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Ecology Division Forest Research

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This is an internal progress report to the FHN Scotland Steering Group describing the work carried out on the Forest Habitat Network (FHN) project for Scotland. The work is jointly funded by Forestry Commission Scotland, Scottish Natural Heritage and Forestry Commission GB.

The work has been agreed and orchestrated by the Project Steering Group.

Executive Summary

This work continues the Biological and Environmental Evaluation Tools for Landscape Ecology (BEETLE) focal species approach to landscape ecology (Watts *et al.* 2005) used in the national and regional analyses (Ray *et al.* 2005; Moseley *et al.* 2005; Grieve *et al.* 2006; Moseley & Ray 2006), to determine the functional connectivity of woodland in Grampian region.

The report provides a detailed analysis of specialised woodland networks in Grampian region of Scotland, with particular attention given to wet woodlands and broadleaved woodland located along riparian areas.

The analyses, presented at both regional and local scales, detail the extent of the current networks and indicate that, while the quality networks are quite widely distributed throughout the regions, much can be done to improve their functional connectivity. Recommendations to improve networks are given, with detailed examples of consolidating, expanding, and linking forest habitat networks at regional and local scales. The woodland networks are presented using a hierarchy of riparian and wet (Carr) woodland specialists, broadleaved specialists, followed by woodland generalists, enabling targeted improvement and linkage to be undertaken.

A number of methodologies were employed to suggest riparian and wet (Carr) woodland habitat in Grampian Region as a spatial inventory of these woodlands is lacking. Wet woodlands from survey data were supplemented by watercourse categories from the Scottish Semi-natural Woodland Inventory, potential distribution of these habitats predicted by the Scottish Natural Heritage (SNH) / Macaulay Institute Native Woodland Model, woodlands designated as wet woodland from a derived flood risk dataset, and the use of indicator plant species.

The identification of riparian and wet (Carr) woodland using indicator plant species provides an additional analysis of these habitats, allowing improvement of networks based on strategies of conservation, restoration, and buffered expansion. It is stressed that these networks contain key woodland areas for biodiversity, indicate dispersal routes, and as such provide the focus for forest habitat network strategies. A common characteristic of riparian woodlands is that they are very narrow, with many lacking core woodland. It is recommended that buffering these areas would greatly increase the functional connectivity of the networks, providing particular benefit to woodlands of high biodiversity.

The integration of the analyses into climate change strategies is briefly discussed, with suggestions for species migration via the woodland generalist and broadleaved specialist networks. Such strategies could consolidate genetic diversity but would require co-operation across a number of regions and agencies.

Networks for open ground species are explored using an analysis for heathland generalists. The potential areas of interaction between woodland and open ground networks are examined using an analysis of network overlap. It is stressed that the network analyses provide a tool for determining how to best improve the functional connectivity of woodland networks and are not designed to be prescriptive. Expansion of forest habitat networks on to open ground habitat should only occur following a site suitability using an Ecological Site Classification analysis and a considered examination of the potential impact on open ground users.

Attention is also given to the way the expansion of woodland can be incorporated with strategies to increase opportunities for woodland use by communities. Grampian contains a range of urban area sizes, providing an opportunity to focus on the way in which people and communities link with woodland and forestry issues at the landscape scale by determining accessibility to woodland at different scales.

The issue of data quality is discussed, with the recommendation that any additional data that are identified be made available to Forest Research to enable improvement of the analysis.

Contents

1. Introduction

The national scale analysis of habitat networks in Scotland identified and mapped networks for woodland generalists, broadleaved woodland specialists and heathland generalists (Sing 2005). This report expands on this work by providing a detailed analysis of specialised woodland networks in the Grampian region of Scotland by giving particular attention to wet woodland and broadleaved woodland located along riparian areas. The report gives detailed approaches to consolidating, expanding, and linking forest habitat networks at regional and local scales.

This work continues the Biological and Environmental Evaluation Tools for Landscape Ecology (BEETLE) least cost focal species approach to landscape ecology (Watts *et al.* 2005) used in the national and regional analyses (Ray *et al.* 2005; Moseley *et al.* 2005; Grieve *et al.* 2006; Moseley & Ray 2006), to determine the functional connectivity of woodland in Grampian region.

Attention is also given to the way the expansion of woodland can be incorporated with strategies to increase opportunities for woodland use by communities. Grampian Region contains the large conurbation of Aberdeen and many smaller communities, which allows an analysis of how people and communities link with woodland and forestry issues at the landscape scale by determining accessibility to woodland at different scales.

This study seeks to aid progress towards the region's contribution to UK and Local Biodiversity Action Plans, particularly for riparian and wet woodland habitats, which include:

- To maintain and enhance the extent and status of semi-natural wet woodlands and encourage a balance of appropriate management regimes (UK objective), habitat creation, data collection, promotion, education, liaison and legislation
- Prevent and/or reduce threats to the resource through continuation/ introduction of established management techniques at all identified sites
- Survey and assess all degraded wet and riparian woodland sites, identify restoration and enhancement priorities
- Expand the area of wet/riparian woodland through habitat creation and management
- Ensure no loss in the key biodiversity (species and genetic populations) associated with riparian and wet woodland by undertaking careful management and restoration work

2. Methods

2.1. Study area

The study area, defined as Grampian Conservancy boundary, with an external 15 km buffer applied to the external boundary (Figure 1), is 1 210 336 ha, of which Grampian region covers 880 115 ha.

Figure 1. Area of analysis, incorporating a 15 km external buffer around Grampian region.

Grampian region is comprised of a mosaic of land cover types, within a varying topography, from the farmland of the Buchan Plains to the wooded slopes of the Cairngorm mountains. Agricultural development has influenced the fragmented wooded landscape of the Buchan Plains, resulting in small wooded areas, occasionally interconnected by strips of woodland boundaries along the fields.

Although much of the rural land in Grampian Region is agricultural, particularly in the north east, the region does have significant areas of woodland. Woodland constitutes approximately 24% of the area of Grampian Region, of which 72% is coniferous woodland, and the remainder broadleaved woodland, mixed woodland, and scrub[1]. The broadleaved component is composed of riparian, wet (Carr), policy, or other semi-natural broadleaved woodlands, with shelter belts, areas of plantation, and ancient trees in parks. Semi-natural and plantation pinewoods are extensive in the Cairngorms, Deeside and in Moray.

The North East Scotland biodiversity action plan identifies riparian woodlands and wet (Carr) woodlands as important habitats, yet the extent of these woodlands has not been ascertained. Riparian woodlands are especially important, in terms of connectivity, as they often form corridors linking other areas of woodland. This study aims to identify those woodlands that are likely to be riparian or wet (Carr) woodland (section 2.3.2).

[1]Woodland figures based on a combination of woodland data sets. The National Inventory of Woodland and Trees (NIWT) data set, which details woodlands with a minimum size of 2 ha, indicates woodland cover at approximately 20%, with coniferous woodland constituting 56%.

2.2. *Data*

All Ordnance Survey® data used in this study is licensed: with the permission of the Controller of Her Majesty's Stationery Office © Crown copyright - Forestry Commission Licence No: GD 100025498. The background mapping used in this report comes from either the OS raster mini-scale digital data at a scale of 1:250 000, or OS raster 1:50 000 scale and 1:10 000 scale.

The following data sets were used to build the land cover used in the analysis

- Land Cover Scotland (LCS88)
- Land Cover Map 2000 (LCM2000)
- National Inventory of Woods and Trees (NIWT)
- Scottish Semi Natural Woodland Inventory (SSNWI)
- Phase 1 habitat data
- Forestry Commission subcompartment database
- Woodland Grant Scheme 3 (WGS3)
- Scottish Forestry Grant Scheme (SFGS)
- Scottish Ancient Woodland from the Scottish Inventory of Ancient and Long-established Woodland Sites (v3) and the Scottish Inventory of Semi-natural Woodlands (v3)
- Riparian and wet (Carr) woodland indicator dataset (derived from North East Scotland Biological Record Centre (NESBReC) data)
- Lowland Zone from the national analysis (Sing 2005; Humphrey *et al.* 2005)
- Elevation Mask from the national analysis showing areas above and below 500 m, based on the Ordnance Survey 50 metre resolution Digital Elevation Model (DEM)
- Flood risk areas derived from the Ordnance Survey 50 metre resolution DEM
- Designated areas: Natura 2000 Special Areas of Conservation (SAC), Special Site of Scientific Interest (SSSI)
- Ordnance Survey® Strategi ®

2.3. *Data preparation*

2.3.1. *Regional land cover matrix*

The land cover matrix[1] was constructed using LCS88, LCM2000, and Ordnance Survey Strategi as the base layer. The NIWT woodland coverage reflects more recent changes from WGS 1 and 2, although the interpretation of forest type is missing from updates. The physical distribution of woodland will be fairly accurate, the attribution of the woodland to broadleaved, mixed or conifer remains less certain. Although at the regional scale the proportions of broad habitat type suggested are likely to be fairly accurate. It should be noted that woodland type described in NIWT and SSNWI follow the broad habitat type classification: conifer, broadleaved and mixed. SSNWI has additional interpreted classes of canopy cover and semi-naturalness. WGS3 and SFGS provide updates for new planting, the Scottish Ancient Woodland dataset allows antiquity to be designated to existing woodland. Forest Enterprise (FE) sub-compartment data provide detailed species information for the state forest resource.

The lowland zone mask (Figure 2), defined using climate, geology and land use, (Humphrey *et al.* 2005) was applied to account for the expected higher biodiversity value of woods described as farms and parklands in the uplands where this land is managed as wood pasture (Ray 2005). Additionally, it is used to differentiate the cost of dispersal (representing the permeability of the land cover for species) through coniferous plantation to reflect the relatively more open canopy of pine plantation compared to spruce plantation was applied to the analyses.

[1]The land cover matrix refers to the dominant component of the landscape, often the open, improved agricultural land surrounding semi-natural woodlands within a UK context.

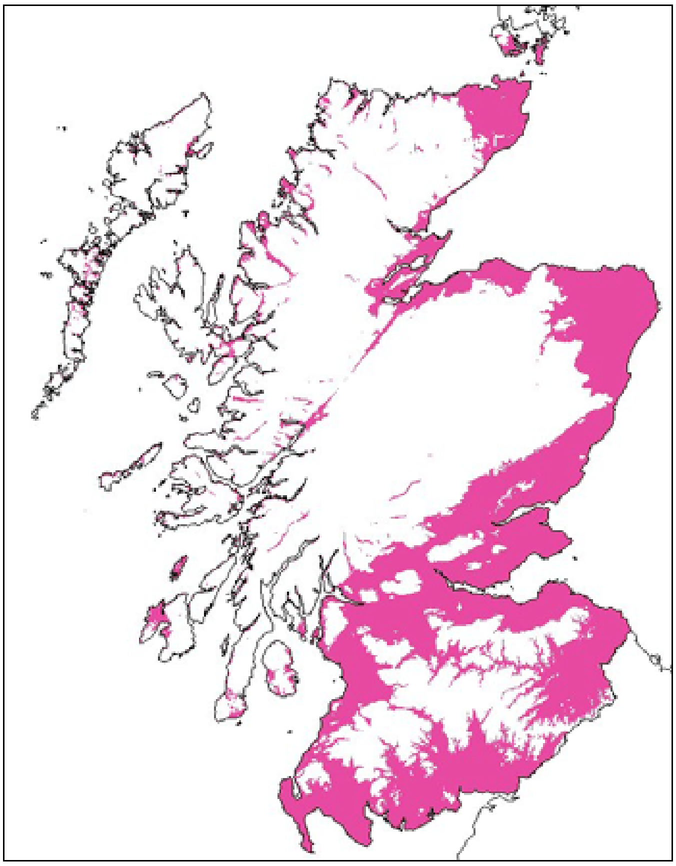

Figure 2. Location of lowland zone (Humphrey *et al.* 2005).

At elevations over 500 m the land cover cost is doubled using the elevation mask to reflect the higher cost of species dispersal through the harsher climatic environment.

2.3.2. Riparian and wet (Carr) woodland identification

This study attempts to identify riparian and wet (Carr) woodlands in Grampian Region by incorporating a number of methodologies, which were given a hierarchy of confidence:

- Wet woodlands identified through surveys
- Scottish Semi-Natural Woodland Inventory where tree type = broadleaved or mixed and category was watercourse
- Woodland polygons associated with a high number of vascular plant indicator species associated with riparian and wet (Carr) woodland (see below)
- Woodland polygons clipped to derived flood risk areas
- Woodland polygons clipped to Native Woodland Model wet woodland types
- A selection of all woodlands within 50 m of watercourses was considered, but dismissed as this would not necessarily pick out riparian habitat and would over emphasise the amount of riparian woodland. An alternative considered, but not explored due to the complexity of the methodology was to identify woodlands on steep sided slopes using a DEM

Assessment of broadleaved and mixed woodland was undertaken to identify areas likely to be riparian or wet (Carr) woodland and improve the detail of the land cover matrix. Two approaches to assessment were undertaken: coincidence mapping, to identify woodlands on the basis of species occurrence; survey data, where local knowledge was available.

Riparian and wet (Carr) woodland assessment using coincidence mapping
The process of interviewing experts with local knowledge, *e.g.* woodland officers, foresters, ecologists, to confirm woodland type and identify quality information is a time consuming process, may be subjective, and does not identify all woodlands as it is restricted to those woodlands the interviewee is familiar with. A procedure for identifying woodlands remotely using coincidence mapping was therefore designed.

This is an adaptation of the methodology using in identifying high biodiversity broadleaved woodlands in the Borders and Lothians study (www.forestresearch.gov.uk/habitatnetworks) and makes the assumption that established riparian and wet (Carr) woodlands will contain more organisms associated with these habitats. As woodlands mature they develop structurally, providing a greater range of micro-habitats, and a longer time frame for organisms to establish. This concept has led to the development of a list of plants which are thought, and have been shown (Peterken 2000; Rose 1999), to indicate ancient woodland conditions. Certainly, woodlands which contain many of these plants tend to be structurally diverse and more likely to provide conditions for a rich assemblage of organisms, from all taxonomic groups.

Whilst the presence of one species may be by chance or could be an introduced species, the presence of additional species strengthens the argument (Peterken 2000). A minimum of four species was considered as a minimum number required to rate an area of associated woodland as poorer riparian and wet (Carr) woodland quality, whilst eight or more species would represent particularly rich woodlands and would be likely to be high quality riparian and wet (Carr) woodland.

Three standards of woodland quality were developed for the study. Woodland that contained:

- less than 4 riparian and wet (Carr) woodland indicator plants = areas with the potential to be classed as riparian and wet (Carr) woodlands
- 4 to 7 riparian and wet (Carr) woodland indicator plants = poorer quality riparian and wet (Carr) woodlands
- 8 or more riparian and wet (Carr) woodland indicator plants = high quality riparian and wet (Carr) woodlands

Twenty-seven riparian and wet (Carr) woodland indicator plants were selected, and their point data distribution was queried from the digital data held by North East Scotland Biological Records Centre (NESBReC). Table 1 indicates the types of woodland with which the plants are associated.

Table 1. A selection of riparian and Wet (Carr) woodland indicator plants for Grampian region.

Species (common name)	Species (scientific name)	NVC Woodland type affinity
1. Wild angelica	Angelica sylvestris	1-9, 11, 20, 25
2. Alder spp.	Alnus spp.	1-10
3. Marsh-marigold	Caltha palustris	1-3, 5-7, 20
4. Lesser pond-sedge	Carex acutiformis	2, 5, 6, 8
5. Greater tussock-sedge	Carex paniculata	1-3, 5, 6
6. Remote sedge	Carex remota	1, 2, 5, 7, 8, 14
7. Great pond-sedge	Carex riparia	1, 5, 6
8. Bottle sedge	Carex rostrata	3, 4
9. Marsh thistle	Cirsium palustre	1-7, 9, 24
10. Marsh willowherb	Epilobium palustre	1-4, 6
11. Field horsetail	Equisetum arvense	6, 7, 24
12. Water horsetail	Equisetum fluviatile	1, 3, 4, 5, 7
13. Marsh horsetail	Equisetum palustre	1-6
14. Wood horsetail	Equisetum sylvaticum	7
15. Meadowsweet	Filipendula ulmaria	1-9, 20, 22, 24
16. Common marsh-bedstraw	Galium palustre	1-8

17. Fen bedstraw	Galium uliginosum	1, 3, 4, 6
18. Yellow iris	Iris pseudacorus	1, 5-7
19. Sharp-flowered rush	Juncus acutiflorus	1, 3, 4, 7
20. Soft rush	Juncus effusus	1-8, 10, 21
21. Water mint	Mentha aquatica	1-3, 5-7
22. Water forget-me-not	Myosotis scorpioides	1, 3, 5, 6
23. Reed canary-grass	Phalaris arundinacea	1-3, 5-7, 24
24. Common reed	Phragmites australis	1-3, 5, 6, 24
25. Lesser spearwort	Ranunculus flammula	1, 3, 5, 7
26. Willow spp.	Salix spp	1-9, 20, 21
27. Common valerian	Valeriana officinalis	1-5, 7, 9, 20

Data Extraction
Two approaches were undertaken to identify woodland associated with the presence of riparian and wet (Carr) woodland species.

1. Point data were based on either eight-figure or four-figure grid references, *i.e.* represented by a point within a 100 m, or 1 km square respectively. The lower accuracy of four-figure grid references required an assumption that these points would, on average, be located in the centre. Polygons in the ancient woodland inventory within a 500 m radius of the ancient woodland indicator points were selected. From this dataset, woodland polygons from SSNWI that intersected the ancient woodland polygons were selected.

The derived data sets were refined to ensure the indicators referred to the relevant woodland, *i.e.* if the data point was located near an area of semi-natural broadleaved or mixed woodland and on the edge of a large area of coniferous plantation, then the former was chosen and the latter deselected.

Broadleaved and mixed woodland polygons intersecting these points were then selected and designated as high quality, poorer quality, or potential riparian and wet (Carr) woodland, as appropriate. Occasionally some of the data points could not be referenced to a broadleaved or mixed woodland polygon with a good degree of confidence. Where this was the case, but the distance from the data point was still within 1km, it was downgraded to a lower category, *i.e.* high quality to poorer quality, poorer quality to potential. This approach means that these woodlands are not classified as core habitat and, as such, cannot form the basis for a network. However, if these woodlands are subsequently surveyed and confirmed to be riparian or wet woodland, the land cover can be amended to reflect this.

Ordnance Survey mapping helped identify woodland polygons associated with riparian and wet (Carr) woodland indicators, with the terms ‘spread’s, ‘issues’ or ‘mosses’, which denote wet areas, allowing confirmation of wet conditions. Topography (flat areas) and marsh symbology were also used to confirm wet woodland areas.

Woodland polygons clipped to derived wet woodland areas
Flood risk data held by SEPA could not obtained for Grampian, so a procedure was developed to derive potential wet woodland areas using an index of wetness calculated using a Compound Topographic Index utility with a 50m resolution Digital Elevation Model in a GIS. This determined where areas were likely to be flooded. The next step was to determine where the flood areas correspond with flat areas, i.e. where water was likely to sit following a flood event. Woodland polygons were then clipped to the derived wet woodland areas and added to the land cover matrix (Section 2.4).

<u>Derived wet woodland areas</u>
Flat areas (slope <=0.5 degrees) with wetness scores in the top 50% of the wetness range. Wetness range = 7.372 to 28.377, therefore chose wetness scores >= 15.5168.

