 26. Frequency of native taxa associated with acid cf neutral or high pH conditions per monad

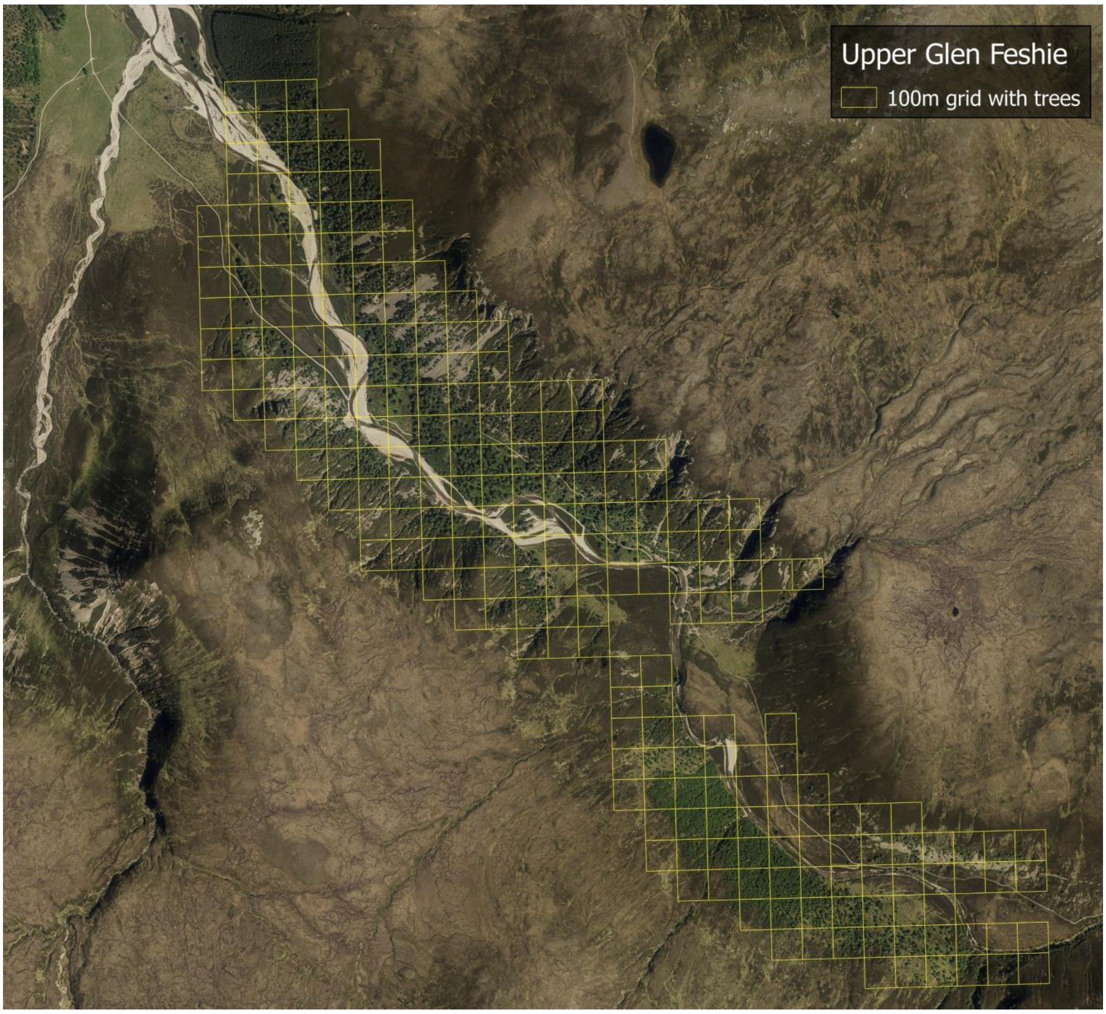

Figure 27. Upper Glen Feshie. 100 m grid cells with visible trees and regeneration, south-east of OS grid reference NN848916. © Microsoft 2022: Image courtesy of Ordnance Survey

Of the 154 native taxa recorded, 65 (42%) have Ellenberg Reaction values of between 6 and 8, signifying neutral to high pH soils. A spectacular example are the sheets of *Ervilia sylvatica* (Wood Vetch) that grow in the pinewood here (Fig. 28).

Figure 28. *Ervilia sylvatica* (Wood Vetch) growing in profusion in open *Pinus sylvestris* woodland in upper Glen Feshie

D.5 Distribution of selected woodland species

Coincidence mapping of six woodland species shows a high degree of overlap for four of these species with areas of Ancient Woodland (NatureScot, 2022) and core Caledonian Pinewood (Forestry Commission, 1999) (Fig. 29). Most records outwith these areas of woodland are nearby.

The two species of *Pyrola* (Wintergreen), while characteristic woodland species, are also found on adjacent heathland, occasionally above 600 m altitude.

The concentration of records within Abernethy Forest in part reflects the more intensive recording in that area. However, the relative lack of records from large plantation areas to the south-west, eg. Inshriach, may be a true reflection of the species' scarcity away from areas with a long history of continuous woodland cover.

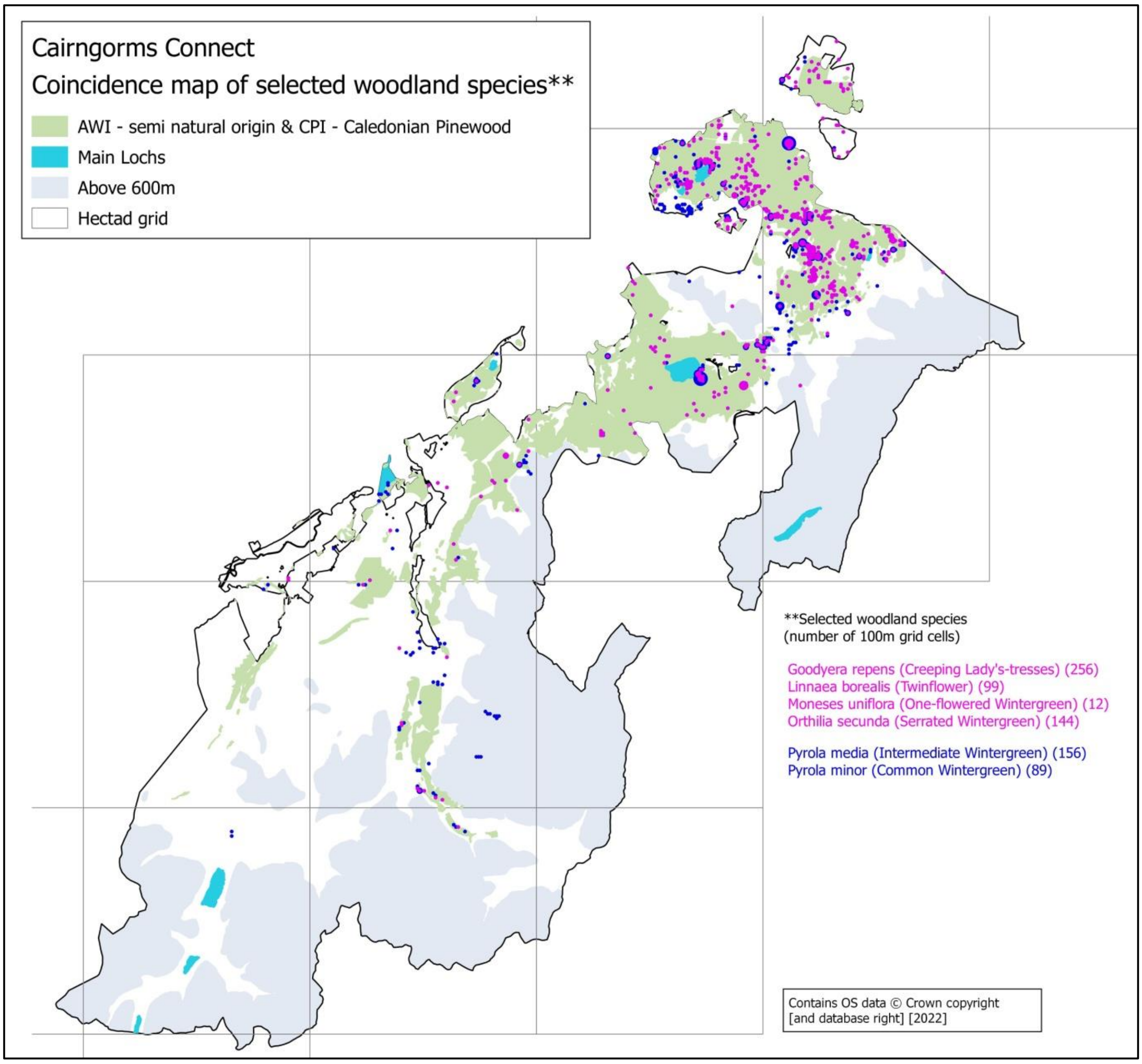

Figure 29. Coincidence map of distribution of six woodland plant species, compared to the extent of Ancient Woodland (Scottish Ancient Woodland Inventory, NatureScot, 2022) and core Caledonian Pinewood (Caledonian Pinewood Inventory, Forestry Commission, 1999)

Discussion and Conclusions

The Cairngorms Connect area is of high public interest to a variety of communities of interest, in addition to the geographically local communities. The project partners undertake a wide range of public outreach events and activities, as well as formal consultations targeted at local communities. While the project partners share a long-term vision, there is no single unified management plan. Forestry and Land Scotland have published a management plan for their ownership area, and NatureScot have a management plan available on line for one of the two NNRs that they own. RSPB Scotland produces 5-yearly management plans for its nature reserves, but the plans for the Abernethy and Insh Marshes NNRs are not published. Insh Marshes has consulted widely, via the Cairngorms Connect website, regarding future options for management of the floodplain. Wildland Ltd. do not publish a management plan. It is, therefore, quite difficult for these wider communities of interest to assess what is happening across the whole area. Therefore, parts A and B of this paper provide an overview of the area, its history, and present and potential habitats.

The rate at which the four landowners are moving towards achieving their shared long-term vision varies. For example, at Abernethy Forest, RSPB Scotland intends to carry out further extractive thinning of plantations over the next 5-10 years and then cease, while Forestry and Land Scotland envisage extracting timber from their plantations for at least another 50 years. Reductions in deer numbers have happened at different rates too. In Glen Feshie, deer densities of 35-40 km^{-2} in 2007, were reduced to <2 km^{-2} (Cairngorms Connect, 2022). At Abernethy Forest, reductions in deer densities happened more gradually, over a longer time period.

Reduction in the forest area has been a consequence of clearance by humans, commencing in the Cairngorms Connect area *c.*4000 years ago, in conjunction with a decrease in the altitude of the tree line due to changing climate. Therefore, some non-wooded areas may have been open habitats for almost as long as they previously supported forest. Within the modern historical period, the forests of the Cairngorms Connect area have been used by man, sometimes exploited, and sometimes (especially in the 20th century) abused. The forest areas we see today are heavily modified and compromised as compared to their *original-natural* state. A thorough and consistent re-mapping of the current woodland area, the distribution and abundance of tree regeneration and clarification of existing and former plantations is a priority.

The natural tree line was considerably higher in the past, and with climate change may again ascend higher in the future. But this is not certain, as the tree line is, in part, determined by wind exposure. Similarly, it is difficult to predict the rate of forest expansion through natural regeneration. The majority of seeds fall to the ground close to parent trees; often quoted as twice the radius of the tree height. However, some seed travels further, and a minority, much further. The thin scatter of *P. sylvestris* seedlings and saplings around Loch Avon are a minimum of 5 km from the nearest possible seed source. Legg (1995) suggested wind dispersed species in effect utilise two scales of seed dispersal. First, the creation of a dense seed rain from which a new stand or population can be established to replace the parent generation. Second, the migration of isolated plants to new geographic locations from which new populations can develop. Natural regeneration of *P. sylvestris* in the Cairngorms Connect area very obviously occurs at both these spatial scales, and the longer distance seed dispersal is crucial to the overall rate of forest expansion.

Parts C and D of the paper make use of a large combined dataset of plant records. It would have been impossible to write the paper without this pooled resource. Overall, the assemblage of native taxa is now well known, though inevitably additions will continue to be made, both of overlooked taxa or ones newly arriving. Some species, especially those with the bulk of their distribution at intermediate altitudes, may be under recorded relative to other taxa. It would be worthwhile surveyors being alert to the possibility of finding *B. pubescens* showing signs of introgression from *B. nana*. This would be of considerable taxonomic interest, as the Scandinavian and Icelandic *B. pubescens* var. *pumila* is not yet confirmed from Scotland. Of the native taxa, 81% have been recorded since 2000, 96% since 1970 and 99% since 1950. There is little indication that native taxa are being lost. However, most taxa are local or rare in the area.

In Section D, attention is given to two parameters that, it is suggested, are key to the majority of the native taxa that occur below the tree line. Only 12% of native taxa are shade tolerant, and even when only considering taxa that occur below the tree line, this does not rise above 15%. In contrast, 88% of native taxa are associated with partial shade to full illumination. This pattern holds at all altitudes and across the whole Cairngorms Connect area, as measured at the monad scale. For taxa of national conservation concern, two thirds are associated with full illumination. Most native taxa are low growing. Around one quarter of taxa, at monad scale, are shorter than 30 cm maximum height across the whole Cairngorms Connect area. To achieve forest expansion to the natural tree line by natural regeneration will require sustained low levels of grazing and browsing, for decades, or longer. This is already leading to a taller field layer and an increased density of tree regeneration. That most taxa favour no more than partial shade, and that a significant proportion are low growing, strongly suggests that these taxa may be disadvantaged in the long term. Limited disturbance and lack of open sites and bare ground for seedling recruitment is another potential constraint on vascular plants. The issue of vegetation succession and shading, leading to possible loss of plant diversity is likely to be much less of an issue at altitudes around and above the tree line. Indeed, here there are likely to be benefits, with possible expansion of tall herb communities.

Paleoecological studies clearly indicate that Scots Pine dominated forest is over represented. The distribution of non W18 indicator species and of taxa associated with neutral to higher pH soils overlap, but are not identical. The occurrence of pinewoods on base rich soils in upper Glen Feshie is highlighted as an example of a rare woodland type. Definitions of woodland types, for example in the National Vegetation Classification (NVC), should not be viewed as targets or as a straitjacket. Vegetation communities are described in terms of species composition, frequency and abundance. Therefore, published vegetation communities, including woodland types, should be seen as nodes within a multidimensional mathematical space. Amphlett (2003) gives examples of woodland and scrub communities that fall outwith the published NVC communities, i.e. pine woods on mires, Juniper on mires and wet heaths, and scrub dominated by *Salix aurita* (Eared Willow). It is reasonable to expect novel combinations of species to emerge, as habitats change, influenced by natural processes and climate change. Our designation and plant community frameworks may need to adapt to this dynamism.