Areas with slopes <= 0.5 degrees with wetness scores >=15.5168

Intersection with SSNWI woodland polygons
SSNWI – tree type is broadleaved, 80-90% broadleaved, mixed, semi-natural, or semi-natural planted – classified as riparian/wet (Carr) woodland habitat
As above but with <10% canopy cover – not classified as habitat, but low cost for riparian/wet (Carr) woodland species dispersal

Woodland polygons clipped to Native Woodland Model wet woodland types
Riparian & wet woodland extent was identified based on potential woodland type as predicted by the SNH MLURI Native Woodland Model (Towers 2002)

- Native woodland model NVC identifiers most likely to form Riparian & wet woodland were chosen (100, 120, 124, 127, 130, 131, 197, *i.e.* the main types (Table 2)) and intersected with SSNWI polygons.

Table 2. National Vegetation Classification (NVC) identifiers and corresponding NVC types used in the Native Woodland Model.

NVC Identifier	NVC type
100	W6 (Alder with stinging nettle)
120	W4 (Birch with purple moor grass & open ground)
124	W4/a (Birch with purple moor grass)
127	W4/Sc5 (Birch with open ground & Peatland with scattered trees/Scrub)
130	W7 Alder-ash with yellow pimpernel
131	W7 + W4 mosaic
197	Sc5/W4 (Peatland with scattered trees/Scrub mosaic/W4 Birch with purple moor grass & open ground)

2.4. Analysis and concepts for modelling habitat networks

Habitat network objectives are usually described from a management perspective, *e.g.* to "seek to link woodlands together into coherent areas which function better ecologically and are more rational to manage" (Worrell *et al.* 2003). However to measure linkage and ecological function, it is necessary to make the fundamental distinction between 'structural connectivity' and 'functional connectivity' (Gergel and Turner 2002). Structural connectivity is the degree of physical connection between elements of the same type; it is an attribute of landscape pattern. Functional connectivity, on the other hand, is an attribute of landscape connectivity that is defined by landscape processes such as species movement and dispersal between patches. Indeed, it is possible to have high functional connectivity in a physically fragmented landscape, with low structural connectivity, as long as the wider matrix supports the particular ecological process (Farina 1998).

Central to the use of the BEETLE least cost approach for evaluating habitat networks is the concept of focal species. In the analysis, the focal species can be a real or imaginary species or range of species that use habitat which is the subject of the analysis: woodland in the case of this study. As an example, a specific focal species of broadleaved woodland could be, for example: great spotted woodpecker; red squirrel; wood anemone; bluebell. Of these species wood anemone and bluebell could be considered specialists, and the woodpecker and red squirrel, generalists. Each of these species has different area requirements and differing dispersal abilities. It would therefore be time consuming to build a landscape model for each species, and rather difficult as little is known about the autecology of so many species. This leads to a fundamental shift in the way we consider the problem, requiring an adjustment to the concept of species within the modelling exercise.

The solution requires the adoption of a generic class of focal species, which doesn't need to consider any particular species. Instead we must only conceptualise the type and size of habitat that the generic focal species (GFS) requires to maintain viability; how far it might disperse, and how effectively it permeates the surrounding less favoured habitat patches of the landscape (the matrix). This modelling approach cannot be based upon empirical data, since a complete set of data does not exist for every species/land cover type combination. However ecologists, rangers and naturalists have a great deal of experienced-based knowledge of species requirements, dispersal, and the utilisation of less favoured habitat patches. The BEETLE least cost approach taps into this knowledge, by setting within the model mutually agreed, relative weights of resistance to dispersal, through different land cover types, for a number of GFS.

The BEETLE model identifies habitat networks by analysing the area surrounding habitat patches within the allowed dispersal distance for the GFS, this having been modified by the weights applied to each land cover patch. As an example, if the GFS maximum dispersal distance is 1000 m, then the actual dispersal of the GFS would be: 1000 m through a land cover class with a dispersal resistance weight of 1, but only 100 m through a land cover with a dispersal resistance weight of 10, or 50 m through a land cover with a dispersal resistance of 20, and so on. BEETLE maintains the accumulated distance through all land cover classes in all directions surrounding habitat, until the dispersal distance limit is reached. At the extent of dispersal, if the buffers representing the accumulated distance touch, they form a functional network. This allows habitat which is within the dispersal range of the GFS to be linked; and eventually BEETLE creates a map of the extent of linked habitat within each separate network. Within the GIS the BEETLE model has the capacity to integrate all land cover patches to determine the distribution and extent of habitat networks.

Table 3 shows a sample of the weights set for two generic focal species, woodland generalists and broadleaved woodland specialists. Habitat is given a weight of 0, meaning that there is no dispersal cost associated with moving about habitat within the species home range. Land cover types that are deemed most suitable for dispersal are given small weights (*e.g.* 1 to 5), whereas land cover types less suitable for dispersal have a higher weighting factor (5 to 50).

Table 3. The proportion of land cover types in Grampian Region (total area approximately 880 000 ha), and examples of the relative weights of resistance to dispersal attributed to a selection of land cover types for woodland generalists and broadleaved woodland specialists.

	Land Cover Description	Percent area of Grampian Region	Woodland generalist	Broadleaved specialist
Forest and woodland*	Coniferous woodland	17.3%	0	3
	Mixed woodland	2.2%	0	1.5
	Broadleaved woodland	4.3%	0	0
	Scrub**	0.2%	0	0
	Total	**24%*** **		
Open land	Montane	2.6%	10	20
	Heath	14.8%	7	8
	Unimproved grassland	0.4%	3	5
	Improved grassland/arable	48.9%	15	20
	Wetlands	<0.1%	15	15
	Blanket bog	5.4%	10	10
	Dunes and bare ground	0.6%	30	30
	Other open land	0.3%	Various	Various
	Total	**73%*** **		
Developed land and water	Urban/roads/rail	1.7%	50	50
	Inland water	0.3%	50	50
	Total	**2%*** **		

**figures for woodland types include a proportional division of general land cover classes, such as ‘young trees’ and are derived from a combination of datasets. NIWT figures (including a proportional division) are 20% total woodland cover, 14.5% coniferous, 1.5% mixed, 1.6% broadleaved, 0.2% scrub.*
***scrub considered good surrogate habitat*
***note small rounding errors in total values, hence less than 100% total

2.4.1. Generic Focal Species and dispersal costs

The analysis undertaken for Grampian Region follows the generic focal species (GFS) approach that was employed in previous work at the national and regional scale (Ray *et al.* 2005; Moseley *et al.* 2005). This work focuses on those GFS which were considered to best represent the opportunities for enhancing the land cover. These were associated with specific woodland types: broadleaved woodland specialists; riparian; and wet (Carr) woodland specialists. Additionally, woodland generalists and heathland generalists were also considered, allowing analysis of the wooded and open ground networks to be undertaken.

Examples of species that utilise woodland and scrub in Grampian can be found in Appendix 2.

Brief descriptions of these GFS classes are as follows:

- Woodland Generalists – representing species which may disperse easily, and are not specifically associated only with woodland, but they may need woodland for a part of their life cycle, or partly within their range. Examples include: fox, badger, green woodpecker, spotted flycatcher, great woodrush, *Amanita submembranacea* – a fungus, bracken, grey squirrel.
- Heathland Generalists – representing species associated with heathland, but often found in (open) woodlands or glades and rides in woodlands on poor soils. Sites may be recognised by a significant presence of heather. Examples include: bracken, purple moor-grass, curlew, brown hare.
- Broadleaved specialist – representing species specifically associated with broadleaved woodland, may be found in mixed woodland to a lesser degree and occasionally in conifer. The term specialist signifies a rather reduced dispersal and a more exacting habitat requirement. Examples include: *Limnophila pulchella* – a cranefly, *Dicrostema gracilicornis* – a sawfly.
- Riparian woodland specialist – representing those species only associated with riparian woodlands. Sites are located adjacent to rivers and streams. Species in this category are generally limited to riparian areas and include: otter, pipistrelle bat, goldeneye, *Brachyptera putata* (a stonefly).
- Wet (Carr) woodland specialists – representing species requiring wet woodland areas, typified by the presence of willow and adjacent fen. These woods would normally have a relatively high broadleaved tree component (30% or more). Examples include: *Lipsothrix ecucullata* (a cranefly), coral-root orchid, alder hoverfly
- High biodiversity pinewood specialist– representing species specifically associated with ancient & long established pine woodland that has a well-developed ground flora and a good vertical structure & deadwood component. Examples include: Scottish crossbill, twinflower, ostrich-plume feather moss, blue-tooth fungi.
- Pinewood specialists – representing species specifically associated with pine woodland. Examples include: red squirrel, crested tit, hairy woodant, *Cladonia botryes* (a stump lichen), creeping ladies tresses.

Habitat for each of the GFS was defined as follows:

Woodland generalists
SSNWI, NIWT, or Phase 1 = any woodland type, excluding farm/parkland or areas with <10% canopy cover.

Heathland generalists
LCS88 = dry, wet, or undifferentiated heath without trees; LCM2000 = dwarf shrub heath; Phase 1 = Dwarf shrub heath. Heath with trees was added to the cost matrix with a cost of 1.

Broadleaved woodland specialists
SSNWI = 80 to 90% broadleaved or broadleaved, with a minimum canopy cover of 10%, excluding farm/parkland; NIWT = Broadleaved; FE = broadleaved species.

Riparian woodland specialists
SSNWI = watercourse woodland, FE = Alder or Willow. SSNWI = 80 to 90% broadleaved or broadleaved, mixed broadleaf/conifer, with a minimum canopy cover of 10%; NIWT = Broadleaved or mixed; FE = Broadleaved or mixed, where the sites have either been qualified by an expert as riparian woodland or they spatially correspond to: sites with at least 8 riparian woodland indicator plants (Table 1); derived flood risk areas; NWM wet woodland areas.

Wet (Carr) woodland specialists
FE = Alder or Willow. SSNWI = 80 to 90% broadleaved or broadleaved, mixed broadleaf/conifer, with a minimum canopy cover of 10%; NIWT = Broadleaved or mixed; FE = Broadleaved or mixed, where the sites have either been qualified by an expert as wet (Carr) woodland or they spatially correspond to: sites with at least 8 wet (Carr) woodland indicator plants (Table 1); derived flood risk areas; NWM wet woodland areas.

High biodiversity pine woodland specialists
SSNWI = 80 to 90% coniferous or coniferous, 80 to 90% semi-natural or semi-natural, with a minimum canopy cover of 50%; NIWT = indicative forest type is semi-natural, coniferous; CPI = Caledonian pinewood; SSNWI and NIWT corresponding with SNH condition monitoring = favourable.

Pinewood specialists
SSNWI = 80 to 90% coniferous or coniferous, 80 to 90% semi-natural or semi-natural; NIWT = indicative forest type is semi-natural, coniferous; CPI = Caledonian pinewood, or Caledonian planted area; FE/Estate sub-compartment database = Scots pine.

The definition of habitat for each of the GFS have been derived from the steering group discussion in January 2005 and considered discussion between forest ecologists and open habitat ecologists as part of the development of habitat network analysis throughout Scotland during 2005 and 2006. It was assumed that woodland specialists would require specified woodland habitat and would also be sensitive to the woodland edge. For broadleaved, pine, and high biodiversity pinewood specialists, this was represented within the GIS by the internal buffering of a distance of 2 tree heights (50 m), which is considered to be the normal extent of any edge effects (Murica 1995). This was modified to 20 m for riparian and wet (Carr) woodland specialists as it was thought that two tree lengths was likely to be much less than 50m. Additionally, as some riparian woodlands are steep sided and will be spatially underrepresented in a digital dataset as slope is not taken into account, a larger buffer would designate a disproportionate amount of the woodland as edge. A 20 or 50 metre internal buffer was removed from the habitat layer where it bordered non-woodland. Although the 20 and 50 metre edges were not considered as source habitat, they were assigned a cost of 1 for the specialist in the land cover matrix.

A detailed list of metadata supporting the analyses can be found in Appendix 1.

Three dispersal ranges for the GFS were identified for comparison at the regional scale:

- dispersal limited species able to disperse 250 metres
- moderately mobile species able to disperse 500 metres
- mobile species able to disperse 1000 metres

Each GFS can take each of the three dispersal characteristics, giving 35 permutations for analysis.

2.5. Woodland in and around communities

Following recognition of the value of woodlands to communities, and initiatives such as Greenspace Scotland (see - http://www.greenspacescotland.org.uk/), and Woodlands in and around towns (WIAT) (Anon. 2005), the Woodland Trust has developed standards for woodland access for communities and people. 'Space for People' (The Woodland Trust 2004), which is fully supported by the Forestry Commission, considers that woodland usage is highly dependent on location – most people visit nearby woodland on foot. Walking distance to woodland is well documented at approximately 500 metres or 6 to 8 minutes walking time, and woodlands of at least 2 ha are preferred, as they are large enough to give a sense of escape from the outside world. The woodland trust access standard suggests:

- that no person should live more than 500 m from at least one area of accessible woodland no less than 2 ha in size
- that there should **also** be at least one area of accessible woodland no less than 20 ha in size within 4 km (8 km round-trip) of people's homes

Wherever the combination of rules cannot be delivered, due to lack of available land in urban situations, the document suggests that the second rule of 20 ha in size within 4 km should be the minimum provided.

The Draft Scottish Forestry Strategy 2006 (Anon. 2006) key targets for 2015 echo these aspirations, with the aim that:

- About one quarter of the population should have access to at least one area of woodland greater than 2 ha within 500 m of their homes
- About two thirds of the population should have access to at least one area of woodland greater than 20 ha within 4 km of their homes

The criteria of woodland size and distance of woodlands from homes were used to determine if any communities in Grampian Region did not meet the requirements for woodland accessibility.

The first analysis used Woodland Trust accessible woodlands, based on the Woodland Trust 'Woods for People v2 dataset, merged with the latest SFGS, WGS and Forest Enterprise Scotland boundary data. It should be noted that these data have not been validated by local offices. A second analysis was undertaken including all types of woodland to indicate how woodland accessibility could be improved if targeted improvement of woodlands was undertaken. The distribution of urban areas were derived from the vector OS Strategi® resource.

Distance calculations in the analyses are based on straight lines and do not take into account road routes, entry points to woodlands, or transport availability. An assumption was made that all woodlands in the study area are potentially accessible, as there are no trespass laws. Access issues related to paths, fences, *etc.*, should be dealt with by the local authority.

3. Results & Discussion

3.1. Habitat Networks

Seven GFS analyses were undertaken for Grampian region, using individual profiles and working with a specially prepared spatial database of land cover types and GFS profiles.

Riparian and wet (Carr) woodlands were identified following the criteria in section 2.3.2. Figure 3 shows the distribution of these woodlands according to identification using these methodologies, highlighting those woodlands associated with the presence of riparian & wet (Carr) woodland indicator plants. The riparian and wet (Carr) woodlands appear to be well distributed across the riparian areas of the region, with lower occurrence in the higher areas of the Cairngorms and the farmland of the far northeast. It is interesting to compare the distribution of these woodlands, that are often located on areas that have been unsuitable for farming, with woodlands classified as ancient and long-established (Figure 4). Many of the riparian and wet (Carr) woodlands have clearly existed for a long time and as such, have had time to develop the characteristics to support a large number of species that are associated with these woodland types.

Those areas identified as having a large number of riparian and wet (Carr) woodland indictor species represent some of the key areas where conservation management should be undertaken and the networks linking the areas may be termed core networks. Around the core networks are the broadleaved woodland specialist networks and woodland generalist networks which are termed focal networks.

The locations of high quality woods are summarised in Table 4.

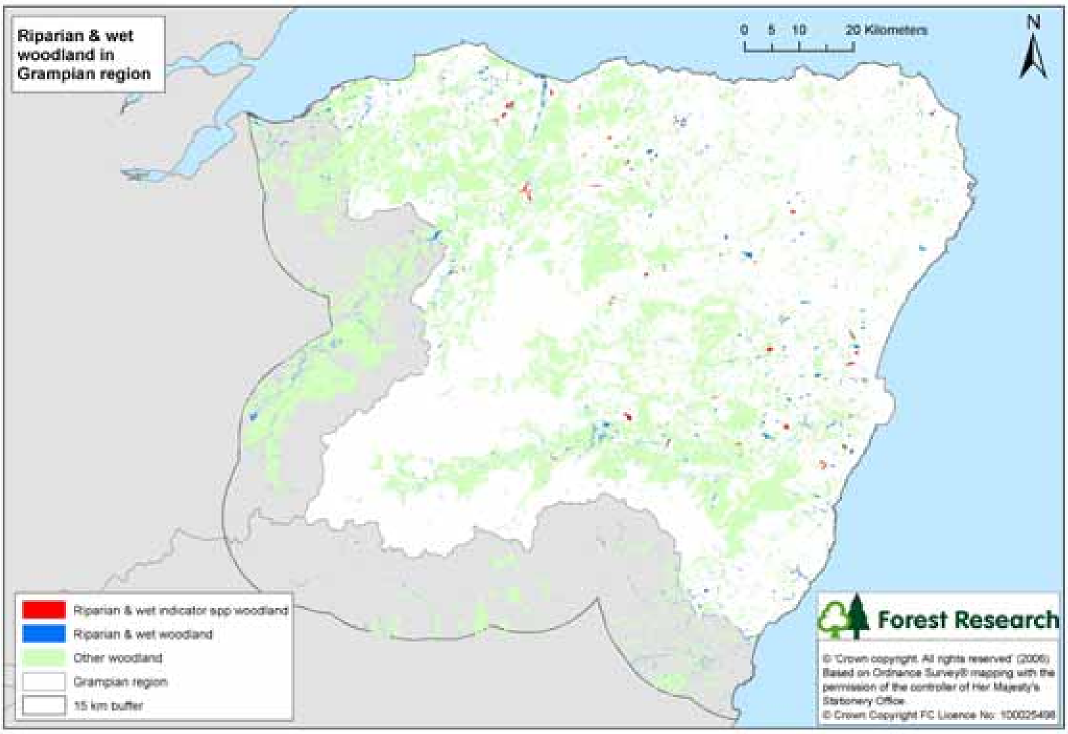

Figure 3. Riparian and wet (Carr) woodlands determined from the presence of riparian and wet (Carr) woodland indicator plant species occurrence (indicated in red), or by: survey; Scottish Semi-Natural Woodland Inventory watercourse class; Native Woodland Model wet woodland classes; and derived wet woodland area data (indicated in blue).

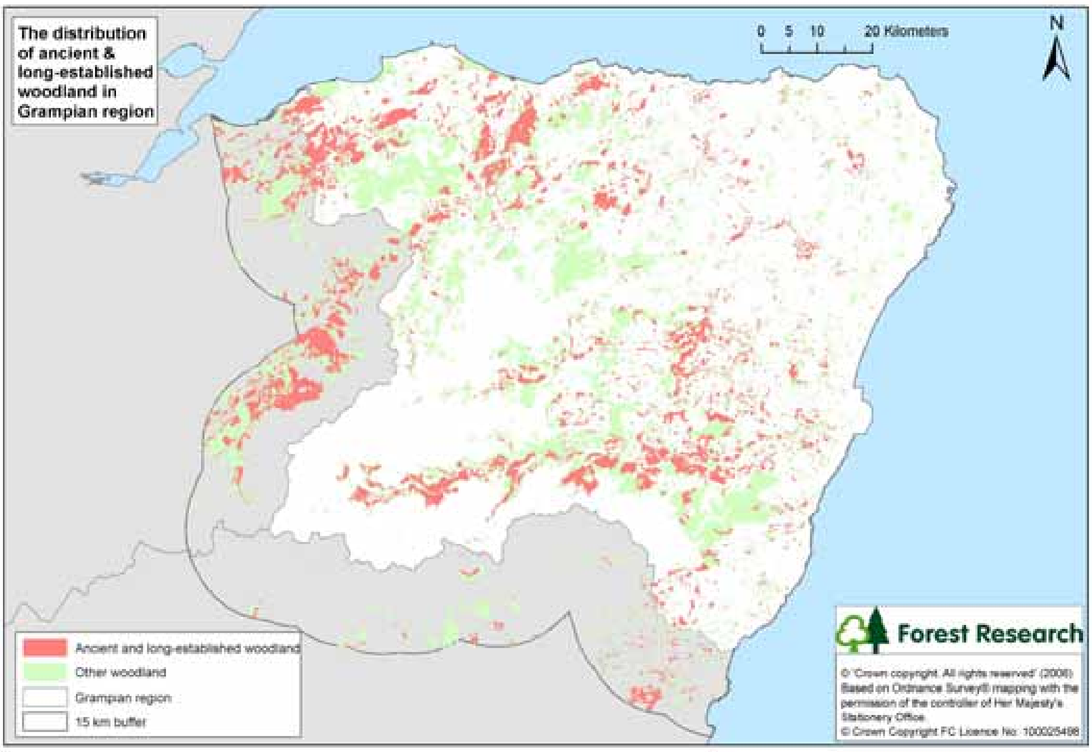

Figure 4. The distribution of ancient and long established woodland within the area of analysis.

Table 4. Very high biodiversity quality (8 riparian/wet (Carr) woodland indicator plants or more) woods in Grampian region.

Woodland name	Grid reference
Woodland by Logieburn	NJ259573
Blackhills	NJ273584
Lochnabo	NJ284600
Upper Dallachy	NJ360624
Upper Allaloth	NJ408585
Woodland by burn of Auchiefow	NJ411597
Woodland on Foggy moss	NJ467541
Gallow Hill	NJ479524
Wood east of Little Balloch Hill	NJ500497
Park burn	NJ590570
Den of Pitlurg	NJ443453
Avochie	NJ535458
Hazelwood	NJ319445
Kininvie	NJ319440
Woodlands by River Fiddich; from Maggieknockater, to Braes of Gauldwell, and Tullich	NJ318460, NJ330442 & NJ322425
Netherton	NJ185292
Mains of Morinish	NJ211303
Tombae	NJ217255
Woodland by Giant’s Stone	NJ418353
Craig Castle	NJ473247
(Bog) woodland by Douglas Slack and Limekiln Braes	NJ469823
Moss of Kirkhill	NJ534288
Wardhouse	NJ566304
Knockespook	NJ547240
Moss of Cairnhill	NJ672325
Roseseat	NJ734311
Moss of Windyhill	NJ804405
(Bog) woodland at Redmoss	NJ914178
Lily Loch	NJ392145
Grandhome	NJ909124
Newhills	NJ865079
Woodlands by Kettock’s Mill, Seaton	NJ935094
Norwood	NJ910028
Arnhill Moss	NJ832067
Craiglug	NJ848053
East Silverburn	NJ848044
Woodland by Redmire Cottage	NO896974
Red Moss	NO861936
Drum Castle	NJ792010
(Bog) woodland by Loch O’ Lays	NO704978
Bandodle burn	NJ660062
Quithel	NJ575987 to NJ564970
North Westertown	NJ573015
North Gellan	NJ500028
Woodland by Ballater golf course and River Don	NJ363951 & NJ360959

For each of the 7 GFS, habitat networks were calculated for 3 dispersal distances: 250 m, 500 m and 1000 m. The reason for this is to assess the degree of permeability of the matrix by overlaying network maps, with the largest dispersal distance underneath and the least on top (Figure 5). It is a form of sensitivity analysis, which provides metrics on the size of networks and degree of fragmentation of the habitat in the landscape. Figure 5 shows there are some small differences in the extent and distribution of 1000 m networks compared to 500 m and 250 m networks, but very little difference between the size and distribution of 500 m and 250 m networks. This suggests the landscape is not very permeable for the dispersal of woodland species

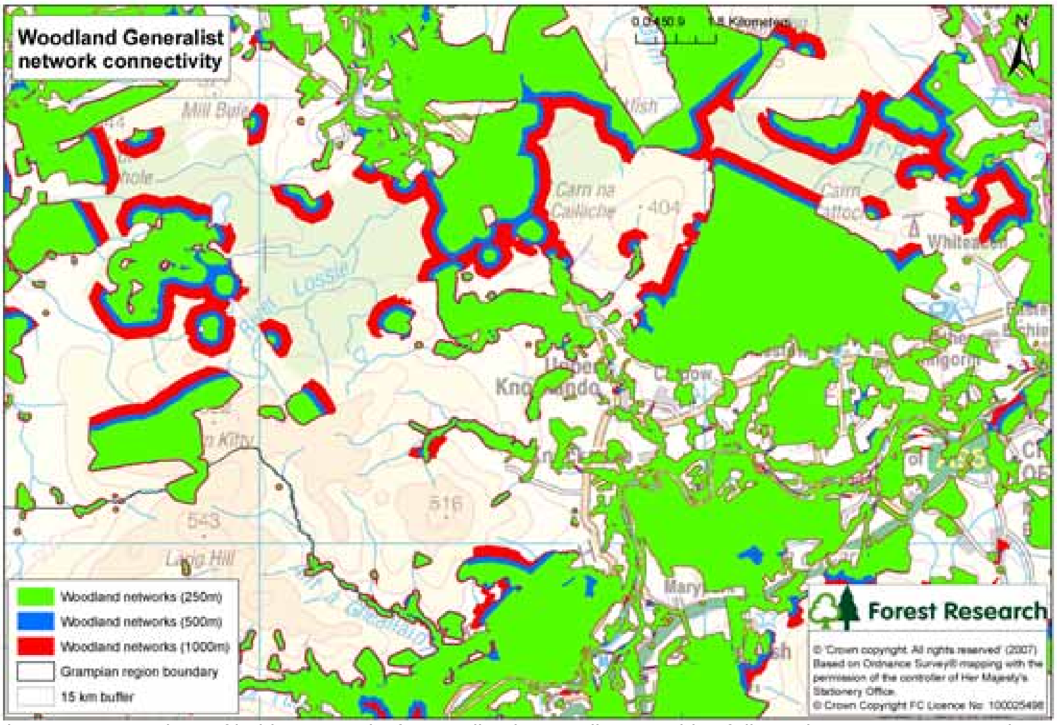

Figure 5. Comparison of habitat networks for woodland generalists capable of dispersing 250 m, 500 m and 1000 m. The networks have been overlaid with the greatest dispersal underneath and the least dispersal network on top.

3.1.1. Woodland generalists

The analysis shows there are a large number of small woodland generalist networks, with the largest networks being located around Deeside, Speyside, and Moray (Appendix 3). It is also clear that woodland generalists have a larger proportion of habitat compared to specialists, but the degree of permeability over large parts of the landscape is poor, for both generalists and specialists. In contrast, heathland generalists have a similar habitat area to that of woodland generalists, but more extensive areas of more moderate (better) permeability (Appendix 4, Table 5). Also in contrast, in the modelling process the permeability of improved farmland is configured for heathland generalists as a ‘moderate barrier’ to dispersal, compared to the ‘high barrier’ for woodland species in farmland.

The metrics for woodland generalists (Table 5) illustrate the relative fragmentation of habitat for different focal species of woodland, and a comparison with heathland. We can test the sensitivity of woodland generalists in the modelled landscape by increasing the dispersal distance from 250 m to 1000 m. This has the effect of reducing the number of woodland generalist networks (Table 5a) by about 33%, indicating increased networks connectivity, while increasing the network area 1.2 times. For this study we have settled on the 1000 m dispersal distance, reflecting moderately mobile woodland generalists: woodland birds, fox, badger, and wind dispersed woodland edge plants.

3.1.2. Woodland specialists

The woodland specialist networks are also largely fragmented (Appendices 5 to 9) and, with the exception of the pinewoods, few networks being greater than 100 ha. However, many of the larger riparian and wet (Carr) woodland networks support a large number of species associated with these habitats, suggesting that there are some relatively robust areas from which to initiate expansion. Figure 6 shows three distributions of networks for specialists of riparian woodland, other broadleaved woodland and woodland generalists, Figure 7 shows a similar distribution but with wet (Carr) woodland networks, rather than riparian networks. The map provides a spatially referenced index of some of the different woodland networks in Grampian Region. In particular, the map provides an estimate of the degree of linkage of riparian and wet (Carr) woodlands with adjacent woodlands of other types. It can be used as a reference for estimating where riparian and wet (Carr) woodlands should be protected and expanded, and how woodland expansion might seek to link existing structures where appropriate, to form stepping stones between two or more networks. This will be explored in detail in section 3.2.1. Because the matrix is not permeable to woodland specialist species dispersal, Figures 6 and 7 tend to re-emphasise the distribution of riparian and wet (Carr) woodlands shown in Figure 3.

The metrics (Table 5b-d) show 1 676 broadleaved networks covering 87 834 ha. Within these structures are 1 595 riparian woodland networks covering 52 214 ha, and 1 324 wet (Carr) woodland networks covering 45 071 ha. The 250 m to 1000 m dispersal sensitivity analysis shows that the number of riparian woodland networks is reduced by 37% with a 2.9 times increase in network size (Table 5c) and the number of wet (Carr) woodland networks is reduced by 40% with a 2.8 times increase in network size. Networks of this type constitute small sections of the woodland generalist networks, they are slightly more fragmented than, broadleaved woodland networks (reduction in networks - 46%, size increase 2.2 times), but can be connected through judicious land-use change between existing networks. The woodland specialist sensitivity analysis indicates that increases in network size and connectivity is likely to be affected by the relatively low cost of dispersal through other woodland types. This is apparent in the smaller increase in area of less favoured habitat in the specialist networks compared to the generalists, suggesting that the matrix is much less permeable to specialists than to generalists. The riparian and wet (Carr) woodland networks are likely to have a larger percentage of less favoured habitat in their networks than broadleaved networks due to a smaller buffer, 20 m rather than 50 m, being used for the riparian and wet (Carr) woodland analyses.

As woodland generalists use all woodland as habitat, all dispersal is through non-woodland. In comparison, dispersal for woodland specialists occurs through both non-woodland and less favoured habitat woodland (including the 20 m or 50 m buffers), the latter being more permeable. Consequently, dispersal for woodland specialists is likely to become increasingly difficult as non-woodland is encountered and it is difficult to make direct comparison with woodland generalist dispersal. Woodland specialist networks will therefore be affected by the proximity to woodland and, for the riparian and wet (Carr) woodlands, is a reflection of how they are distributed within the woodland matrix.

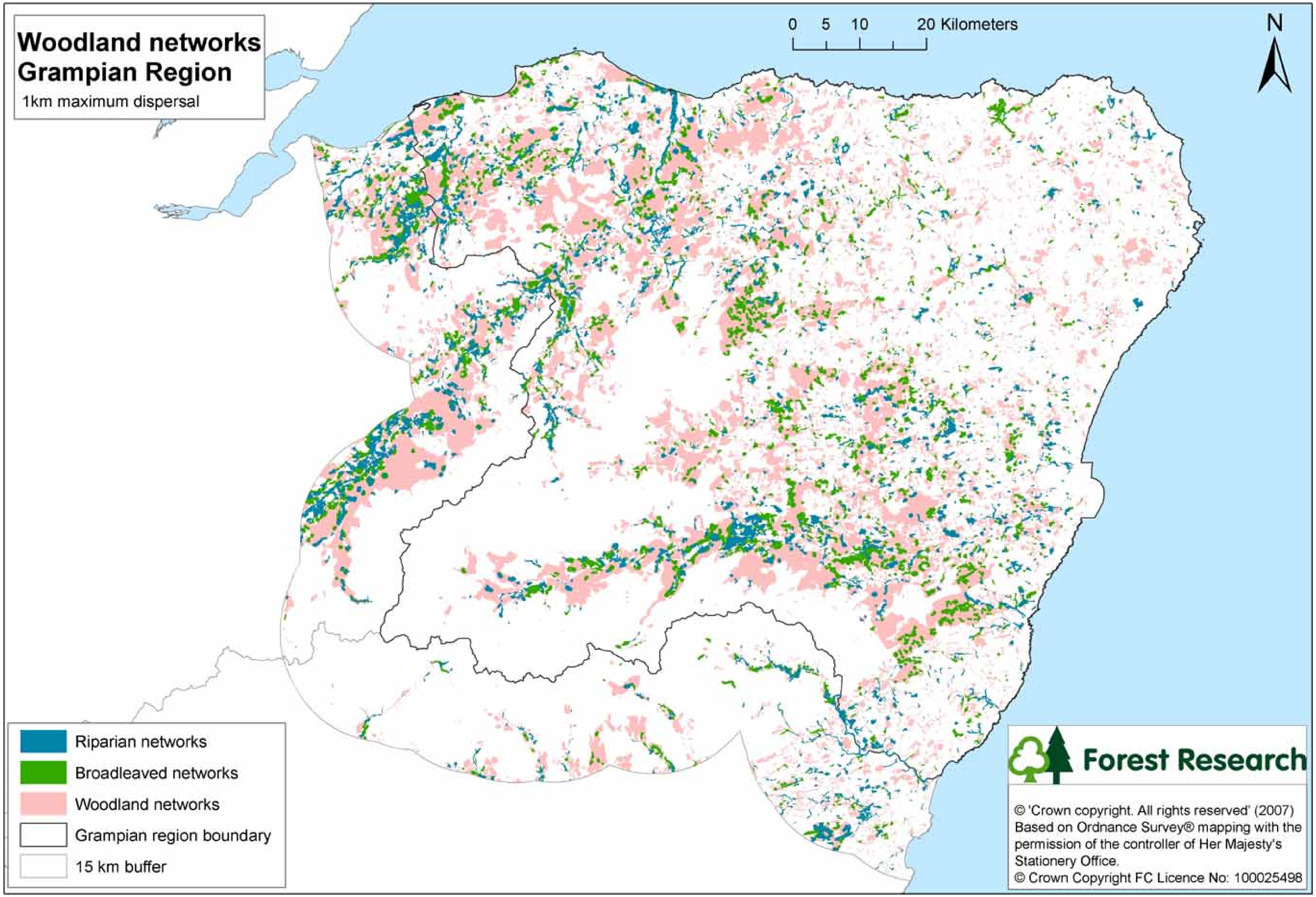

Figure 6. Woodland networks, assuming a maximum dispersal distance of 1km, for riparian woodland specialists, broadleaved specialists, and woodland generalists in Grampian Region.

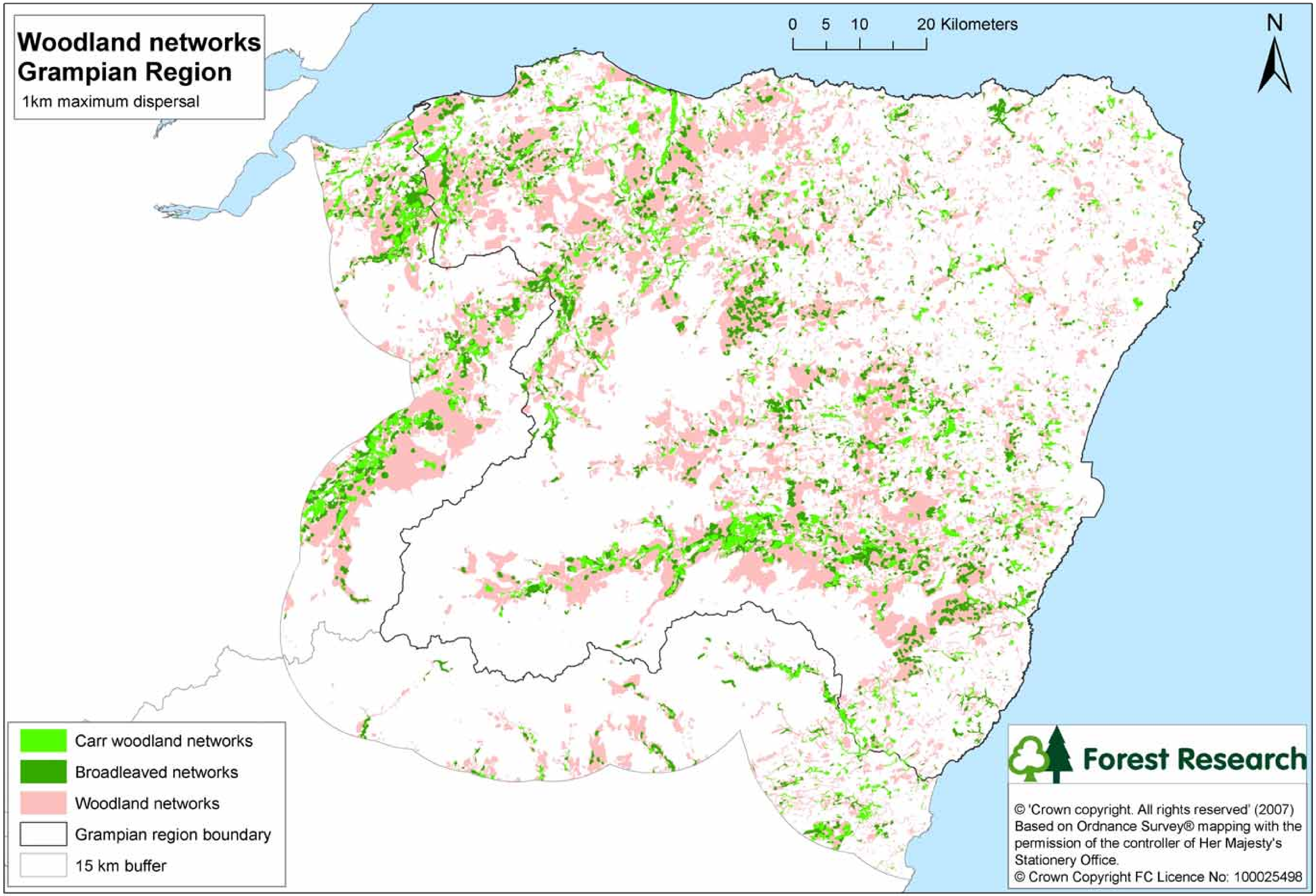

Figure 7. Woodland networks, assuming a maximum dispersal distance of 1km, for wet (Carr) woodland, and broadleaved specialists, and woodland generalists in Grampian Region.

3.1.3. *Heathland generalists*

An assessment of Grampian landscape permeability was undertaken for heathland generalists to provide an indication of the extent of networks for an open habitat (Figure 8). Figure 8 shows clearly the large heathland networks extending from the hillsides adjacent to Deeside, through the Cairngorms, and northwest towards Inverness. Small patches also occur towards the north east of the region on the higher ground above the agricultural lowlands.