The distribution of a set of characteristic, and charismatic woodland species shows an association with areas mapped as Ancient Woodland and/or Caledonian Pinewood. While there may be an element of recording bias, the relative lack of records from large plantation areas to the south-west, eg. Inshriach, may be a true reflection of the species' scarcity away from areas with a long history of continuous woodland cover.

What are the implications of this for forest expansion? It is likely to be advantageous for new areas of woodland to be contiguous with existing woodland. The benefits to colonisation by woodland taxa probably apply to almost all taxonomic groups. Given that the ambitious long-term plan is to expand woodland to the natural tree line, and that parts of this area are remote from existing woodland, new woodland planting has been undertaken.

Old growth *P. sylvestris* woodland can comprise high-crown stands, with a ± continuous canopy, at relatively high stem density or old open-grown trees, at low stem density, often referred to as 'granny pines'. Both are natural, the latter occurring where regeneration occurs at low density, and the developing trees are not shaded by adjacent neighbouring trees. Of course, every intermediate may occur. In addition to their exceptional value as landscape features, large, old, open grown pines are favoured by some key pinewood species, including male Capercaillie (*Tetrao urogallus*) in winter and nesting Crossbills (*Loxia* spp.) (Summers, 2018). Site managers may not be able to finely adjust conditions to favour specific regeneration densities, but they should be ready to accept low densities of pine regeneration as sufficient to create a pinewood ecosystem, at least in some areas. In Abernethy, old open pines in a former ploughed and planted plantation, with unnaturally high density of pine regeneration, have been 'rescued' from shading, by felling all surrounding pines (Fig. 30). The halo of cleared ground is visible around each tree.

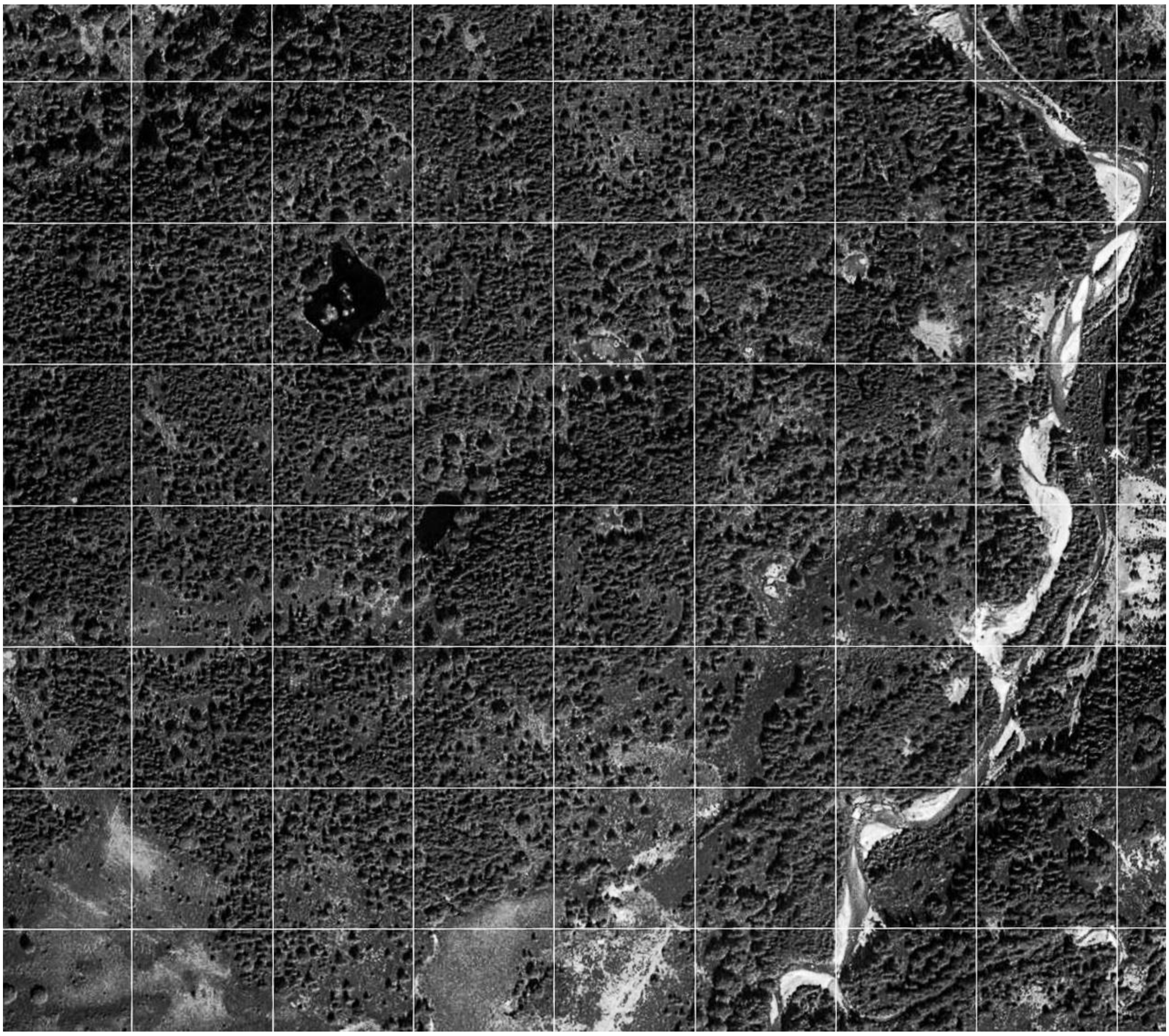

Figure 30. Dense regeneration and planted pines within ex plantation, Clais Eich, Abernethy Forest, felled around old open-grown *Pinus sylvestris*. Grid lines are 100 m apart. Centre of photograph OS grid reference NJ019127. © Google 2022

In a natural boreal forest, the various processes of disturbance, operating at a range of spatial and temporal scales, and range of intensities, creates a diverse mosaic of forest and field layer patches, and micro-habitats. The main agents of disturbance are: fire, wind-blow, wind-snap, insect outbreaks, fungal attacks, snow-break, flooding, avalanche, density dependent self-thinning and large herbivores.

It has been accepted knowledge for over 150 years that Scots Pines can regenerate freely beyond the canopy of the parent trees, and that regeneration is rarely found within existing stands (Dunlop, 1997). This is the so called 'moving forest principle'. However, if we consider that woodland, primarily dominated by *P. sylvestris*, covered almost all the ground below the tree line for around 4000 years, prior to *c.*4000 BP, then where did the 'moving forest' move to? The obvious answer is that disturbances were sufficient to allow pine to periodically regenerate. In actuality, pine will regenerate below the canopy of older pines as long as there is sufficient illumination, e.g. in the woodland by Loch Mallachie, in Abernethy Forest (Miller, 1996). A recent Polish study (Zawadzka & Słupska, 2022) recorded sub-canopy regeneration of *P. sylvestris* in 29 forest stands affected by hurricane level winds in July 2002. The forest stands varied from 49-117 years of age, and from 17-30 m in height. Patches of sub-canopy regeneration had a mean area of 408 m^2 (range 15-2340 m^2), with a density equivalent to 7820 ha^{-1}. The 'moving forest' principle is actually an artefact of observing pine forests within a deforested landscape.