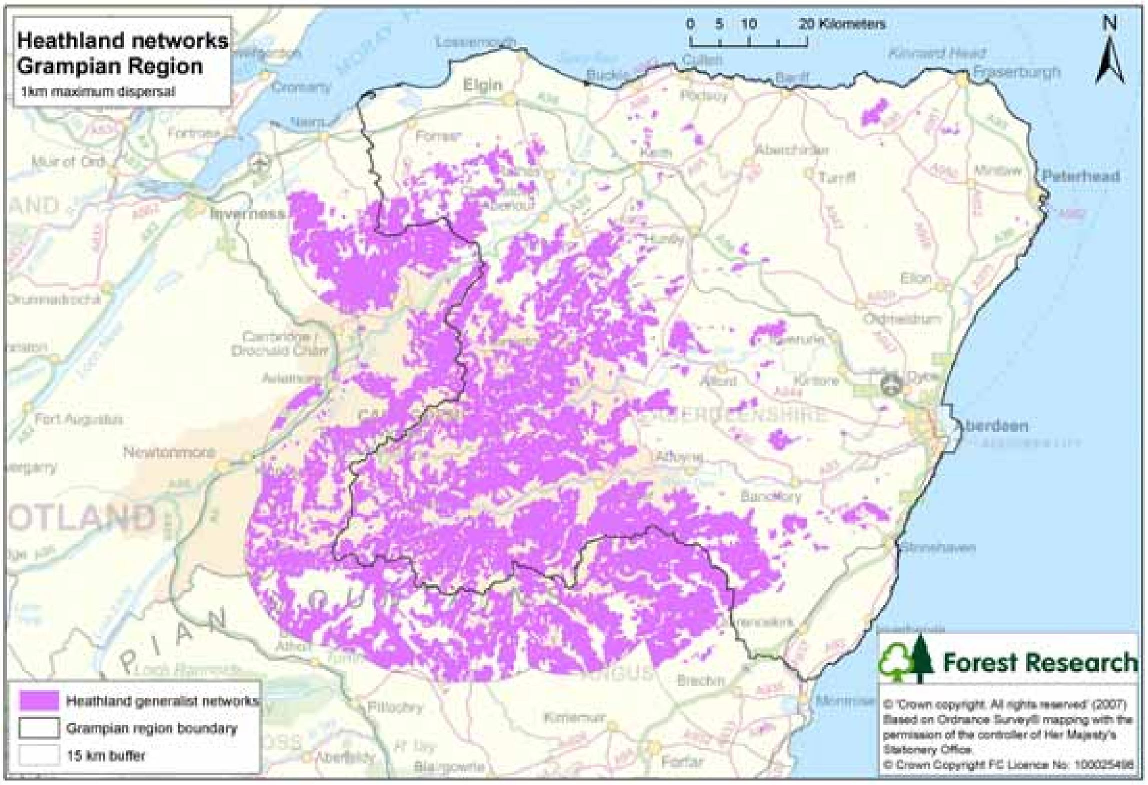

Figure 8. Heathland generalist networks, assuming a maximum dispersal distance of 1km, in Grampian Region.

The analysis indicates that most of the heathland generalist networks are relatively large (Appendix 4). The matrix is slightly more permeable to heathland generalists than woodland species, allowing heathland generalist networks to extend into other semi-natural habitat and bordering farmland. This issue is also apparent in the metrics and sensitivity analysis (Table 5e). The number of heathland GFS networks is reduced by 64% when the dispersal distance is increased from 250 m to 1000 m, while the network area increases by 1.2 times. This is better response to the sensitivity analysis than for woodland generalists (33% reduction in network size, increase in network area 1.2 times), indicating that the heathland generalist networks are less fragmented at the higher dispersal distance (Table 5a). The total area of heathland network is very similar to the woodland generalist network, but more consolidated as is apparent in the far lower number of networks and much higher mean network size.

Table 5. Landscape metrics for the seven generic focal species analyses in the study area (Grampian region and a 15 km external buffer).

a) Woodland generalists

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)	Area of less favoured habitat network (ha)	Percentage less favoured habitat in network (ha)
250	8 363	274 613	32.8	41 131	43 772	16
500	7 334	296 359	40.4	46 815	65 518	22
1000	5 567	340 091	61.1	75 127	109 250	32

b) Broadleaved woodland specialists (50 m internal buffer applied)

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)	Area of less favoured habitat network (ha)	Percentage less favoured habitat in network (ha)
250	3 094	40 360	13.0	458	26 454	66
500	2 308	57 253	24.8	1 217	43 347	76
1000	1 676	87 834	52.4	3 266	73 928	84

c) Riparian woodland specialists (20 m internal buffer applied)

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)	Area of less favoured habitat network (ha)	Percentage less favoured habitat in network (ha)
250	2 550	17 744	7.0	149	13 518	76
500	2 016	29 469	14.6	429	25 243	86
1000	1 595	52 214	32.7	1 128	47 988	92

d) Wet (Carr) woodland specialists (20 m internal buffer applied)

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)	Area of less favoured habitat network (ha)	Percentage less favoured habitat in network (ha)
250	2 185	15 863	7.3	145	11 794	74
500	1 552	26 023	16.8	482	21 954	84
1000	1 324	45 071	34.0	1 268	41 002	91

e) High biodiversity pinewood specialists (50 m internal buffer applied)

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)	Area of less favoured habitat network (ha)	Percentage less favoured habitat in network (ha)
250	108	16 822	155.8	5 708	4 107	24
500	75	19 174	255.7	6 268	6 459	34
1000	62	22 894	369.3	7 390	10 179	44

f) Pinewood specialists (50 m internal buffer applied)

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)	Area of less favoured habitat network (ha)	Percentage less favoured habitat in network (ha)
250	1 135	73 603	69.3	9 435	36 990	47
500	806	89 623	111.2	9 987	48 010	54
1000	566	113 263	200.1	11 320	7 1650	63

g) Heathland generalists

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)	Area of less favoured habitat network (ha)	Percentage less favoured habitat in network (ha)
250	1 058	274 265	259.2	84 318	30 384	11
500	649	298 134	459.4	95 502	54 253	18
1000	378	337 529	892.9	248 493	93 648	28

3.1.4. *Priority open habitat*

In producing habitat networks, we have analysed land cover permeability (see Section 2.3), with the functional forest habitat networks comprising woodland components in an intimate mixture with elements of open habitat. Whilst the open habitat components are still physically separate from the woodland, it is important to emphasise their location so that they can be fully considered when forest habitat network development is being planned (Figure 9). The location of designated sites and site suitability are equally important considerations prior to planning land-use change (Figure 10).

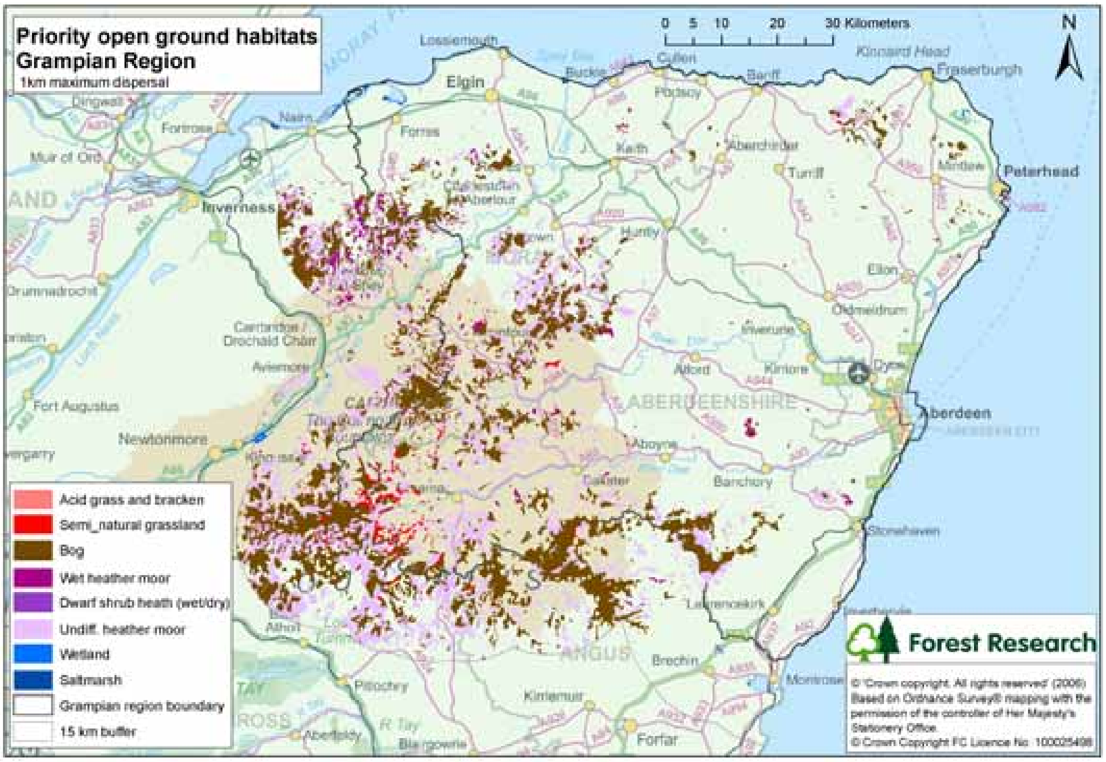

Figure 9. Priority open ground habitat in Grampian Region.

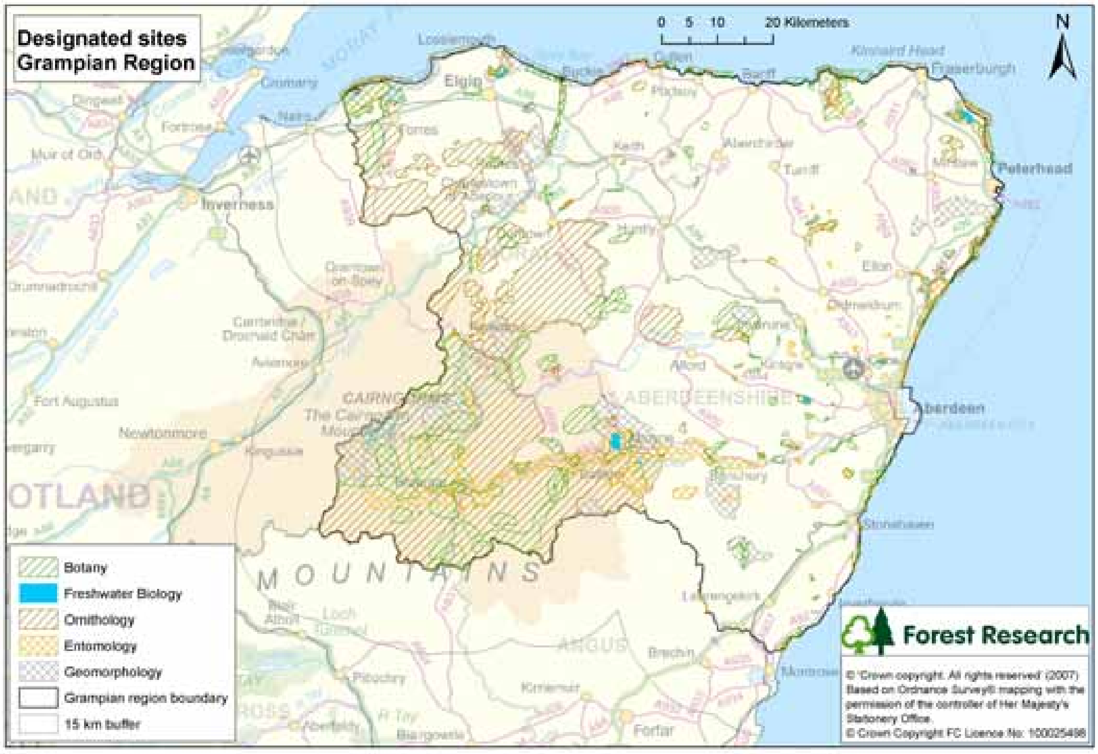

Figure 10. Designated sites in Grampian Region.

3.1.5. Potential interactions between woodland and heathland networks

To demonstrate how woodland and open ground networks can co-exist, an analysis was undertaken to identify areas where potential interactions may occur between woodland specialists and generalists, with heathland generalists (Figures 11 to 13). There is little overlap of the riparian and wet (Carr) woodland networks and heathland generalists (Table 6), which is unsurprising as the riparian and wet (Carr) habitats tends to be located in lowland areas.

Table 6. The overlap of the heathland generalist networks with wet (Carr) woodland, riparian, broadleaved specialists, and woodland generalist networks at a maximum 1000 m dispersal distance within Grampian Region, including a 15 km buffer.

Generic focal species	Area of GFS (ha)	Area of overlap (ha) between woodland and heathland networks	Percentage of woodland networks in heathland networks	Percentage of heathland networks in woodland networks
Wet (Carr) woodland specialist	45 071	1 118	0.3	2.5
Riparian	52 214	2 181	0.6	4.2
High biodiversity pinewood	22 894	3 184	0.9	13.9
Pinewood	113 263	10 441	3.1	9.2
Broadleaved specialist	87 834	6 906	2.0	7.9
Woodland generalist	340 091	38 608	11.4	11.4
Heathland generalist	337 529			

The interaction between heathland generalist and broadleaved specialist networks is larger, representing approximately 8% of the broadleaved specialist network, but only 2% of the heathland generalist network. The heathland overlap of pinewoods is likely to be slightly larger than that of other woodland types as pinewood stands often extend up hillsides, giving way to heathland at higher elevations. Many of the overlapping areas occur along steep sided ravines bordering moorland. The largest network overlap is between the woodland and heathland generalists, with equal percentages of overlapping heathland and woodland.

The analyses indicate that there is a small amount of overlap between woodland networks and heathland networks, but it is worth reiterating that these are functional networks, and movement across a woodland network by an open ground generalist can occur at points where the woodland is not contiguous or is very open. Therefore, network overlap is not a problem in itself, rather it allows us to identify where expansion of one network could potentially affect another. However the expansion of woodland onto heathland can be a contentious issue. To expand and secure native woodlands some regeneration onto moorland will be essential, however new planting would not normally be considered where it will adversely affect heathland habitats, by fragmentation or extensive habitat loss on ecologically functioning heathlands.

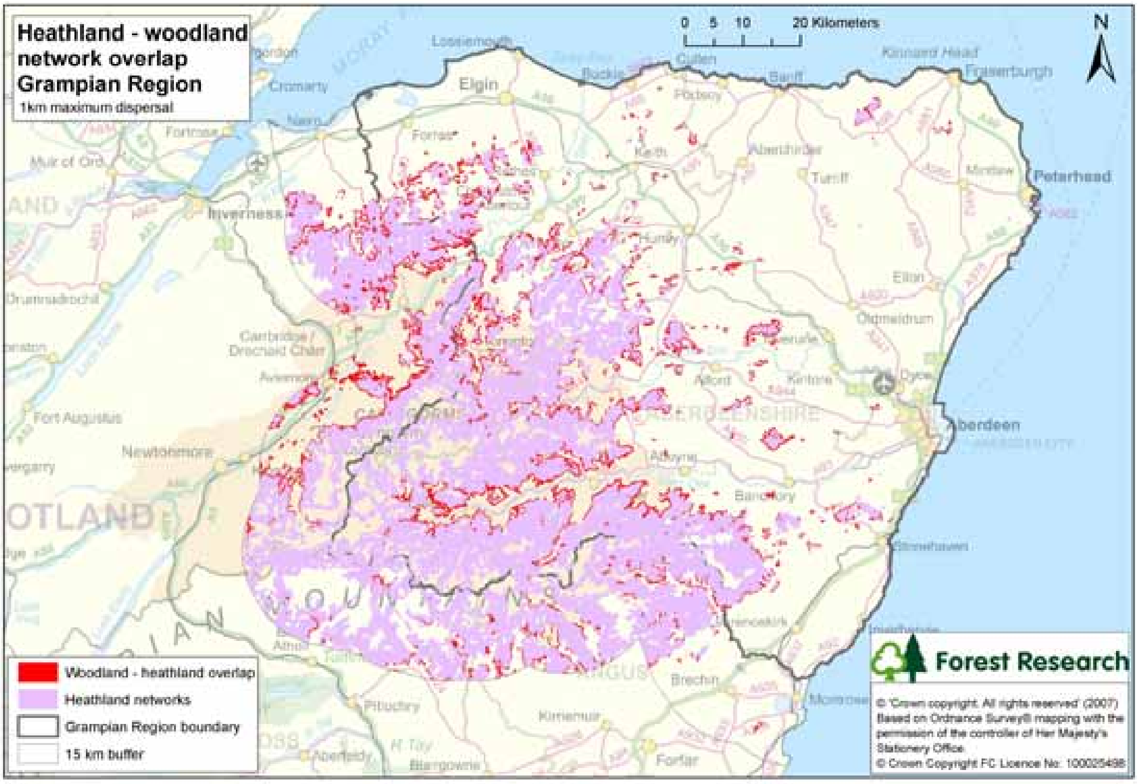

Figure 11. Potential interactions in Grampian Region between heathland generalists and woodland generalists (1000 m maximum dispersal distance). The distribution of heathland generalist networks and the area of overlap with the woodland generalist are shown.

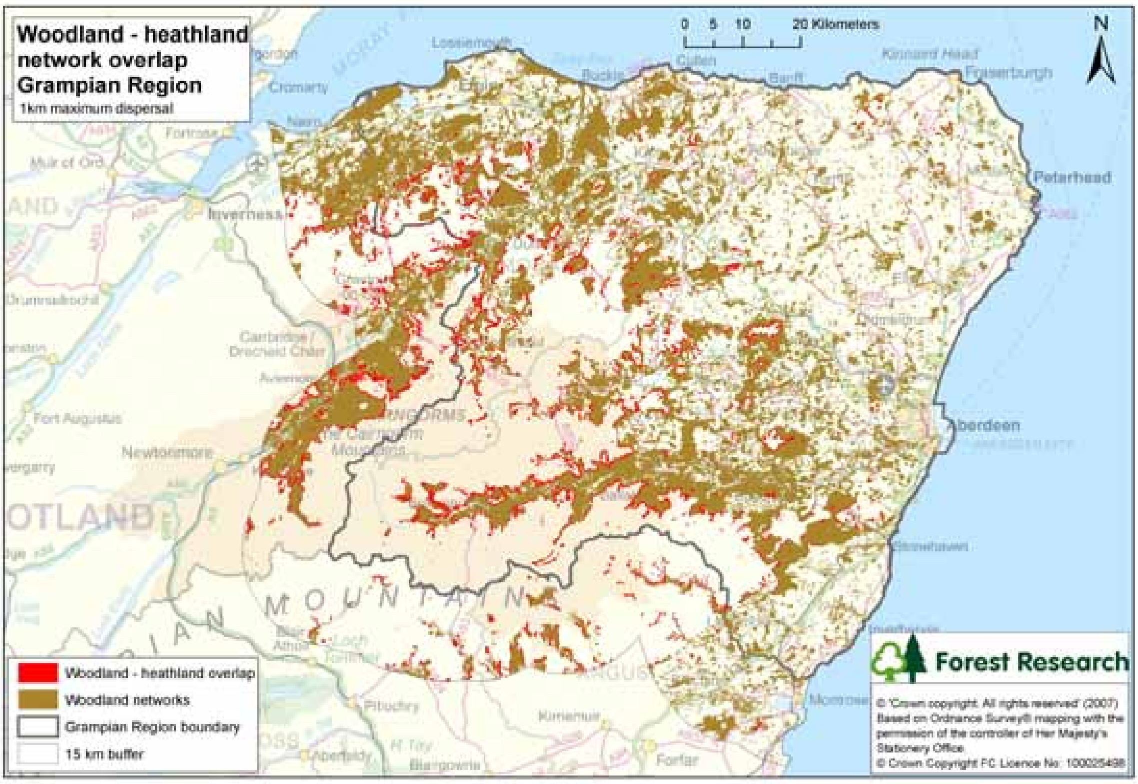

Figure 12. Potential interactions in Grampian Region between woodland generalists and heathland generalists (1000 m maximum dispersal distance). The distribution of woodland generalist networks and the area of overlap with the heathland generalist are shown.

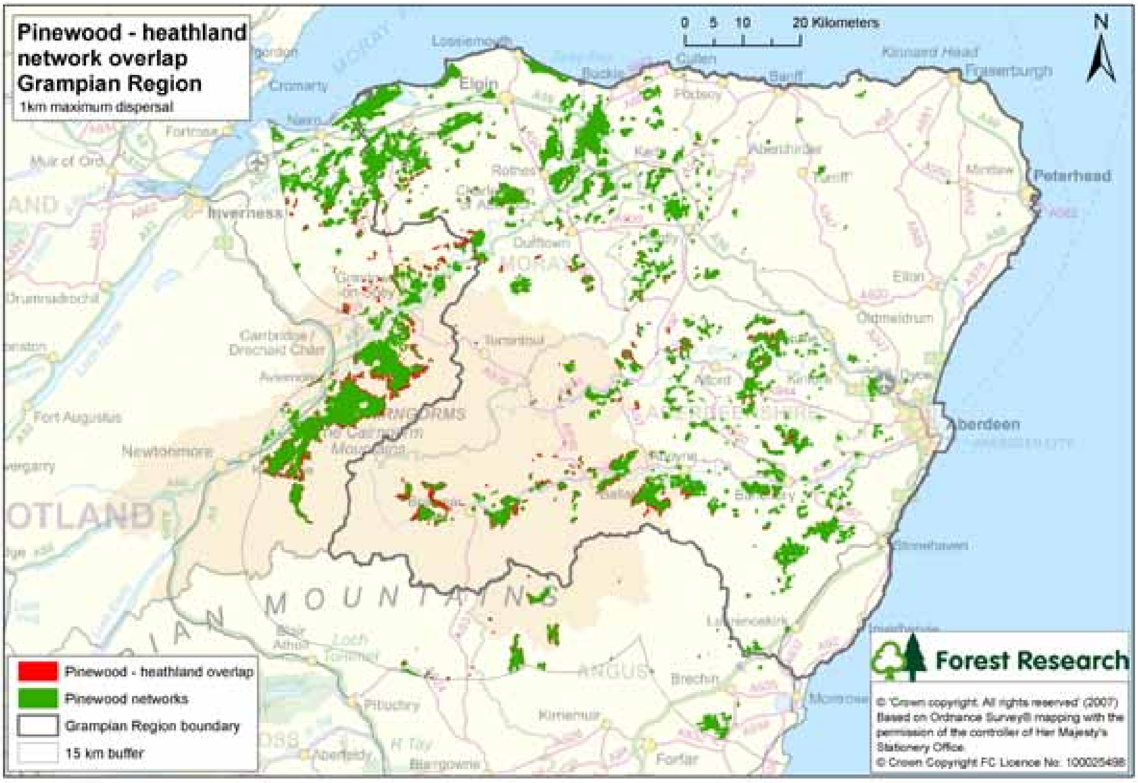

Figure 13. Potential interactions in Grampian Region between heathland generalists and pinewood specialists (1000 m maximum dispersal distance). The distribution of pinewood specialist networks and the area of overlap between the heathland generalist are shown.

3.2. Application of the analyses

The networks produced by the analyses in this report can be used to increase woodland biodiversity at regional and local scales. In most cases, decisions could be made regionally, with implementation at the local level. In general, it is suggested the priorities for addressing woodland fragmentation should be:

1. **Consolidation** of existing high quality habitat, to reduce further fragmentation and maintain habitat viability, and conserve biodiversity.
2. Buffered **expansion** and **improvement** to increase patch size.
3. Increase **connectivity** to provide opportunities for dispersal and to increase patch size.

These approaches can be related to the individual woodland networks as follows:

- Those woodlands within **riparian or wet (Carr) woodland networks** (identified by the presence of at least 8 riparian or wet (Carr) woodland indicator species or identified by a survey) should be targeted for **consolidation** and **buffered expansion**.
- Those woodlands containing 4 to 7 riparian or wet (Carr) woodland indicator species should be targeted for **improvement**, to improve the condition of the woodland to encourage a greater number of these woodland indicator species. This would then bring these areas into the **riparian or wet (Carr) woodland category**. Management should concentrate on approaches that maintain and enhance the existing ground flora. **Structural management** (in terms of tree species, ground flora, drainage) of broadleaved woodland on potential riparian and wet (Carr) woodland sites can be undertaken to improve the suitability of these habitats to riparian and wet woodland species.
- **Broadleaved networks** can be viewed on top of woodland generalist networks in a GIS to indicate where broadleaved specialist networks can be **expanded** through **restructuring** of other woodland, *i.e.* conversion to broadleaved, removal of conifers from mixed woodland (Figures 6 & 7).
- **Woodland generalist networks**: where appropriate, some managed open habitat may be converted into a more semi-natural open habitat, which will allow greater dispersal of woodland generalists and allow greater network size and **connectivity** (Figures 6 & 7).
- Examination at the different dispersal distances (250 m, 500 m, and 1000 m) allow the analyses to be applied for species with different dispersal abilities. This is particularly important in demonstrating how networks become increasingly fragmented for more sedentary species.
- **Plantation on Ancient Woodland Site (PAWS) restoration**: sites close to existing networks should be targeted for restoration. This may be undertaken strategically, for example by targeting action in the 20 largest networks where the consolidation of broadleaved woodland via PAWS restoration should benefit woodland biodiversity over a wide area. Potential sites may also be taken locally by investigating the permeability of the land cover matrix between existing networks by running the least-cost model at a larger dispersal distance, *e.g.* at 2000 m for 1000 m networks. This provides an indication of whether restoration of the PAWS to a broadleaved woodland would link adjacent broadleaved networks (Figure 14). The restored woodland needs to be of sufficient size (a minimum width of 110 m for broadleaved networks) to provide core habitat for the network.

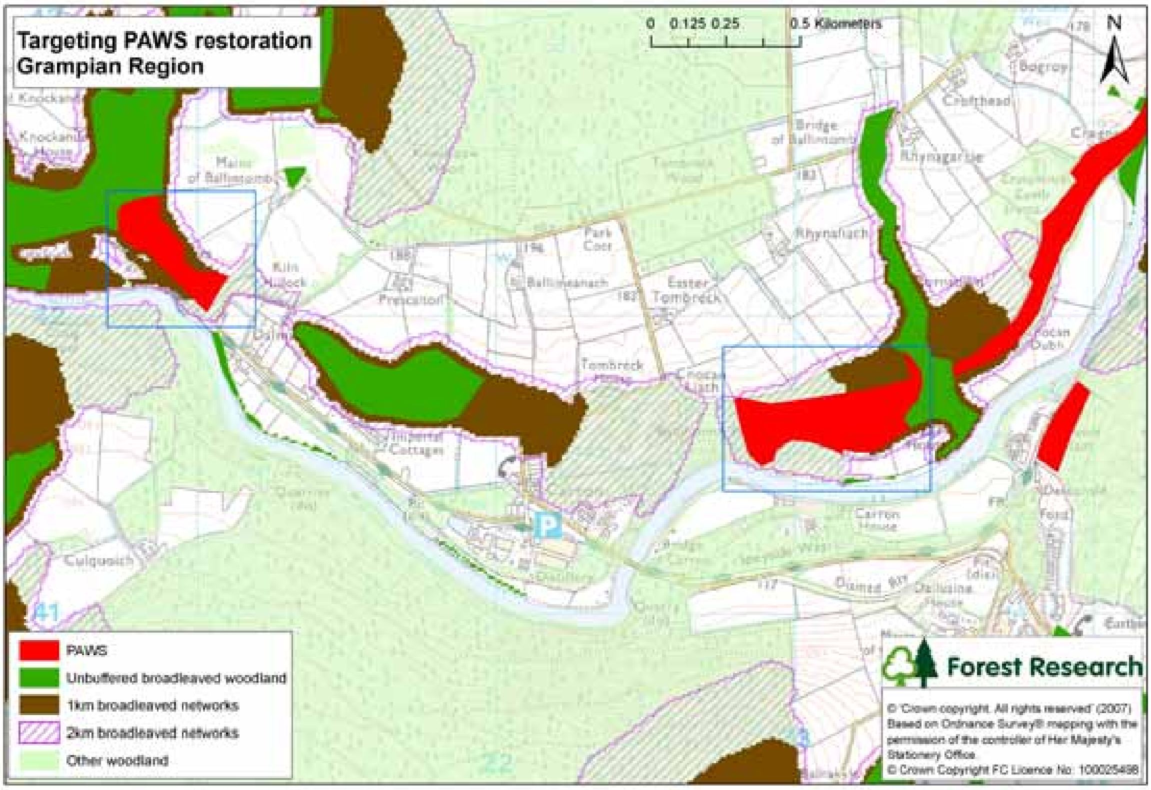

Figure 14. Targeting sites for PAWS restoration (indicated by red areas with the blue boxes) by determining whether changing the intervening land cover would link the broadleaved networks (adjacent brown areas).

The analyses may also be used to:

- Examine broadleaved woodland specialist networks to **identify potential threats** posed by grey squirrel movement into red squirrel enclaves (Figure 15).
- Determine how forest plans can be developed to **minimise disruption** to existing FHNs.
- Identify **open ground** areas where forest expansion is not appropriate (Figure 9).

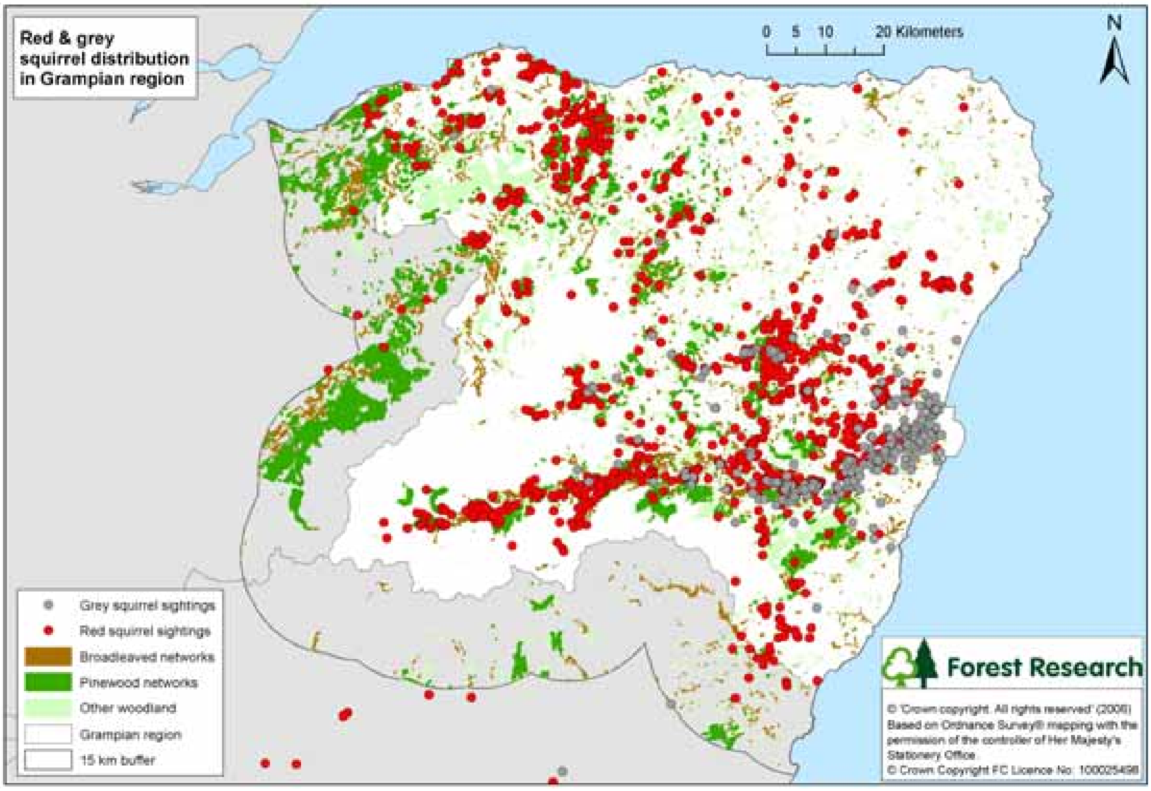

Figure 15. Red and Grey squirrel distribution in relation to broadleaved and pinewood networks in Grampian Region.

The strategic decisions that are important for improving regional FHN robustness and connectivity require implementation at a local level, which is affected by site variation, and thus involves determination of the most applicable approach. The increased detail at the larger scale allows identification of:

- fragmented woodland that can be **consolidated** by **woodland improvement**. These areas can be identified locally as small clusters of networks.
- existing habitat patches or 'nodes', from which buffered **expansion** and/or **improvement** can be undertaken to increase patch size.
- opportunities for **connecting** existing **specialist networks** to increase patch size, allowing species with high area requirements to be supported.

3.2.1. Riparian network improvement priorities

Riparian woodland improvement

Many of the riparian woodlands are fragmented and lack core habitat, requiring management to consolidate and expand them (Figure 16). This could be achieved by firstly undertaking management to improve the biodiversity quality of the adjoining woodland, then ensuring that suitable native broadleaved species are planted along the riparian areas to link existing woodlands. Areas for management should be targeted to reverse habitat fragmentation by creating larger areas of habitat and transitions with other semi-natural habitats. The priorities for the identification of sites for maintenance, restoration or the creation of new riparian habitats are set out below.

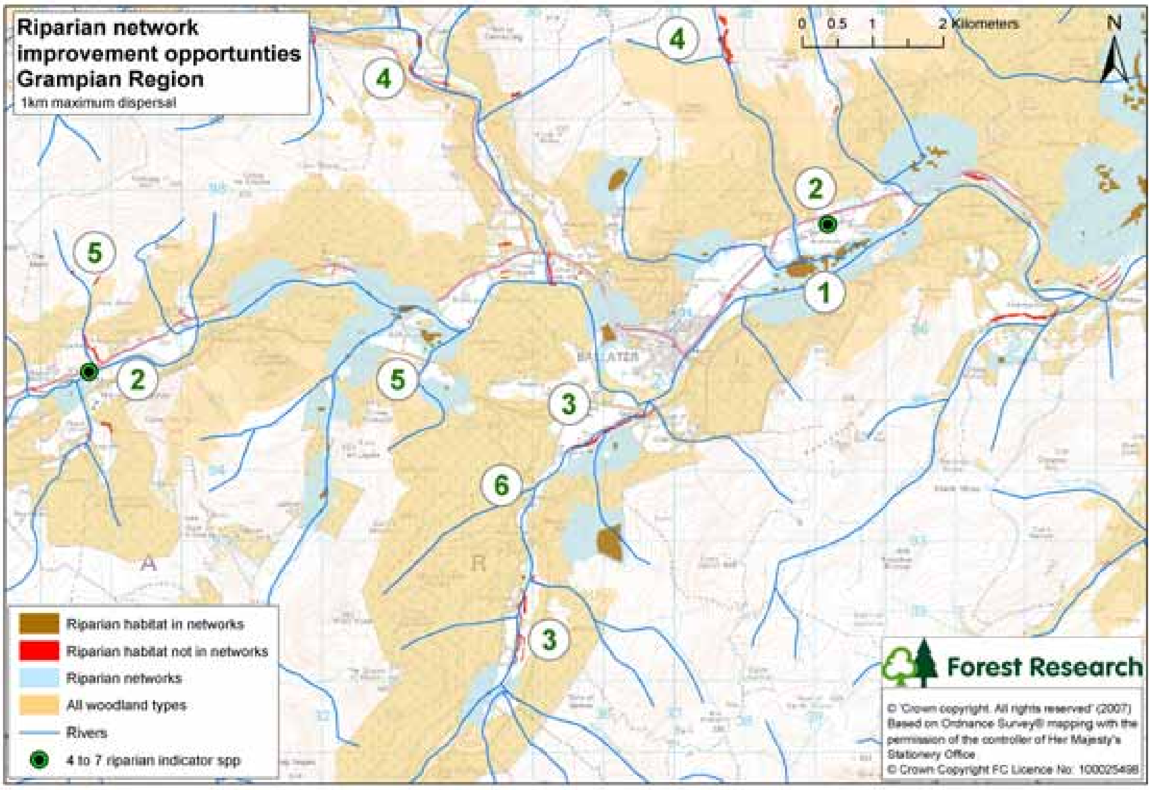

Figure 16. Opportunities for enhancing riparian networks in an area of Deeside. The riparian habitat patches out-with networks (indicated in red) currently lack core habitat and require management to consolidate and expand them.

1. Areas of habitat within the riparian networks where appropriate management should be undertaken to achieve of maintain favourable condition, *e.g.* management of areas of riparian woodland within the riparian habitat network (core sites).

2. Areas of habitat associated with 4 to 7 riparian woodland indicator species should be managed to protect the integrity of the woodland and create conditions favourable for further species colonisation.

3. Areas of habitat out-with the riparian network but downstream and adjacent to the networks, where restoration and expansion will provide large enough areas to support a range of species associated with riparian woodland. These should be priority areas for restoration.

4. Areas of riparian woodland out-with, upstream, and isolated from existing networks. These should be high priority areas as the threat of species loss and the low likelihood of future colonisation means these are particularly vulnerable areas.

5. Management of intervening wetland habitat, which will facilitate dispersal of riparian species between habitat, increasing network size and connectivity.

6. Creation of new areas of riparian woodland between existing riparian networks which will, over time, form stepping stone habitat to functionally link the networks.

Use of riparian & wet (Carr) woodland indicator plants to help prioritise improvement of degraded woodland

A number of areas were identified as having 4 or more riparian/wet (Carr) woodland indicator species, but either:

1. Had less than the minimum 10% broadleaved woodland cover to be considered to have the structural attributes associated with high quality woodland.
2. Were not broadleaved or mixed woodlands.

3. Did not currently have woodland present.
4. Were not wide enough to constitute habitat.

The presence of the riparian/wet (Carr) woodland indicator species suggests that, at some time, the conditions were present to provide habitat for these species. These areas present ideal opportunities for:

1. Improvement to bring the quality of woodland to a higher standard. The resultant woodland may then form part of a riparian/wet (Carr) woodland network.
2. Conversion of existing woodland to broadleaved or mixed woodland.
3. Planting or the encouragement of natural regeneration, where appropriate, to provide the woodland cover required for these species.
4. Buffered expansion of the existing woodland to provide ‘core’ habitat.

3.2.2. Broadleaved networks along valleys

The analyses gave an opportunity to examine the broadleaved and riparian woodland networks in relation to the criteria set for the Grampian Locational Premium Scheme, which required applicants to “demonstrate how proposals will contribute to the delivery of the local Biodiversity Action Plan (LBAP) and make a positive contribution towards developing a Forest Habitat Network (FHN)”.