A related question refers to the persistence of broadleaves within the *original-natural* forest, given that, in the absence of vegetative reproduction (suckering or layering), most broadleaf tree species have a much shorter potential lifespan than *P. sylvestris*. The modelling by Pratt (2006) indicated that the area of mixed *P. sylvestris* – broadleaf woodland and broadleaf woodland (as a percentage of the total woodland area), varied between 20 and 37% over a *c.*2000-year period, prior to 4260 BP. Again, the persistence of broadleaves, must, in large measure be due to disturbance. All broadleaves are browsing limited, and *Betula* and *Salix* species are also limited by availability of a suitable seedbed. Kuuluvainen (1994) emphasised the importance of disturbance created gaps in maintaining early successional tree species in boreal forests. As a society, we have still yet to come to terms with just how messy a forest of natural character could be. Yet this chaos will, in time, be what drives biodiversity within the Cairngorms Connect forest area.

Detailed research on the genetics of *Linnaea borealis* (Wiberg *et al.*, 2016) and *Salix lapponum* (Downy Willow) and *S. myrsinites* (Whortle-leaved Willow) (Finger, 2020) has led to well justified, targeted planting. However, some tree planting remains contentious (Dunlop *et al.* 2013; Summers, 2018). The argument for increasing the broadleaf element in some parts of the pine dominated forest is well evidenced, but it does not automatically follow that planting is always the appropriate management response. Other options include: a). reducing browsing, by further deer culling; b) increasing natural protection from browsing by leaving all windblown trees, and mimicking windblow in plantations by pulling over trees; c) enhancing ground conditions to favour tree regeneration by pulses of heavier grazing, burning, and creation of pit and mound microtopography by pulling over trees in plantations; d) spreading of seed.

Some heath areas have a very low diversity of vascular plants. Adding trees to such areas, by natural regeneration or planting, makes for only a modest increase in diversity; species poor heaths becoming species poor woodland. What is the long term thinking for such areas? Should herbaceous woodland species be introduced into some parts of the newly expanding woodland?

The timescales over which a forest develops and changes are hard for us to grasp. There may, therefore, be a tendency to think statically, despite being aware of processes that act over decades and centuries, and that the climate is changing. For the four Cairngorms Connect land owners to share a long-term vision, for so large an area, is exactly what is required. But is a 200-year vision even meaningful? It is inconceivable that we can predict the state of the environment, climate, society and politics, so far ahead. The benefit of having an agreed long-term vision, is that short- and medium-term management goals can be compared to, and tested against, the long-term vision. Are actions now, compatible with the long-term vision, and do they move habitats forwards towards that distant goal? Although not comprising a single management unit, the Cairngorms Connect project will, hopefully, encourage a less parochial, less single ownership-based view of land and species management. In order to scale up nature conservation, and achieve economies of scale (e.g. in deer control), more large scale partnerships like Cairngorms Connect should be developed.

Acknowledgements
The vascular plant data analysed in this paper was collected by well over 500 individual recorders, and includes substantial datasets from RSPB Scotland, NatureScot and others. The mapping made use of a number of publicly and freely available datasets, under the open (UK) government licence. The maps were created using QGIS, a free and open source Geographic Information System - https://www.qgis.org/en/site/. Tim Rich provided Ellenberg values for *Hieracium* species. Andy Scobie clarified a number of GIS queries. Richard Mason provided recent unpublished datasets from RSPB at Abernethy Forest. David Hetherington helped me track down shapefiles of recently planted areas via the FLS website. I came across the insight that there are 'communities of interest', in addition to geographically local communities, in a response from Mountaineering Scotland to one of the Cairngorm Connect partners. An earlier draft of this paper was commented on by Mark Hancock (RSPB), Andy Scobie (NatureScot) and Richard Thompson (FLS).

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Appendix 1

Taxa of National Conservation Concern, recorded from the Cairngorms Connect area.

TAXON	Common name	Most recent year	Red List	National status	Endemic
Alchemilla glomerulans	Clustered Lady's-mantle	2007	VU	NS	
Alopecurus magellanicus	Alpine Foxtail	2020		NS	
Arabidopsis petraea	Northern Rock-cress	2021	VU	NS	
Arctostaphylos alpinus	Alpine Bearberry	2013		NS	
Aristavena setacea *	Bog Hair-grass	2021		NS	
Athyrium distentifolium	Alpine Lady-fern	2021		NS	
Betula nana	Dwarf Birch	2019		NS	
Calamagrostis purpurea	Scandinavian Small-reed	2018	DD	NR	
Calamagrostis stricta	Narrow Small-reed	2013	VU	NR	
Carex aquatilis x nigra = C. x hibernica	Water x Common Sedge	2020	VU	NR	
Carex atrata	Black Alpine-sedge	2020		NS	
Carex bigelowii x nigra = C. x decolorans	Stiff x Common Sedge	2013		NS	
Carex capillaris	Hair Sedge	2013		NS	
Carex chordorrhiza	String Sedge	2017		NR	
Carex diandra	Lesser Tussock-sedge	2005	NT		
Carex lachenalii	Hare's-foot Sedge	2013	NT	NR	
Carex rariflora	Mountain Bog-sedge	2013		NR	
Carex rupestris	Rock Sedge	2013		NS	
Carex saxatilis	Russet Sedge	2012		NS	
Carex vaginata	Sheathed Sedge	2016		NS	
Cerastium alpinum	Alpine Mouse-ear	2020	VU	NS	
Cerastium alpinum x fontanum = C. x symei	Alpine x Common Mouse-ear	1951		NS	
Cerastium cerastoides	Starwort Mouse-ear	2006		NS	
Cerastium nigrescens	Arctic Mouse-ear	2013	NT	NS	
Cherleria sedoides *	Cyphel	2013	VU	NS	
Cicuta virosa	Cowbane	2019		NS	
Cochlearia micacea	Mountain Scurvygrass	1989		NS	Scottish endemic
Coeloglossum viride	Frog Orchid	2020	VU		
Corallorhiza trifida	Coralroot Orchid	2021	VU	NS	
Cornus suecica	Dwarf Cornel	2019	NT		
Cystopteris dickieana	Dickie's Bladder-fern	2016	VU	NR	
Cystopteris montana	Mountain Bladder-fern	2013		NR	
Dactylorhiza maculata x Gymnadenia borealis = X Dactylodenia evansii	Heath Spotted-orchid x Heath Fragrant-orchid	2020		NS	
Deschampsia cespitosa subsp. alpina	Alpine Hair-grass	2013	DD		