The criteria for riparian woodland proposals specified that:

- Schemes must be over 2 ha
- These must fall within Nitrate Vulnerable Zones.
- Adjoining woodlands may also be required to be brought into management.
- Must contribute significantly to Forest Habitat Network.
- These may also contribute to flood alleviation plans.

Whilst not differentiating between native and non-native species for the determination of existing networks, the BEETLE analysis complements these criteria, whilst emphasising the requirement for protection and expansion of biodiversity. It also allows targeted planting, since the approach indicates where land cover permeability will result in network connectivity. The networks produced focus on riparian, wet (Carr) woodland, and broadleaved networks and it is likely that future planting will be biased towards the creation of broadleaved native woodlands, particularly in riparian and wet areas. Future locational premium schemes or challenge funds may help consolidate existing areas of riparian and wet (Carr) woodland if they are used in conjunction with the Forest Habitat Networks. Such an approach has been successfully undertaken in Highland Region to link existing networks (www.forestresearch.gov.uk/habitatnetworks).

The BEETLE analysis takes into account variation in the land cover to determine whether areas are functionally linked, but also allows for the less utilisable woodland edge. Although the effect of buffering habitat results in very small or very narrow (< 50 m width) riparian or wet (Carr) woodlands not being classified as ‘core’ habitat (instead being given a very low resistance to dispersal in the land cover), it provides a focus on those habitats that are more likely to support viable species populations. The riparian and wet (Carr) woodland networks do consider other wet habitat to have a low cost for dispersal, therefore creation of other wetland habitat is likely to benefit and enhance these networks.

The broadleaved specialist network analysis (Figure 17) indicates that many of the broadleaved networks are associated with valleys, in particular around riparian areas. Woodlands not currently identified as riparian should be surveyed to determine whether they currently have the characteristics of riparian woodland. If so, they can be designated as such in future network analyses, if not then they may be targeted for management to improve their condition. Consolidation and expansion of these areas sits well with previous Grampian Locational Premium riparian woodland criteria, but also requires that the width of the woodland be 50 m to 110 m to allow for the woodland edge. Broadleaved riparian woodland networks would link with non-riparian (native and non-native) broadleaved networks, providing corridors for expansion through the valleys.

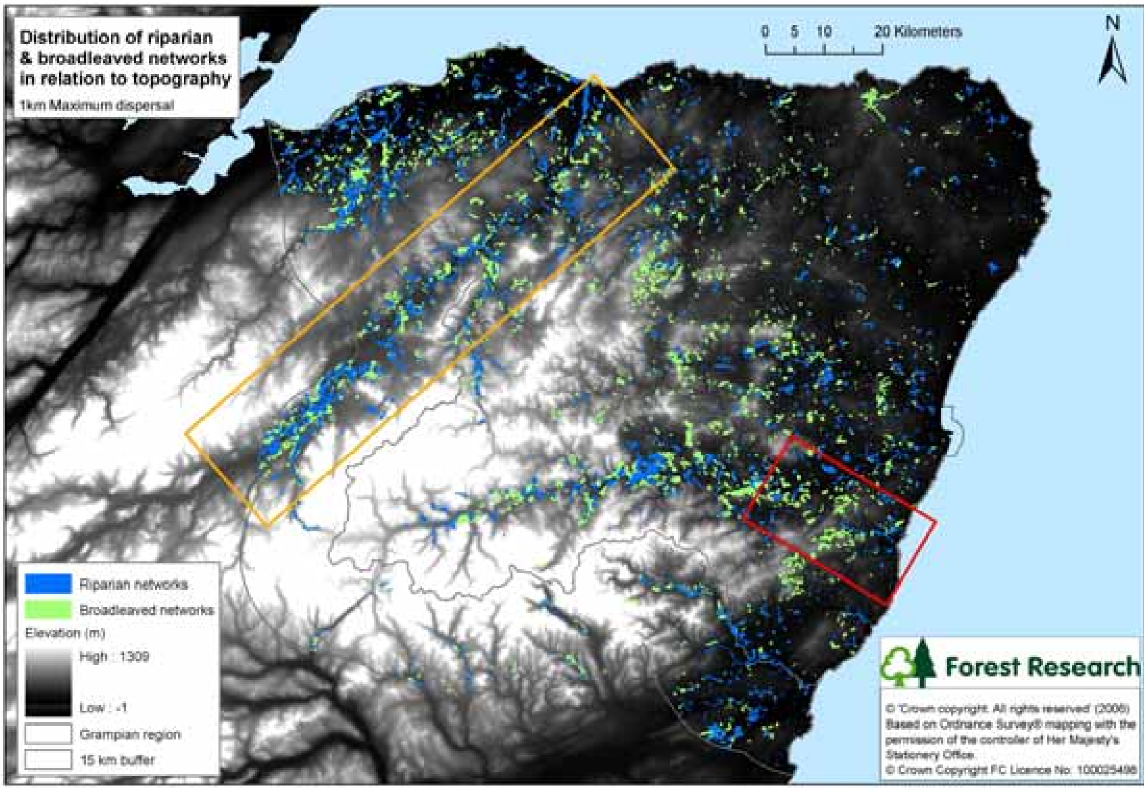

Figure 17. Broadleaved specialist networks are associated with the riparian areas running through the valleys. The orange box highlights a potential species dispersal route through Strathspey, the red box a potential route over the Slug Road running from Stonehaven to Banchory.

The valleys would provide valuable dispersal routes for species from the south. Such routes will become increasingly important as climate change affects the northerly distribution range of a number of species. One of these routes runs along Strathspey, linking the Highlands to Morayshire, which would allow species to disperse northwards through Central Scotland, and into the northeast of Grampian Region. Another route, between Stonehaven and Banchory where an area of low elevation ground links the two areas, has recently been identified by Scottish Natural Heritage as a pinch point.

3.3. Catchment analysis and data quality issues

To demonstrate the usefulness and robustness of the analysis, two studies were undertaken (Figure 18). The first examined a catchment area, selected by the steering group, to investigate how the network analyses can be applied at a catchment scale. The second compared networks produced in the analysis against those produced using data that were not available in digital format at the time of the analysis.

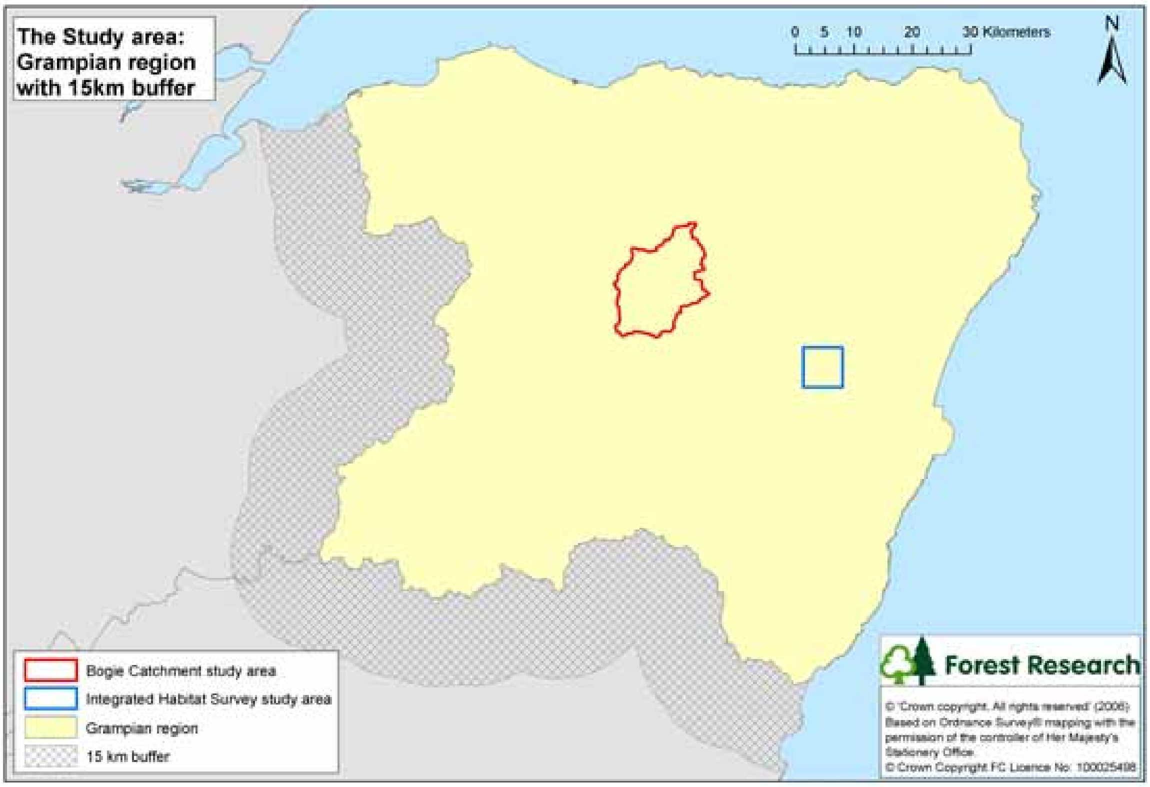

Figure 18. Location of Bogie Catchment and Integrated Habitat Survey data study areas.

3.3.1. Bogie catchment analysis

Description

The Bogie is a typical medium sized river in the north east of Scotland, rising as the burn of Craig in the Grampian foothills on acidic heather moorland, with very few trees apart from dwarf willows, the odd birch and rowan. There is no woodland at all for the first 7 kilometres until the policy woodland around Craig Castle is reached, with large mature broadleaves such as oak, ash, elm with a few firs, spruces and pines. It becomes the Bogie at Auchindoir bridge where another sizeable burn joins the Burn of Craig. The next area of trees is at Glenbogie about a kilometre away, where policy woodlands from Glenbogie House come down to the riverbanks. Here the land was too steep for agriculture, so semi-native woodlands exist in fragments and were supplemented in recent years with new planting under WGS.

A few blocks of commercial conifers also exist. From this point onwards the flood plain of the Bogie becomes agricultural with a mixture of grazing and arable crops depending on topography. Trees are rare except for a single line of alder with some goat willows right on the banks of the river. The middle Bogie runs through Old Red Sandstone geology and the soil derived from this is deposited on the flood plain to form a rich silty sandy loam soil. This soil is easily erodable, so the trees are very important for stabilising the banks. There are small riparian woods at Gartly and near Bucharn and Greenhaugh farms south of Huntly. It is estimated that less than 10% of the flood plain, banks and river terraces are occupied by woodland larger than 0.25 hectares, although there are single lines of alder for a good length of the river course (Steve Brown, Pers. Comms.).

Methodology

An analysis was undertaken within the catchment to demonstrate how the networks can be used at this scale, to suggest areas for improvement, and to make a comparison with the regional networks.

Steve Brown (FCS) provided detailed information on the woodlands along the Bogie; the comments below refer to those woodlands highlighted in Figure 20.

1. Very thin strips of quite old alder on the riverbanks, with no recruitment. The river meanders markedly around here, which is perhaps why these have not been removed for agriculture. There is potential to expand the woods in this area as the land is not high quality farmland.
2. A thin strip of alder with birch to the north. The woodland to the south is a planted mixture of sycamore, larch and spruce.
3. The northern wood is composed of a thin strip of alder; there is a nice wet woodland with elm on the river terrace on the other side of the river just south of Greenhaugh. The wood to the west of the railway line is interesting and looks semi-natural. There is a lot of blackthorn on the western edge with gean and ash on lower dry slopes. Some willows and a few alders lie on the wet flood plain.

Results & recommendations

Whilst the catchment contains a large proportion of woodland, much of this is dominated by conifers, particularly Clashindarroch forest, which forms a major component of one large network (Table 7). The remaining woodlands are smaller and more fragmented. The number and size of riparian and wet (Carr) woodland networks within the catchment is perhaps surprisingly small, with the mean network areas being substantially less than the regional mean (Table 7).

Table 7. Landscape metrics for the four generic focal species analyses in the Bogie Catchment area, with the percentage of the total regional network areas that these constitute.

Network	Internal buffer size (m)	Number of networks identified	Total area of networks (ha)	Area of largest network (ha)	Percentage of regional networks area	Mean area of Bogie networks (ha)	Mean area of regional networks (ha)
Wet (Carr)	20	21	318	42	0.7%	14.5	34
Riparian	20	22	418	54	0.8%	19.0	32.7
Broadleaved	50	61	2 853	42	3.2%	46.8	52.4
Woodland	None	133	8 504	5 814	2.5%	64.0	61.1

However, it is clear from the distribution of broadleaved networks (Figures 19 & 20) that there are many opportunities for expanding the riparian and wet (Carr) woodland networks, which are prioritised below:

- Riparian, wet (Carr) woodland, and broadleaved woodland specialist networks should be targeted for consolidation, buffered expansion, and structural management to improve quality.
- Many of the riparian woodlands are very thin and do not, presently, constitute core habitat and therefore are not contributing to the riparian habitat network for the catchment. These areas should be targeted for buffered expansion to at least 50 m width, with those adjacent to riparian and wet (Carr) woodland networks given priority.
- The survey undertaken by Steve Brown indicates that a number of these woodlands are ageing, with little recruitment. These areas should be targeted for improvement to ensure they can continue to constitute habitat for existing species and have the potential to act as sources for dispersal to other woodlands.
- Sites that have been identified with a high potential for restoration to wet (Carr) woodland, *e.g.* sites that have undergone modification such as drain blocking, should be targeted.
- Conversion of conifer plantations, adjacent to the woodland networks, to native broadleaved woodland should be considered.
- Where appropriate, woodland stepping-stones should be introduced to link existing networks.

This catchment scale analysis demonstrates how the FHN outputs can be used to identify, and prioritise, management opportunities that may not be apparent at a regional scale. Further prioritisation can be then undertaken on a case-by-case basis.

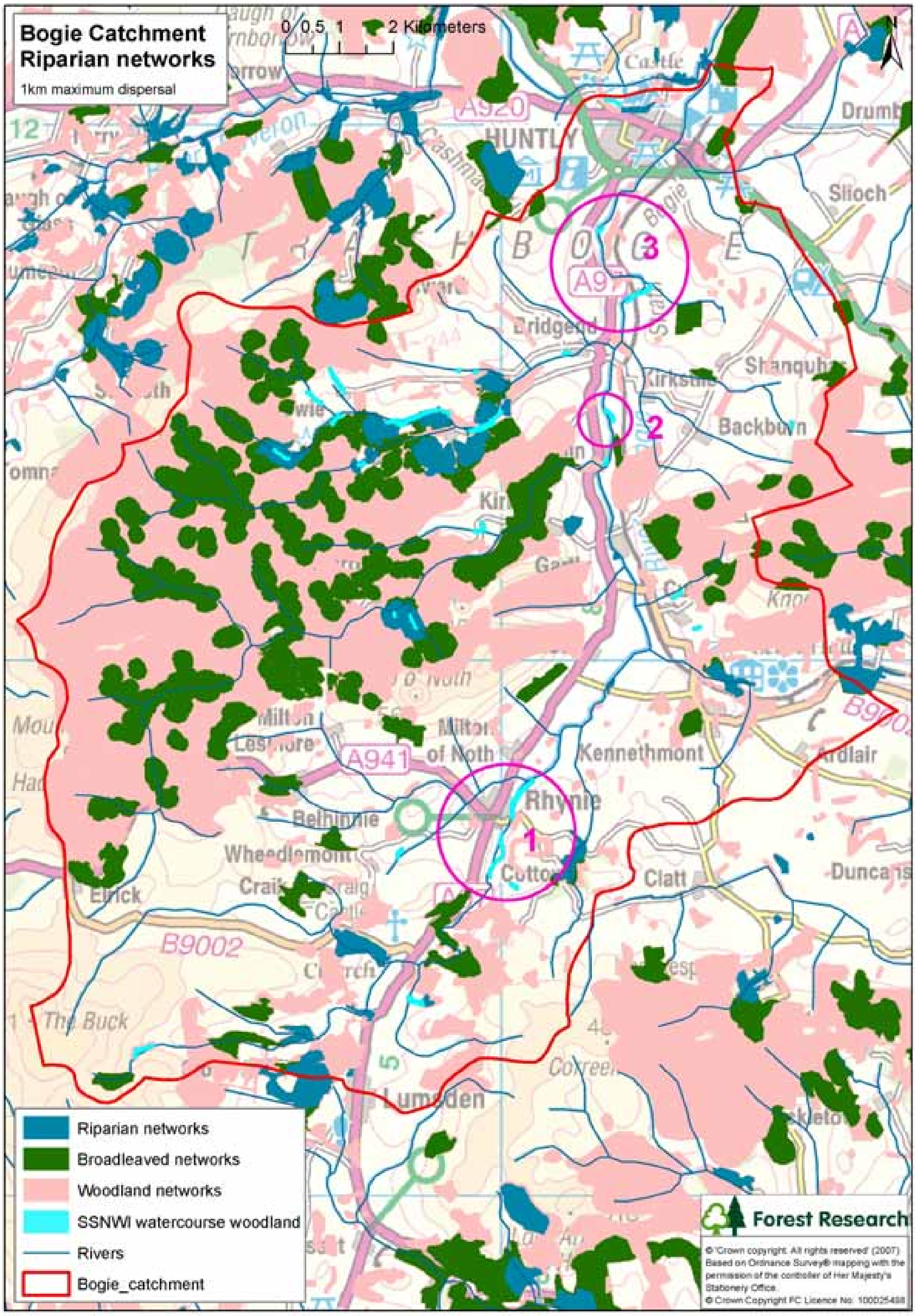

Figure 19. Current riparian, broadleaved, and woodland networks, within the Bogie Catchment with watercourse woodlands indicated by the Scottish Semi-Natural Woodland Inventory. Many of the watercourse woodlands are very narrow and do not currently have core habitat, but could be improved by buffered expansion, with those adjacent to networks to be given priority. Woodlands within the purple circles are referred to in the text.

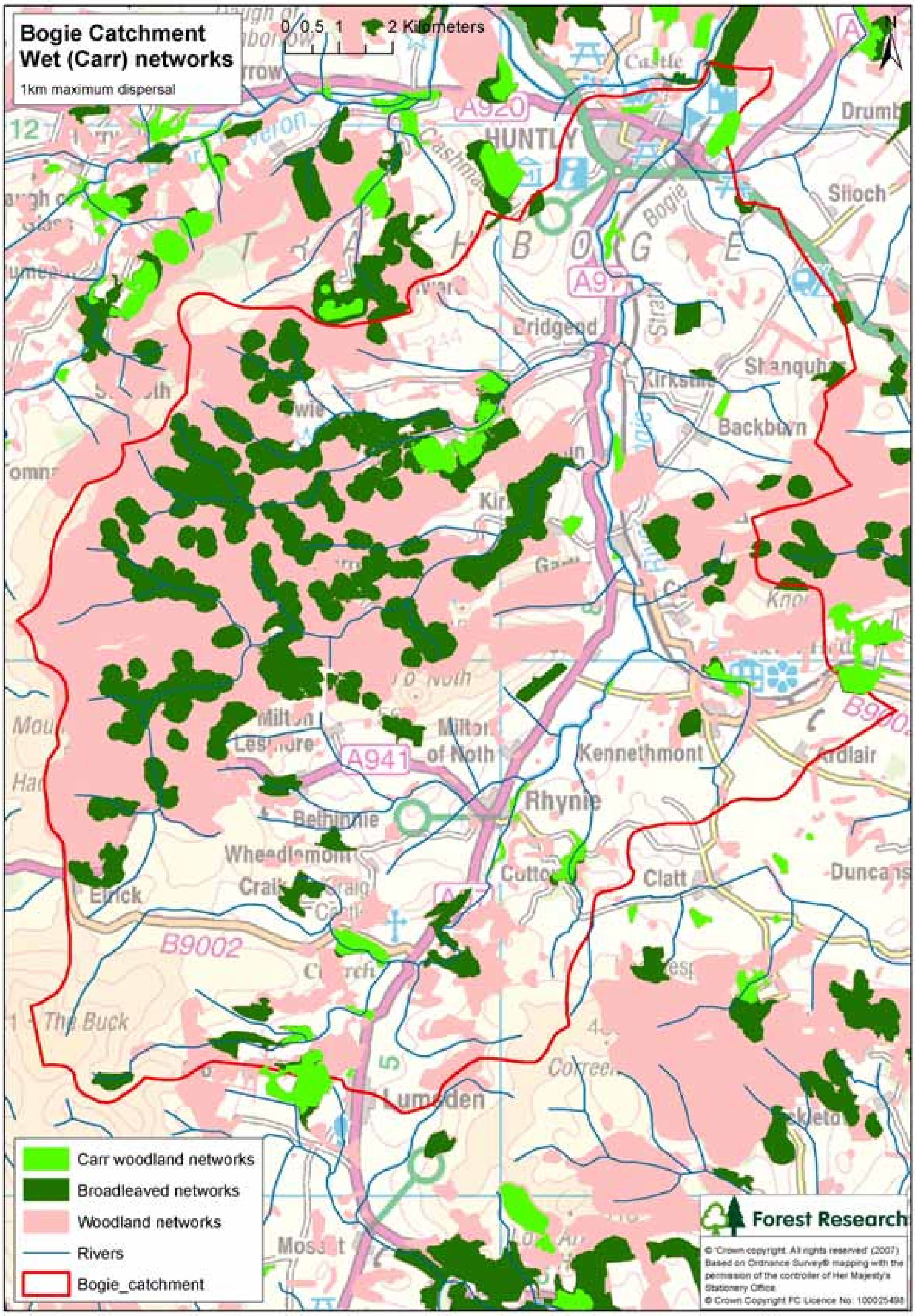

Figure 20. Wet (Carr), broadleaved, and woodland networks, within the Bogie Catchment.

3.3.2. Data quality comparison

Many of the data sets used in this analysis are based on interpretation of aerial photographs taken between 1987 and 1989; some areas may have been misinterpreted at the time or have changed in the last 20 years. Integrated Habitat Survey (IHS) data, where available, can provide more recent information and may allow greater detail to be applied to the land cover matrix. These data were not available in digital format at the time of the analysis, but have since been completed for some of the study area. To investigate whether these data can provide a better determinant of riparian and wet (Carr) woodland networks, a comparison of original networks with NESBReC Integrated habitat survey data was undertaken for a small area in Grampian Region (Figure 21). Data were also obtained from SEERAD, to indicate areas where management practices such as wetland management may affect land cover permeability.

Methodology

The IHS categories were interrogated to derive a number of sub-categories which would provide a more accurate reflection of how species can utilise these areas, for example, the category 'Other natural grassland' was split into the following wet areas:

Wet neutral grassland was classified as wetlands no drains no trees (84)
Wet & dry neutral grassland with trees present were classed as wet (Carr) woodland (1630) code 0 or scattered trees/scrub (1510)

These data were then added to the existing land cover data and an analysis run for the five woodland GFS within the study area.

Results

A comparison of the network metrics (Tables 8 & 9) shows that, whilst the total area of woodland networks is similar (1 746 ha and 1 737 ha) the IHS networks are more fragmented (61 networks against 41 networks) and smaller. The largest difference between the two data sets is evident when comparing the riparian networks (Figure 21, Tables 8 & 9), showing a 42% reduction in the number of networks and 45% reduction in network area when using IHS data. Consequently, the current data may overestimate the riparian, pine, & broadleaved networks and underestimate the wet (Carr) woodland networks. The differences may reflect changes in the land cover since the aerial photography was taken, but also the lack of watercourse designations by the IHS data.

Table 8. Network metrics for the study area using current data

Network	Internal buffer size (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
Wet (Carr)	20	21	608	29.0	305
Riparian	20	24	651	27.1	387
Broadleaved	50	36	1 175	32.6	347
Pine	50	7	451	64.4	132
Woodland	None	41	1 737	42.4	1 174

Table 9. Network metrics for the study area using Integrated Habitat Survey data

Network	Internal buffer size (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
Wet (Carr)	20	37	736	19.9	116
Riparian	20	10	361	36.1	233
Broadleaved	50	15	762	50.8	418
Pine	50	7	379	54.1	107
Woodland	None	61	1 746	28.6	1 068

Figure 21. Comparison of riparian networks produced using Integrated Habitat Survey data and those produced using existing data.

Whilst the use of the IHS data has been useful for reflecting land cover change, it needs to be used carefully so that some of the descriptive categories of older data sets, such as SSNWI watercourse are taken into account. SEERAD data was useful for representing how management activities can lower the cost to dispersal for a range of species, although much of this was reflected in the IHS categories. This analysis has also emphasised that any schemes which aim to improve habitat in a region are most beneficial when located close to existing habitat, *e.g.* wetland management grants should be targeted close to existing wetland networks. Such an approach has been investigated in the East Neuk case study area of the Lowland Habitat Network project, which examined agri-environmental schemes that benefit unimproved grassland networks www.forestresearch.gov.uk/habitatnetworks. Other SEERAD data, such as grants for hedgerows and field margins, would be extremely useful for reflecting how management to reduce land management intensity can improve the permeability of the land cover matrix for many species.

3.4. Woodlands in and around communities

Following the space for people standard set by the Woodland Trust, we tested the existing urban areas and the planned core development areas for access to woodland. The standard requires that people have the following access from their homes:

1. 2 ha of woodland within 500 m

   AND

2. 20 ha within 4 km

3.4.1. 2ha woodlands within 500 m

Figure 21 shows that many of the large existing communities in Grampian Region are not served by small woodlands within a few minutes walking distance. These include the majority of Aberdeen, Peterhead, Fraserburgh, and Elgin, with smaller areas throughout the region.

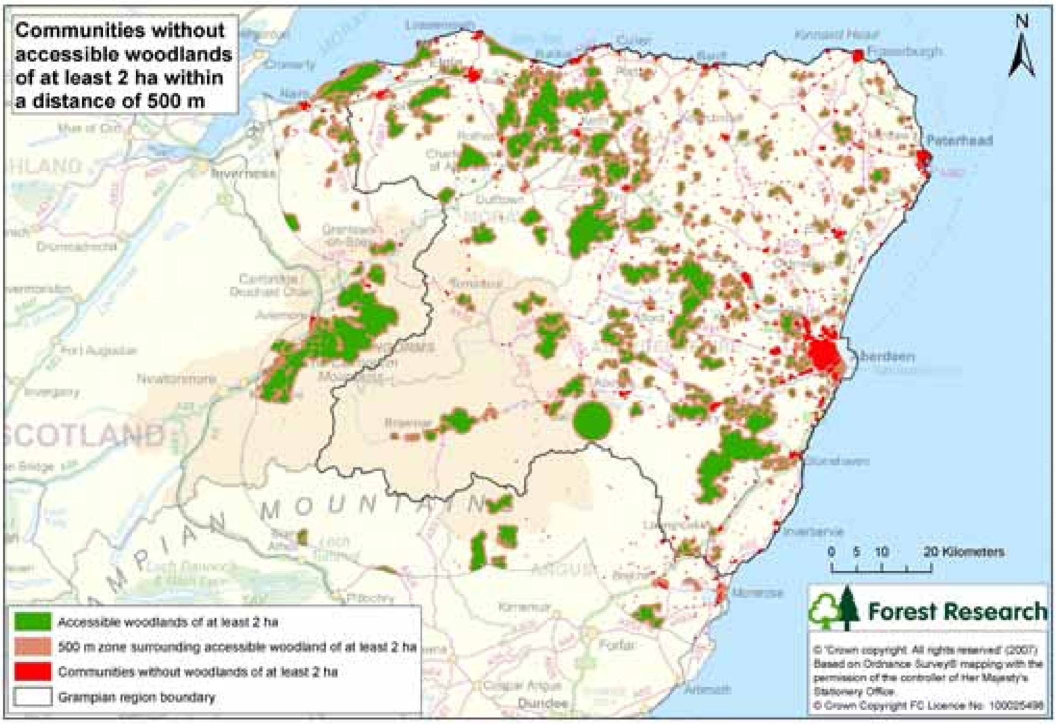

Figure 21. Communities not served by accessible 2 ha woodlands within a distance of 500 m in Grampian Region.

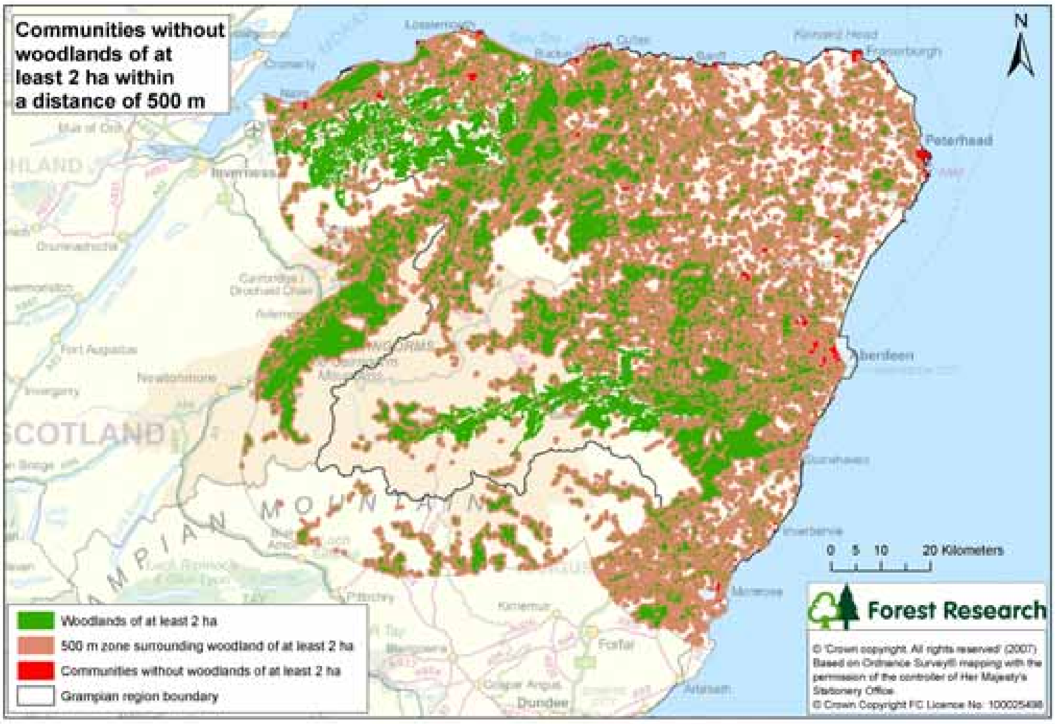

Figure 22. Communities not served by any 2 ha woodlands within a distance of 500 m in Grampian Region.

If all woodlands of at least 2 ha were considered accessible, then many areas do meet the criteria, although much of Peterhead, Fraserburgh and Elgin still do not.

3.4.2. 20ha woodlands within 4 km

The region is better served with larger woodlands over 20 ha, their distribution being reasonably adequate for the second access criteria of 20 ha within 4 km of communities. Figure 22 shows there is a lack of suitable woodland in a number of locations, with large areas in Peterhead, Fraserburgh, and towards the north of Aberdeen again failing to meet the criteria.

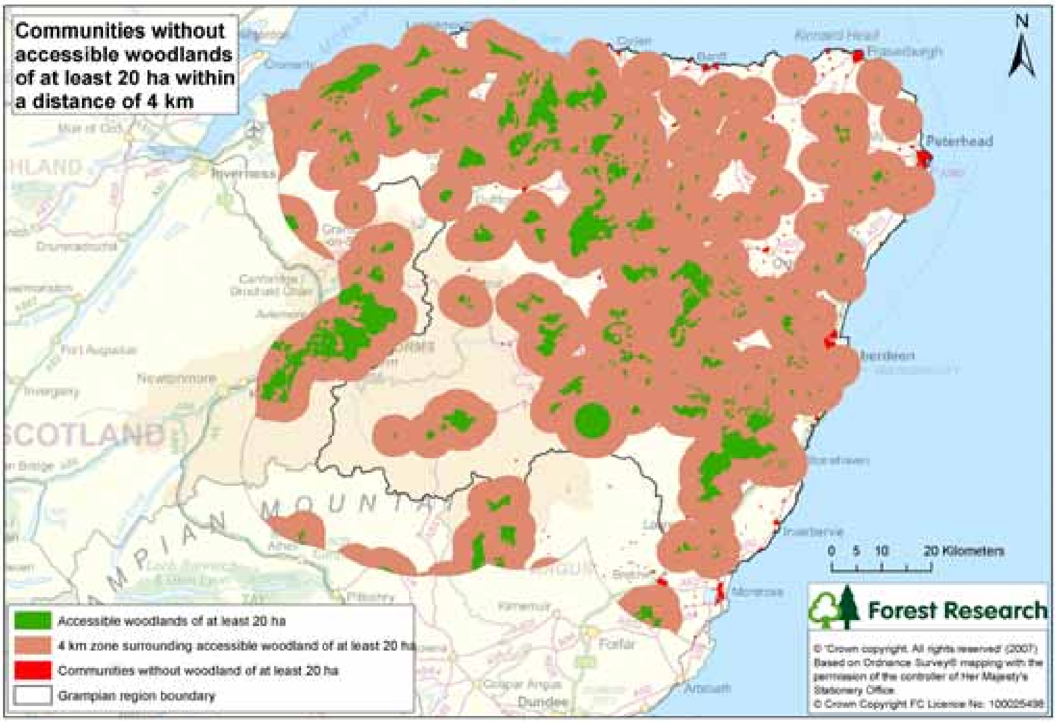

Figure 22. Communities not served by accessible 20 ha woodlands within a distance of 4 km in Grampian Region.

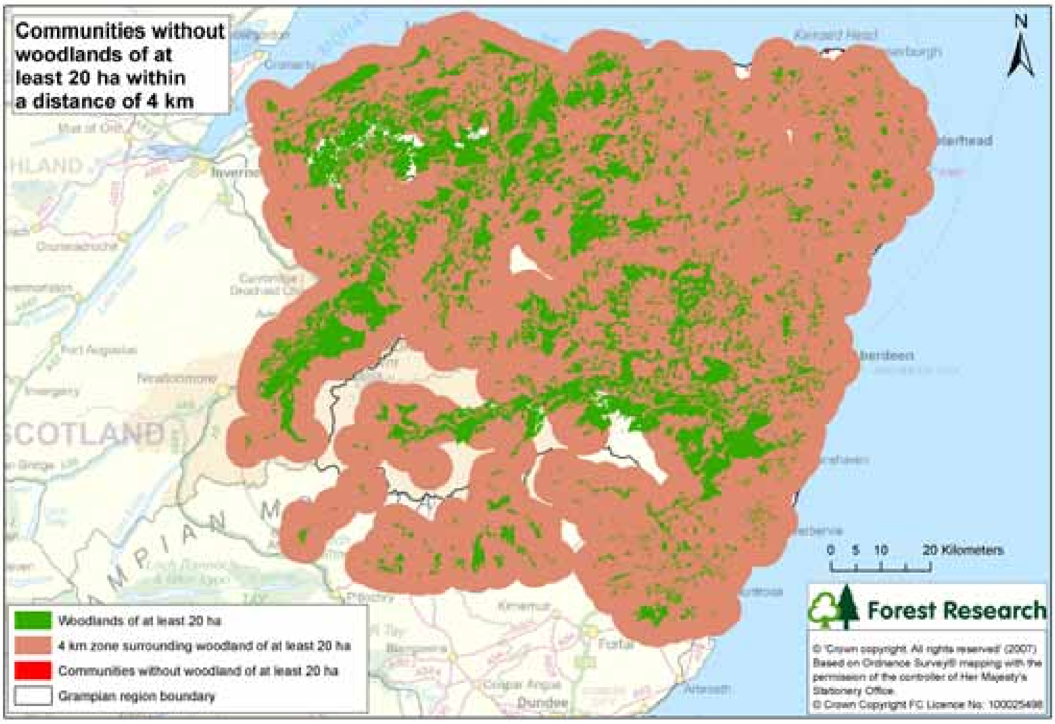

Figure 22. Communities not served by any 20 ha woodlands within a distance of 4 km in Grampian Region.

These results indicate that the Draft Scottish Forestry Strategy 2006 (Anon. 2006) key target for 2015 of "about two thirds of the population should have access to at least one area of woodland greater than 20 ha within 4 km of their homes" is being met on the basis of the whole study area. However, whilst it is likely that the second criterion, of "about one quarter of the population should have access to at least one area of woodland greater than 2 ha within 500 m of their homes" can be met when considering the area as a whole, some local populations will not have access to woodland.

Provision of new woodland to meet the above criteria should by carefully planned and not impinge on open-ground habitat, ecologically valuable brown field land or archaeological sites. The structure of woodland should be appropriate to local requirements. Whilst diverse, multi-layered woodlands are appropriate for rural areas where people expect a wildlife experience, they may be seen as threatening in urban areas. The locality of woodland in relation to deprived communities is particularly important, as transport is too expensive. It is recognised that woodland usage will vary according to geographic location and population density and it is recommended that the Woodland Access Standard suggestion of at least one area of accessible woodland within each distance threshold be used to deal with variation in local use.

4. Discussion

4.1. Determination of habitat quality

This is a desk study to identify extant Forest Habitat Networks of Grampian Region. The method brings together several data sets to try and better understand woodland biodiversity and the functional connectivity required for its dispersal, viability and resilience. Several assumptions have been made; some of which are rather arbitrary. Perhaps the more secure assumption is that riparian and wet (Carr) woodland indicator plants can also be used to indicate woodlands with the characteristics to support species that utilise these habitats.

This assumption relies on the knowledge that with antiquity, woodlands tend to develop structurally and biologically, with time for slow dispersing species to colonise. However, human disturbance and intervention can cause a structural and biological decline *e.g.* PAWS. This raises the notion of testing woodland quality by the presence of an indicator. Ancient woodland indicator plants have been shown to support the occurrence of woodlands of some antiquity (Peterken 2000). In this study we follow this principle for riparian and wet (Carr) woodlands with the additional idea that woodlands which support a number of plant indicators are also likely to support a wider woodland biodiversity through all taxonomic groups. The biological records centres (BRC) hold digital records of species occurrence, and NESBReC have supplied the riparian and wet (Carr) woodland indicator plant data in this study. However, the records are open to false negative results, since 'no records' cannot be assumed to mean 'not present', only 'not recorded'. We have tested 27 species to try and minimise non-recording of certain species, however woodlands that are infrequently visited are perhaps less likely to have complete records.