Diphasiastrum x issleri *	Issler's Clubmoss	2021	NT	NR	
Draba norvegica	Rock Whitlowgrass	2013		NS	
Drosera anglica	Great Sundew	2018	NT		
Dryas octopetala	Mountain Avens	2020		NS	
Equisetum pratense	Shady Horsetail	2020		NS	
Equisetum pratense x sylvaticum = E. x mildeanum	Shady x Wood Horsetail	2010		NS	
Euphrasia arctica	Arctic Eyebright	2019	NT		
Euphrasia confusa	Confused Eyebright	2008	VU		
Euphrasia frigida	Upland Eyebright	2017	EN		
Euphrasia micrantha	Slender Eyebright	2017	VU		
Euphrasia nemorosa	Common Eyebright	1991	NT		
Euphrasia ostenfeldii	Ostenfeld's Eyebright	1973	VU	NS	
Euphrasia scottica	Scottish Eyebright	2008	NT		
Genista anglica	Petty Whin	2021	NT		
Gentianella campestris	Field Gentian	2019	VU		
Hieracium aggregatum	Aggregate-headed Hawkweed	1969	NT	NR	Scottish endemic
Hieracium alpinum	Alpine Hawkweed	2006		NS	
Hieracium anfractiforme	Jagged-toothed Hawkweed	1974		NS	Scottish endemic
Hieracium beebyanum	Beeby's Hawkweed	1950		NS	GB & Ireland Endemic
Hieracium caesiomurorum	Long-stalked Hawkweed	1956		NS	
Hieracium caledonicum	Caledonian Hawkweed	1973		NS	Scottish endemic
Hieracium calvum	Bald-leaved Hawkweed	1981	CR	NR	Cairngorms endemic
Hieracium centripetale	Velvet-headed Hawkweed	1887		NS	Scottish endemic
Hieracium cerinthiforme	Clasping-leaved Hawkweed	1957		NS	GB & Ireland Endemic
Hieracium chloranthum	Green-flowered Hawkweed	1998		NS	Scottish endemic
Hieracium completum	Complete Hawkweed	1977		NS	Cairngorms endemic
Hieracium cremnanthes	Cliff Hawkweed	2008		NR	Scottish endemic
Hieracium diaphanoides	Diaphanous Hawkweed	2018		NS	
Hieracium eximium	Hirsute Hawkweed	2006		NS	Scottish endemic
Hieracium flocculosum	Stellate-haired Hawkweed	1974		NS	GB & Ireland Endemic
Hieracium fucatifolium	Painted-leaved Hawkweed	1983		NR	Scottish endemic
Hieracium glandulidens	Glandular-toothed Hawkweed	1977		NS	Scottish endemic
Hieracium globosiflorum	Round-headed Hawkweed	2006		NR	Cairngorms endemic

Hieracium gothicoides	Broad-headed Hawkweed	1956		NR	Scottish endemic
Hieracium grampianum	Grampian Hawkweed	1974		NS	Scottish endemic
Hieracium graniticola	Granite Hawkweed	1981	CR	NR	Cairngorms endemic
Hieracium grovesii	Grove's Hawkweed	1983	EN	NR	Cairngorms endemic
Hieracium hanburyi	Hanbury's Hawkweed	1998		NS	Scottish endemic
Hieracium holosericeum	Shaggy Hawkweed	1981		NS	GB endemic
Hieracium insigne	Noble Hawkweed	1977	EN	NR	Scottish endemic
Hieracium iricum	Erin Hawkweed	1974		NS	
Hieracium laetificum	Black-headed Hawkweed	1977		NS	Scottish endemic
Hieracium lasiophyllum	Stiff-haired Hawkweed	1956		NS	
Hieracium lingulatum	Oblong-leaved Hawkweed	1983		NS	Scottish endemic
Hieracium macrocarpum	Large-fruited Hawkweed	1967	VU	NR	Scottish endemic
Hieracium memorabile	Memorable Hawkweed	1967		NS	Scottish endemic
Hieracium molybdochroum	Mountain Hawkweed	1966	VU	NR	
Hieracium nitidum	Shining-leaved Hawkweed	2021		NS	Scottish endemic
Hieracium orithales	Short-stemmed Hawkweed	1969	NT	NR	Scottish endemic
Hieracium oxybeles	Pointed-leaved Hawkweed	1974		NS	GB & Ireland Endemic
Hieracium petrocharis	Crag Hawkweed	1956		NS	Scottish endemic
Hieracium pictorum	Picts Hawkweed	1974		NS	Scottish endemic
Hieracium piligerum	Brindled Hawkweed	1975		NS	GB endemic
Hieracium pseudanglicoides	Entire-leaved Hawkweed	1983		NS	Scottish endemic
Hieracium pseudanglicum	Upland Hawkweed	2008		NS	Scottish endemic
Hieracium pseudocurvatum	Cairngorm Hawkweed	1966	CR	NR	Cairngorms endemic
Hieracium pseudopetiolatum	Narrow-leaved Hawkweed	1852	EN	NR	Scottish endemic
Hieracium rubicundiforme	Rubicund Hawkweed	1975		NS	GB & Ireland Endemic
Hieracium saxorum	Rock Hawkweed	1974		NS	GB & Ireland Endemic
Hieracium stenopholidium	Western Hawkweed	1969		NS	
Hieracium subcrinellum	Blunt-leaved Hawkweed	1969		NS	GB endemic

Hieracium subhirtum	Hairy-headed Hawkweed	1973		NS	Scottish endemic
Hieracium subtenue	Dark-bracted Hawkweed	2021		NS	Scottish endemic
Hieracium subtenuifrons	Highland Hawkweed	1966		NR	Scottish Endemic
Hieracium subumbellatiforme	Slender Hawkweed	1955		NS	Scottish endemic
Hieracium uiginskyense	Uig Hawkweed	1974		NS	GB & Ireland Endemic
Hymenophyllum wilsonii	Wilson's Filmy-fern	2018	NT		
Juncus castaneus	Chestnut Rush	2021	VU	NS	
Linnaea borealis	Twinflower	2020		NS	
Luzula arcuata	Curved Wood-rush	2014	VU	NR	
Lycopodiella inundata	Marsh Clubmoss	1970	EN	NS	
Lycopodium annotinum	Interrupted Clubmoss	2021		NS	
Lycopodium lagopus	Hare's-foot Clubmoss	2021	VU (Waiting List)		
Melampyrum sylvaticum	Small Cow-wheat	2008	EN	NS	
Meum athamanticum	Spignel	2012	NT	NS	
Micranthes nivalis *	Alpine Saxifrage	2013		NS	
Moneses uniflora	One-flowered Wintergreen	2019	VU	NR	
Nuphar pumila	Least Water-lily	2017		NS	
Omalotheca supina *	Dwarf Cudweed	2020	NT		
Omalotheca sylvatica *	Heath Cudweed	2021	EN		
Persicaria minor	Small Water-pepper	2016	VU		
Phleum alpinum	Alpine Cat's-tail	2013		NS	
Pilularia globulifera	Pillwort	2004	NT	NS	
Pinus sylvestris	Scots Pine	2021		NS	
Platanthera bifolia	Lesser Butterfly-orchid	1998	VU		
Platanthera chlorantha	Greater Butterfly-orchid	2019	NT		
Poa alpina	Alpine Meadow-grass	2013		NS	
Poa flexuosa	Wavy Meadow-grass	2013	VU	NR	
Poa glauca	Glaucous Meadow-grass	2013	VU	NS	
Polystichum lonchitis	Holly-fern	2020	VU		
Potamogeton gramineus x natans = P. x sparganiifolius	Ribbon-leaved Pondweed	1942		NS	
Potamogeton praelongus	Long-stalked Pondweed	1991	NT		
Potentilla crantzii	Alpine Cinquefoil	2007		NS	
Pseudorchis albida	Small-white Orchid	2021	VU		
Pyrola media	Intermediate Wintergreen	2021	VU	NS	
Ranunculus flammula subsp. scoticus	Lesser Spearwort	1997	DD	NS	

Rhinanthus minor subsp. borealis	Yellow-rattle	2015	DD		
Rhinanthus minor subsp. monticola	Yellow-rattle	2016	DD		
Ribes spicatum	Downy Currant	2021		NS	
Rubus arcticus	Arctic Bramble	pre-1844	RE		
Sagina procumbens x saginoides = S. x normaniana	Scottish Pearlwort	2013		NS	
Sagina saginoides	Alpine Pearlwort	2013	EN	NS	
Salix arbuscula	Mountain Willow	1968		NS	
Salix herbacea x repens = S. x cernua	Dwarf x Creeping Willow	2013		NS	
Salix lanata	Woolly Willow	2020	VU	NR	
Salix lapponum	Downy Willow	2021	VU	NS	
Salix myrsinifolia x myrsinites = S. x punctata	Dark-leaved x Whortle-leaved Willow	2010		NS	
Salix myrsinites	Whortle-leaved Willow	2021	EN	NS	
Salix reticulata	Net-leaved Willow	2013		NS	
Saxifraga hypnoides	Mossy Saxifrage	2019	VU		
Scleranthus annuus	Annual Knawel	1973	EN		
Sibbaldia procumbens	Sibbaldia	2013	VU	NS	
Sorbus rupicola	Rock Whitebeam	1988		NS	
Taraxacum caledonicum	Caledonian Dandelion	1973		NS	Scottish endemic
Taraxacum ceratolobum	Bright Green Dandelion	1919		NS	
Taraxacum obtusifrons	Obtuse-leaved Dandelion	2015		NS	
Teesdalia nudicaulis	Shepherd's Cress	2015	NT		
Trichophorum cespitosum s.s.	Deergrass	2016	DD	NS	
Utricularia intermedia s.s.	Intermediate Bladderwort	1983	DD		
Utricularia stygia	Nordic Bladderwort	2019	DD		
Vaccinium microcarpum	Small Cranberry	2020		NS	
Veronica alpina	Alpine Speedwell	2013		NS	
Veronica fruticans	Rock Speedwell	2007	NT	NS	
Veronica serpyllifolia subsp. humifusa	Thyme-leaved Speedwell	2018	NT		
Viola canina	Heath Dog-violet	2019	NT		
Viola tricolor	Wild Pansy	2017	NT		
Woodsia ilvensis	Oblong Woodsia	2020	EN	NR	

CR	Critically Endangered
DD	Data Deficient
EN	Endangered
NT	Near Threatened
RE	Regionally Extinct
VU	Vulnerable
VU (Waiting List)	Vulnerable (on Waiting List)

NR Nationally Rare
NS Nationally Scarce

* Change of taxon name in Stace (2019)

Appendix 2

Native taxa, Very Rare or Rare in the Cairngorms National Park, or in the Scottish Biodiversity List, and recorded from the Cairngorms Connect area.

TAXON	Common name	Most recent year	CNP frequency / Scottish Biodiversity List (SBL)
Anthriscus caucalis	Bur Chervil	1972	Very Rare
Bidens cernua	Nodding Bur-marigold	2018	Very Rare
Calamagrostis epigejos	Wood Small-reed	2016	Rare
Callitriche hermaphroditica	Autumnal Water-starwort	1973	Rare
Callitriche platycarpa	Various-leaved Water-starwort	1991	Very Rare
Carex hirta	Hairy Sedge	1985	Very Rare
Carex laevigata	Smooth-stalked Sedge	1996	Rare
Carex limosa	Bog-sedge	2015	Rare
Carex rostrata x vesicaria = C. x involuta	Bottle x Bladder-sedge	2015	Very Rare
Carex sylvatica	Wood-sedge	2018	Rare
Carex viridula	Small-fruited Yellow-sedge	2006	Rare
Cerastium diffusum	Sea Mouse-ear	1998	Rare
Circaea alpina x lutetiana = C. x intermedia	Upland Enchanter's-nightshade	2018	Rare
Convolvulus arvensis	Field Bindweed	1973	Very Rare
Crassula tillaea	Mossy Stonecrop	2014	Rare
Dactylorhiza maculata x purpurella = D. x formosa	Heath Spotted x Northern Marsh-orchid	1973	Rare
Draba incana	Hoary Whitlowgrass	2013	SBL: Near Scarce
Drosera anglica x rotundifolia = D. x obovata	Hybrid Sundew	2016	Rare
Drymochloa altissima	Wood Fescue	1986	Very Rare
Dryopteris carthusiana x dilatata = D. x deweveri	Narrow Buckler x Broad Buckler-fern	2019	Very Rare
Eleocharis acicularis	Needle Spike-rush	1991	Rare
Epilobium parviflorum	Hoary Willowherb	1966	Rare
Euphrasia confusa x scottica	Confused x Scottish Eyebright	1974	Very Rare
Galium album	Hedge Bedstraw	2009	Rare
Glyceria notata	Plicate Sweet-grass	1983	Very Rare
Helosciadium inundatum	Lesser Marshwort	1987	Rare
Hieracium anglicum	English Hawkweed	1974	Rare
Hieracium argenteum	Silver Hawkweed	1974	Rare

Hieracium duriceps	Hard-headed Hawkweed	1974	Rare
Hieracium latobrigorum	Yellow-styled Hawkweed	1973	Very Rare
Hieracium shoolbredii	Shoolbred's Hawkweed	1976	Rare
Hylotelephium telephium	Orpine	2020	Rare
Hypericum androsaemum	Tutsan	2016	Rare
Hypericum tetrapterum	Square-stalked St John's-wort	1972	Very Rare
Isoetes echinospora	Spring Quillwort	2009	Rare
Jacobaea aquatica x vulgaris = J. x ostenfeldii	Marsh x Common Ragwort	2018	Very Rare
Jasione montana	Sheep's-bit	2010	Very Rare
Juncus acutiflorus x articulatus = J. x surrejanus	Sharp-flowered x Jointed Rush	1930	Very Rare
Juncus conglomeratus x effusus = J. x kern-reichgeltii	Compact x Soft-rush	2013	Rare
Juniperus communis	Common Juniper	2021	SBL: Very Common
Lysimachia vulgaris	Yellow Loosestrife	2020	Rare
Melica uniflora	Wood Melick	1956	Very Rare
Mentha arvensis	Corn Mint	1973	SBL: Scarce
Ononis repens	Common Restharrow	2020	Rare
Paris quadrifolia	Herb-paris	1975	Very Rare
Persicaria hydropiper	Water-pepper	1973	Very Rare
Persicaria lapathifolia	Pale Persicaria	1973	Very Rare
Potamogeton berchtoldii	Small Pondweed	2004	Rare
Potamogeton crispus	Curled Pondweed	1991	Rare
Potamogeton gramineus	Various-leaved Pondweed	1991	Rare
Rosa mollis x sherardii = R. x perthensis (f x m)	Soft Downy x Sherard's Downy-rose	1903	Very Rare
Rosa rubiginosa	Sweet-briar	2013	Rare
Rubus radula	Hairy Bramble	2019	Very Rare
Rumex crispus x longifolius = R. x propinquus	Curled x Northern Dock	2006	Rare
Salix cinerea x phylicifolia = S. x laurina	Laurel-leaved Willow	2020	Rare
Salix pentandra	Bay Willow	1998	Rare
Salix viminalis x caprea = S. x smithiana	Broad-leaved Osier	1983	Very Rare
Schoenoplectus lacustris	Common Club-rush	2013	Rare
Stachys palustris x sylvatica = S. x ambigua	Marsh x Hedge Woundwort	2016	Rare
Taraxacum aequilobum	Twisted-bracted Dandelion	2015	Very Rare
Taraxacum ancistrolobum	Few-lobed Dandelion	2015	Very Rare
Taraxacum cyanolepis	Bluish-bracted Dandelion	1973	Rare
Taraxacum duplidentifrons	Double-toothed Dandelion	2015	Rare

Taraxacum euryphyllum	Wide-stalked Dandelion	2020	Rare
Taraxacum fasciatum	Dense-bracted Dandelion	2015	Very Rare
Taraxacum lamprophyllum	Lustrous-leaved Dandelion	2015	Very Rare
Taraxacum lingulatum	Long-bracted Dandelion	2015	Very Rare
Taraxacum maculosum	Spotted Dandelion	1974	Rare
Taraxacum nordstedtii	Nordstedt's Dandelion	2020	Rare
Taraxacum oblongatum	Oblong-leaved Dandelion	2015	Very Rare
Taraxacum pannucium	Green-stalked Dandelion	2015	Very Rare
Taraxacum subhamatum	Large Hook-lobed Dandelion	2015	Very Rare
Taraxacum subnaevosum	Pale-bracted Dandelion	pre-1989	Very Rare
Typha latifolia	Bulrush	2016	Rare
Utricularia australis	Bladderwort	1991	Rare
Veronica montana	Wood Speedwell	2002	Very Rare

Appendix 3

Native taxa, recorded at monad or better precision, with >90% of records from <600 m altitude, and Ellenberg Light values 6-9, and Ellenberg Moisture (F) values 2-8.

Achillea millefolium
Achillea ptarmica
Agrostis canina s.s.
Agrostis stolonifera
Aira caryophyllea
Aira praecox
Alchemilla xanthochlora
Alopecurus geniculatus
Anthriscus caucalis
Anthriscus sylvestris
Anthyllis vulneraria
Aphanes arvensis agg.
Arabidopsis thaliana
Arctium minus s.l.
Arenaria serpyllifolia s.l.
Arrhenatherum elatius
Asplenium adiantum-nigrum s.s.
Asplenium ruta-muraria

Atriplex patula
Atriplex prostrata s.s.
Helictochloa pratensis (Avenula pratensis)
Avenula pubescens
Barbarea vulgaris
Bellis perennis
Betula pendula
Betula pubescens
Brachypodium sylvaticum
Briza media
Bromus hordeaceus
Calamagrostis epigejos
Calamagrostis purpurea
Calystegia sepium
Cardamine hirsuta
Cardamine pratensis
Carex caryophyllea
Carex hirta

Carex leporina
Carex pallescens
Centaurea nigra s.s.
Cerastium arvense
Cerastium fontanum
Cerastium glomeratum
Cerastium semidecandrum
Chamaenerion angustifolium (Chamerion angustifolium)
Chenopodium album s.s.
Cirsium arvense
Cirsium heterophyllum
Cirsium palustre
Cirsium vulgare
Conopodium majus
Crassula tillaea
Crataegus monogyna
Crepis capillaris

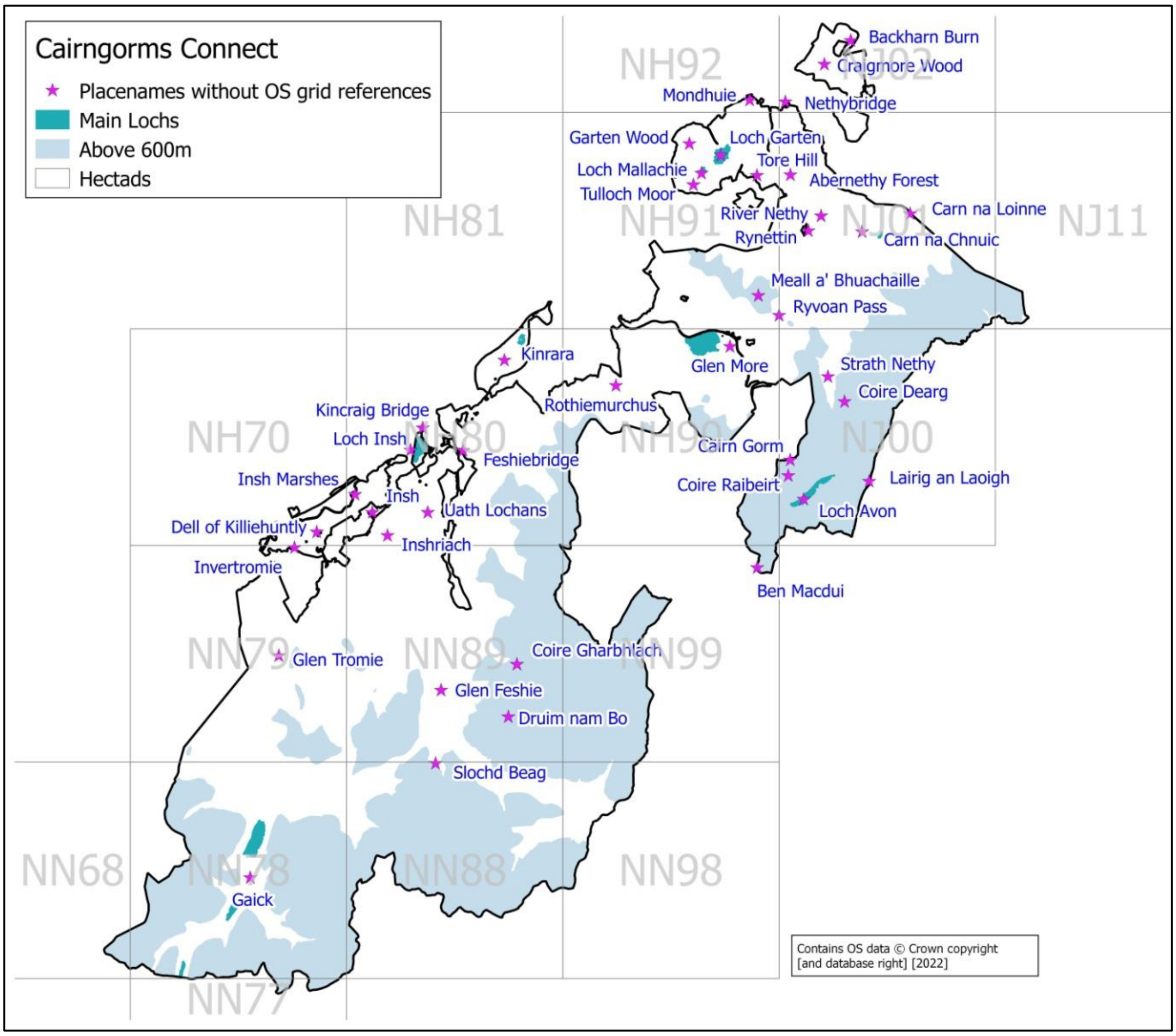
Cynosurus cristatus
Cytisus scoparius
Dactylis glomerata
Dactylorhiza fuchsii
Dactylorhiza maculata x Gymnadenia borealis = X Dactylodenia evansii
Dactylorhiza purpurella
Digitalis purpurea
Dryopteris carthusiana
Elymus caninus
Elymus repens (Elytrigia repens)
Epilobium obscurum
Epilobium palustre
Equisetum arvense
Equisetum palustre
Equisetum pratense x sylvaticum = E. x mildeanum
Erica cinerea
Erica tetralix
Erodium cicutarium s.s.
Euphrasia arctica
Euphrasia micrantha
Euphrasia ostenfeldii
Festuca filiformis
Ficaria verna
Logfia minima (Filago minima)
Filipendula ulmaria
Fragaria vesca
Galeopsis tetrahit agg.
Galium album
Galium aparine
Galium verum
Genista anglica
Gentianella campestris
Geranium lucidum
Geranium molle
Glechoma hederacea
Omalotheca sylvatica (Gnaphalium sylvaticum)
Gnaphalium uliginosum
Gymnadenia borealis
Helianthemum nummularium
Heracleum sphondylium
Hieracium anfractiforme

Hieracium beebyanum
Hieracium caesiomurorum
Hieracium chloranthum
Hieracium diaphanoides
Hieracium flocculosum
Hieracium fucatifolium
Hieracium gothicoides
Hieracium iricum
Hieracium latobrigorum
Hieracium nitidum
Hieracium oxybeles
Hieracium piligerum
Hieracium rubicundiforme
Hieracium saxorum
Hieracium triviale
Hieracium uiginskyense
Holcus lanatus
Holcus mollis
Hydrocotyle vulgaris
Hypericum humifusum
Hypericum maculatum
Hypericum perforatum
Hypericum pulchrum
Hypochaeris radicata
Jasione montana
Juncus acutiflorus
Juncus bufonius s.s.
Juncus conglomeratus
Juncus conglomeratus x effusus = J. x kern-reichgeltii
Juncus effusus
Koeleria macrantha s.s.
Lapsana communis
Lathyrus linifolius
Lathyrus pratensis
Lepidium heterophyllum
Leucanthemum vulgare
Linaria vulgaris
Linum catharticum
Lolium perenne
Lotus corniculatus
Lotus pedunculatus
Luzula campestris
Lycopodium clavatum
Medicago lupulina

Mentha aquatica
Mentha aquatica x arvensis = M. x verticillata
Mentha arvensis
Meum athamanticum
Molinia caerulea
Myosotis discolor
Myosotis sylvatica
Odontites vernus
Ononis repens
Ophioglossum vulgatum
Parnassia palustris
Pedicularis palustris
Pedicularis sylvatica
Persicaria maculosa
Persicaria minor
Phleum bertolonii
Phleum pratense s.s.
Pilosella officinarum
Pimpinella saxifraga
Plantago lanceolata
Plantago major
Plantago maritima
Platanthera bifolia
Poa annua
Poa humilis
Poa pratensis s.s.
Poa trivialis
Polygala serpyllifolia
Polygala vulgaris
Polygonum aviculare agg. (incl. s.s.)
Populus tremula
Potentilla anserina
Primula veris
Prunella vulgaris
Prunus spinosa
Pseudorchis albida
Pteridium aquilinum
Puccinellia distans
Quercus petraea
Quercus robur
Ranunculus bulbosus
Ranunculus repens
Rhinanthus minor

Rhinanthus minor subsp. monticola
Rosa caesia s.l.
Rosa canina agg.
Rosa canina s.s.
Rosa rubiginosa
Rubus fruticosus agg.
Rubus idaeus
Rubus radula
Rumex crispus
Rumex crispus x longifolius = R. x propinquus
Rumex longifolius
Rumex longifolius x obtusifolius = R. x hybridus
Rumex obtusifolius
Sagina apetala s.l.
Salix aurita x cinerea = S. x multinervis
Salix caprea
Salix caprea x cinerea = S. x reichardtii
Salix cinerea
Salix cinerea x phylicifolia = S. x laurina
Salix myrsinifolia x phylicifolia = S. x tetrapla
Salix pentandra
Salix repens
Salix viminalis x caprea = S. x smithiana
Sambucus nigra
Schedonorus pratensis
Scutellaria galericulata
Sedum acre
Hylotelephium telephium (Sedum telephium)
Jacobaea vulgaris x aquatica = J. x ostenfeldii
(Senecio aquaticus x jacobaea = S. x ostenfeldii)
Jacobaea vulgaris (Senecio jacobaea)
Senecio sylvaticus
Senecio vulgaris
Silene dioica x latifolia = S. x hampeana
Silene uniflora
Sonchus arvensis
Sonchus asper
Sonchus oleraceus
Sorbus rupicola
Spergularia marina
Spergularia rubra
Stachys palustris
Stachys palustris x sylvatica = S. x ambigua
Stachys sylvatica
Stellaria graminea
Stellaria media s.s.
Succisa pratensis
Symphytum tuberosum
Tanacetum vulgare
Taraxacum aequilobum
Taraxacum ancistrolobum
Taraxacum cyanolepis
Taraxacum duplidentifrons
Taraxacum euryphyllum
Taraxacum fasciatum
Taraxacum hamatum
Taraxacum lamprophyllum
Taraxacum lingulatum
Taraxacum maculosum
Taraxacum naevosiforme
Taraxacum nordstedtii
Taraxacum oblongatum
Taraxacum obtusifrons
Taraxacum pannucium
Taraxacum polyodon
Taraxacum subhamatum
Taraxacum sublaeticolor
Taraxacum subnaevosum
Teesdalia nudicaulis
Teucrium scorodonia
Torilis japonica
Trichophorum cespitosum s.s.
Trifolium campestre
Trifolium dubium
Trifolium medium
Trifolium pratense
Trifolium repens
Tussilago farfara
Ulex europaeus
Urtica dioica
Vaccinium microcarpum
Valeriana officinalis
Verbascum thapsus
Veronica arvensis
Veronica chamaedrys
Veronica officinalis
Viburnum opulus
Vicia cracca
Ervilia hirsuta (Vicia hirsuta)
Vicia sativa
Viola canina
Viola canina x riviniana = V. x intersita
Viola lutea
Viola tricolor
Woodsia ilvensis

Appendix 4: Place names referred to in the paper, without an OS grid reference



Appendix 5

The Wildland boundary from OS grid reference NN688813, near Meallan Buidhe, to the summit of Carn an Fhidhleir / Carn Ealar follows the v.c.89 (East Perthshire) / v.c.96 boundary. From the summit of Carn an Fhidhleir / Carn Ealar the Wildland boundary follows the v.c.92 (South Aberdeenshire) / v.c.96 boundary to OS grid reference NN937981 at Carn na Criche. The only significant discrepancy is a 1.1 km length of the Wildland boundary on the watershed between the River Feshie and the Geldie Burn in the 1 km squares NN9187 and NN9287. Here the Wildland and vice-county boundaries diverge by a maximum of *c.*115 metres. The RSPB (Abernethy) boundary follows the v.c.92 (South Aberdeenshire) / v.c.94 boundary from NH980017 (on Cairn Lochan) to the Lairig an Laoigh (at NJ033004).