The riparian and wet (Carr) woodland indicator plant criteria thresholds of 4 or more plants to identify 'poorer quality' and 8 or more plants to identify 'high quality' are more pragmatic than arbitrary. Certainly, a case could be made to identify a lower quality woodland class, containing 1 to 3 plants. This would remove the possibility of underestimating the number of quality woodlands. Indeed it would overestimate low quality woodlands, since many woods with little quality would qualify by chance. In addition, the extra work required to associate woods with a lower number of indicator plants is considerable. To keep within the resources of this study we settled on just three classes: 0 to 3 indicator plants, 4 to 7 indicator plants, and 8 or more indicator plants, which required us to identify only the last 2 classes.

Whilst some of the records had a 100 m grid reference, others were only accurate to 1 km, and many did not have supporting text to indicate to which woodland the entry referred. Consequently, some designations were based on the most appropriate nearby woodland. Although it was possible to obtain expert knowledge of some woodlands, this knowledge was limited to those areas where the expert had familiarity. We would therefore recommend that local knowledge be used to confirm woodland quality and wherever discrepancies occur between the data used and reality, then that information should be noted to ensure changes are made to the digital database, and amendments made prior to an update analysis. Wherever the discrepancy is about the woodland quality classification, then the woodland shapes will not change, only the core woodland components, representing source areas for woodland species dispersal. This type of error is less serious, and local modifications can be made by editing the FHN shapefile.

A general note of caution should be added: the methodology described above assumes that the woodland is large enough to support viable populations. Although species may persist for 100 years or more due to being both long-lived and through genetic propagation, those currently existing in very small woodlands may already be in genetic decline that cannot be halted by the prescriptions offered here. This phenomenon is more likely to occur in landscapes that have been altered more drastically, such as agricultural areas and the built environment, where dispersal through the land cover is increasingly restricted and woodlands increasingly fragmented.

4.2. Habitat networks

The pinewood, broadleaved, riparian, and wet (Carr) woodlands are fragmented remnants of what was once a more widely distributed woodland cover. Although of high biodiversity quality, many woodlands have become degraded by neglect, with others having been heavily managed, and often containing a proportion of non-native tree species from past planting. However, the tree species is less important than to continuing to manage the woods in a way to maintain structural and tree species diversity focussing more on the wide range of micro-habitat which should involve a diverse field layer, under-story, and adequate supply of deadwood. These woodlands now support a diminished biodiversity, compared to earlier times. The UK has lost most of its woodland specialists (compared to more wooded countries of Europe). This loss has been caused by gradual fragmentation: loss of habitat and a reduction in the ability of species to disperse across the wider countryside. It is extremely important that we try to maintain the landscape structure in a way that will provide a range of habitats to protect the biological diversity of Grampian Region.

Major woodland management and landscape ecology issues relating to climate and people have become increasingly apparent, these include: developing strategies to maintain biodiversity, as the impacts of climate change develop; plan woodland and open habitat in a way which maintains the functional connectivity between habitat patches; improve peoples perception and enjoyment of woodland to stimulate their appreciation of nature; ensure tree species that are suited to site now, and during the rotation, are selected. The essential objective of habitat networks is to ensure the landscape can accommodate the movement of species and the flow of genes, to help protect against fragmentation. The major task facing forest agencies and planners is to assimilate this complex ecological issue with other social and infrastructure needs of society into strategies and plans that will deliver a solution which suits the different facets of sustainable development.

The pinewood networks are extensive within Grampian Region, with the larger elements of ancient pinewood around Speyside and Deeside providing valuable sources for species dispersal to other pinewoods. These older, more biologically diverse woodlands, should thus be the focus of strategies to increasing the robustness of the pinewood resource, which are particularly important for a range of threatened species.

The broadleaved woodland networks provide an important framework to identify opportunities, not only to consolidate and improve the broadleaved woodland component within the region, but they also allow targeted improvement of riparian and wet (Carr) woodland networks. The broadleaved networks should be used, where appropriate, as a guide to allow targeted new native broadleaved woodland planting, to ensure these woodlands are created where they will most benefit biodiversity.

Three classes were used to identify riparian and wet (Carr) woodland in the study. We have deliberately set the standard high for assessing biodiversity quality. The assumption is founded on the premise that woodlands of high biodiversity require protection, buffered expansion, and sensitive management; to maintain canopy structure, mimic natural disturbance, supply deadwood, and recruit replacement trees into the canopy. Active management to mimic natural disturbance will be an important feature of woodlands hosting 4 or more indicator plants.

For woodlands with fewer than 4 indicator plant species, the type of woodland management to improve biodiversity may differ. For example, grazing or browsing pressure might be a problem, the canopy cover possibly too dense, the supply of deadwood too small, or the tree species mix possibly inappropriate for the semi-natural woodland type.

It must be remembered that for the riparian and wet (Carr) woodland specialist analyses, although habitat is defined by the presence of indicator species, all woodland is considered part of the network. For all the specialist analyses, 'potential' riparian and wet (Carr) woodland has been attributed with a low dispersal resistance (0.5 or 1). So although not registering as habitat (and a potential biodiversity source area), it will contribute to specialist woodland networks when close to the designated habitat.

It is vital that we consolidate and expand remnants of ancient woodland and riparian & wet (Carr) woodland to protect species in the face of climate change, but should also allow for the likely northern dispersal of species by improving the wooded linkage at watershed areas. Riparian woodlands may provide a particularly important conduit for dispersal and as such these areas should be targeted for improvement and expansion. It is also important to allow for dispersal from the west, which may be achieved by improving linkage from Strathspey.

Improvements in data quality, *e.g.* Integrated Habitat Survey, National Inventory of Woodland and Trees 2, and the Scottish Native Woodland Survey, will allow future analyses to be undertaken in greater detail. Allied to this, directed species surveys will aid identification of quality woodland and may allow additional data sets to be incorporated.

The analyses detailed here provide an indication of the opportunities for directed woodland consolidation and expansion to increase biodiversity, they are not intended to be prescriptive. It is important to reiterate that the woodland habitat networks are ***functional*** networks representing the dispersal of woodland species from source habitat patches through a diverse land cover matrix. As such, the networks show where woodland species can disperse through open ground habitats. Connecting nearby FHNs does not require contiguous woodland planting; it may be achieved by planting a relatively small woodland 'stepping stone' or by a reduction in intensive open ground management. Any alteration of open ground habitat to facilitate dispersal should only take place following a considered site analysis and should not disadvantage open ground specialists.

The consolidation and expansion of woodlands, particularly those located on SSSIs and other notified sites, should first examine their often complex composition, which may comprise a mosaic of habitats, where the promotion of the woodland element might lead to an overall reduction in biodiversity.

Although the analyses here focus on woodland, we have also examined the interaction of woodland creation with heathland habitats/species. Detailed analysis of other open ground specialists was outside the scope of this work, but it is important that these should be considered when assessing the possibilities for improving the FHNs. Other open ground habitats are locally important, for example there is often a conflict of land use between afforestation and both wetland and unimproved grassland habitats, particularly along riparian corridors.

4.3. Woodlands in and around communities

People need space to live and this should include more natural spaces, within and surrounding their communities. Woodland allows people space to relax and observe elements of natural ecosystems, in a world that is increasing in complexity driven by technology. The 'Space for People' standards, echoed by Draft Scottish Forestry Strategy 2006 (Anon. 2006) key targets for 2015, are the minimum woodland access standards suggested, and should be followed in all new developments to improve the resilience of people to increasingly more stressful lives.

Woodlands also add character and charm in urban settings. They can screen housing and reduce the impact of development on existing communities. They ease the impact of change on communities, since people see some benefit to urban expansion. For residents, in time, when new woodlands develop and mature, their own space in the community becomes more secluded and personal. This adds value to the urban space, in which residents are aware of the benefit that woodlands bring, becoming attached to their community woodlands, and caring for the maintenance of woods in urban spaces. Woodlands, as part of open space, can promote a sense of place and be a source of community pride and also offer opportunities for people to play an active part in caring for the local environment (Scottish Executive 2003).

In many areas where trees and woodlands form a small but significant proportion of the land cover, woodlands can fill the important role of linking urban areas into the surrounding landscape. Trees and woodlands provide an important conduit for the movement of wildlife and people through networks in both urban and rural environments (Scottish Executive 1999). The UK Government has just signed the European Landscape Convention (ELC), which aims to ensure that the importance of landscapes is recognised. The ELC defines landscape as '...an area, as perceived by people, whose character is the result of the action of natural and/or human factors. The 'Woodlands in and around Towns' initiative has an important role to play in meeting the sentiment of these ELC objectives.

Finally woodlands bring wildlife into urban settings. Woodland birds, spring blossom, autumn colours, and woodland plants are welcome signs of the change in seasons, adding value to peoples' lives, and providing incentives and opportunities to explore and learn more about the natural world.

4.4. Integration of Habitat Networks into LBAP aims

The approaches presented here provide a useful tool to address the region's Local Biodiversity Action Plans for woodland and suggestions for their use include:

- **To maintain and enhance the extent and status of semi-natural wet woodlands and encourage a balance of appropriate management regimes (UK objective), habitat creation, data collection, promotion, education, liaison and legislation.**
- **Expand the area of wet/riparian woodland through habitat creation and management.**
- **Prevent and/or reduce threats to the resource through continuation/introduction of established management techniques at all identified sites**

The analyses have demonstrated the importance of consolidating, buffering, and connecting the highly fragmented riparian and wet (Carr) woodlands of the Region. However, the rehabilitation and buffering of existing nodes should take precedence over connecting with new woodland, since the former approaches will realise faster biodiversity gains due to the time taken for new woodland to gain the attributes associated with good quality woodland.

- **Survey and assess all degraded wet and riparian woodland sites, identify restoration and enhancement priorities**

The determination of riparian and wet (Carr) woodlands using a range of methods (survey data, SSNWI watercourse categories, coincidence mapping, habitats predicted by the Scottish Natural Heritage (SNH) / Macaulay Institute Native Woodland Model, a derived wet woodland dataset) have provided a starting point for an inventory of these habitats. Confirmation through survey and local knowledge will help to refine these data, allowing strategic improvement of the existing networks to be undertaken.

- **Ensure no loss in the key biodiversity (species and genetic populations) associated with riparian and wet woodland by undertaking careful management and restoration work.**

A habitat network approach will help to reduce the risk of biodiversity loss. Site specific measures and monitoring may be needed to reduce the risk to particular species & genetic populations.

The protection of the remaining riparian and wet (Carr) woodland within the Region is crucial. Without these remaining patches, the source of woodland biodiversity for these habitats will disappear in the landscape as the patches are the reservoir and refuge for woodland biodiversity. The best way to safeguard these patches is to expand them in a way to extend the core area of woodland they contain. The core woodland area is the central part of woodland that is not influenced by the edge. The buffered expansion of existing riparian and wet (Carr) woodland with new woodland, by planting or natural regeneration, is the best way of protecting the existing woodland biodiversity. Reducing management intensity of the surrounding matrix will provide a secondary buffer.

New patches of woodland are also required in the landscape to bridge the gap between existing woods, by reducing woodland isolation. Clearly for woods to develop core habitat conditions there is a minimum size to consider, which will be more than two edge effects across the woodland patch (about 100 m for broadleaved networks). In planning the opportunities for woodland in core development areas, these issues should be considered.

5. Recommendations

5.1. Data quality

- This desk study has only made use of digital spatial data sets, combined in a way to determine a high standard of biodiversity quality. Wherever the biodiversity quality of a particular woodland is suspected, from experience or validation by other surveys, the woodland should be re-designated appropriately within the forest habitat network. An update of the data sets should be undertaken once there is a sufficient amount of new data to justify the amount of time required. Consequently, early submission of such data to Forest Research by all parties would allow data quality to be quickly improved, ideally within one year.

5.2. Habitat network priority

Improvement of the wooded landscape networks should follow a series of priorities:

1. Protect and manage high biodiversity quality woodlands, *e.g.* high biodiversity riparian woodlands.
2. Restore or improve degraded habitat by targeting areas with good restoration/improvement potential, *e.g.* PAWS or heavily grazed sites; particularly those adjacent to ancient semi-natural woodlands, where opportunities for species dispersal can be high.
3. Improve the matrix, by reducing intensive land use, increasing hedgerows in agricultural landscapes; reduction in pesticide/herbicide use; reduction in grazing densities.
4. Create new habitat by targeting to improve network size or connectivity. This may be particularly appropriate for the creation of new habitat for flood alleviation.

5.3. Woodland biodiversity protection

- All woodlands, but particularly riparian and wet (Carr) woodland should be expanded by planting contiguous patches as many of the broadleaved woodlands in Grampian Region consist of long, relatively thin woodland with little ‘core’ woodland. Increasing the amount of core woodland will result in a large number of nodes from which species can disperse, and hence a large network area.
- The Forestry Commission Forest and Water Guidelines suggest a riparian buffer of 5-20 m depending on width of watercourse. Additionally, all riparian and wet (Carr) woodland should be protected from development by a buffer zone of at least 250 m in width, allowing room for core woodland expansion and a surrounding scrubby and open ecotone. This will provide a more natural environment for communities (within a woodland setting), and will help reduce disturbance, and minimise the woodland edge effect on core woodland species.

5.4. Woodland management

- Woodlands containing riparian and wet (Carr) woodland compartments should be targeted for consolidation and expansion. The surrounding low quality woodland should be improved to provide a range of woodland conditions for species dispersing from the high quality compartments.
- Active management should be encouraged on woodlands occurring on ancient woodland sites to improve the quality of the woodland. Steps taken may include livestock exclusion, deer management or removal of non-native species.
- Maintain and enhance ancient woodland features in PAWS and restore to native woodland, at an ecologically appropriate pace, sites with a significant biodiversity legacy, *e.g.* indicated by the presence of ancient woodland indicators, or at key locations in native woodland habitat networks where the remnant ancient woodland plant communities are most at risk.

5.5. Woodland expansion

- Tree species planted should be suited to the habitat type, *e.g.* native broadleaved species to be selected for riparian, wet (Carr) woodland, and broadleaved networks, and ideally of a suitable seed zone. Use ESC (Ray 2001) to assess site types and inform species choice.
- Those riparian and wet (Carr) woodlands having less than four indicator species present should be targeted for structural management, to improve the condition of the woodland to encourage a greater number and diversity of woodland species. This could, in time, bring these areas into the riparian or wet (Carr) woodland categories. Management should concentrate on approaches that maintain and enhance the appropriate woodland ground flora (see NVC for details).
- Sites that have been identified with a high potential for restoration to wet (Carr) woodland, *e.g.* sites that have undergone modification such as drain blocking, should be targeted.
- Riparian, wet (Carr) woodland, and broadleaved woodland specialist networks should be targeted for consolidation, buffered expansion, and structural management to improve quality. Where appropriate, woodland stepping-stones should be introduced to link existing networks.
- FHN development should take care to maintain structural and managerial measures to discourage grey squirrel incursions around red squirrel strongholds and to non-native invasive species such as Himalayan balsam.

5.6. Open-habitat management

- FHN development should take care not to adversely affect open ground networks. Detailed examination of open ground habitat should precede any strategies to expand existing FHNs.

- Woodland generalist networks: to improve the permeability of the landscape, where appropriate, surrounding open habitat should be managed in a less intensive way or restored to semi-natural habitat, which will allow greater dispersal of woodland generalists and allow greater network size and linkage, *e.g.* improved grassland to semi-natural grassland.
- The identification and qualification of hedgerows and their contribution to biodiversity may provide useful data for future analyses.

5.7. Woodlands in and around communities

- New developments should endeavour to ensure Space for People targets, suggesting accessibility to woodlands of 2 ha or more within 500 m, are not compromised.
- Woodland planting on development sites should be substantial; 150 m width will eventually provide at least 50 m of core woodland conditions. This is the minimum recommended size for new woodland. The planting of street and ornamental trees will have no impact on improving the woodland biodiversity of the region. Under these circumstances, development would only increase the fragmentation of neighbouring woodland habitat.
- Within all of the urban fringe planners and developers should be encouraged to take every opportunity to add new woodland and protect existing woodland; to safeguard the biodiversity of the region, mitigate the impact of climate change, and improve community landscapes.

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Appendix 1. Metadata for designating woodland type.

Rules for woodland designation and codes assigned.

Riparian woodland

SFGS-New native woodlands-nbl, mb with grant for riparian estab or improvement (1308)
SSNWI broadleaved woodlands with watercourse category (1601)
VARIOUS-bl woodland within 50m of watercourse (1602)
VARIOUS-bl clipped to NWM wet woodland NVC (1604)
VARIOUS-bl + scrub clipped to derived wet woodland areas (1605)
SSNWI ≥ 80% broadleaved woodland associated with 8 or more riparian & wet (Carr) woodland indicators (1606)
NIWT broadleaved associated with 8 or more riparian & wet (Carr) woodland indicators (1606)
VARIOUS-bl woodlands with at least 8 riparian/wet (Carr) woodland indicators (1606)
VARIOUS-bl woodlands with 4 to 7 riparian/wet (Carr) woodland indicators (1607)
SSNWI mixed woodlands with watercourse category (1613)
SSNWI conifer woodlands with watercourse category (1614)
VARIOUS-mixed woodland within 50m of watercourse (1615)
VARIOUS-mixed woodland clipped to NWM wet woodland NVC (1616)
VARIOUS-mixed woodland clipped to derived wet woodland areas (1617)
VARIOUS-mixed woodlands with at least 8 riparian/wet (Carr) woodland indicators (1618)
VARIOUS-mixed woodlands with 4 to 7 riparian/wet (Carr) woodland indicators (1619)
SSNWI < 10% canopy cover with at least 8 riparian/wet (Carr) woodland indicators (1620)
SSNWI-semi-nat, bl and mixed watercourse woodland <10% canopy cover (1622)
VARIOUS-bl & mixed? clipped to derived wet woodland areas + scrub, <10% canopy (1623)
VARIOUS-bl & mixed? clipped to NWM wet woodland NVC <10% canopy (1624)

Wet (Carr) woodland

VARIOUS-bl clipped to NWM wet woodland NVC (1604)
VARIOUS-bl + scrub clipped to derived wet woodland areas (1605)
SSNWI ≥ 80% broadleaved woodland associated with 8 or more riparian & wet (Carr) woodland indicators (1606)
NIWT broadleaved associated with 8 or more riparian & wet (Carr) woodland indicators (1606)
VARIOUS-bl woodlands with at least 8 riparian & wet (Carr) woodland indicators (1606)
VARIOUS-bl woodlands with 4 to 7 riparian & wet (Carr) woodland indicators (1607)
VARIOUS-mixed woodland clipped to NWM wet woodland NVC (1616)
VARIOUS-mixed woodland clipped to derived wet woodland areas (1617)
VARIOUS-mixed woodlands with at least 8 riparian & wet (Carr) woodland indicators (1618)
VARIOUS-mixed woodlands with 4 to 7 riparian & wet (Carr) woodland indicators (1619)
SSNWI-semi-nat, bl and mixed watercourse woodland <10% canopy cover (1622)
SSNWI and NIWT woodlands identified by survey as wet woodland (1625)
SSNWI ≥ 80% broadleaved associated with 4 to 7 riparian & wet (Carr) woodland indicators. (1607)
NIWT broadleaved associated with 4 to 7 riparian & wet (Carr) woodland indicators. (1607)
SSNWI < 10% canopy cover with at least 8 riparian & wet (Carr) woodland indicators (1620)
VARIOUS-bl & mixed? clipped to derived wet woodland areas + scrub, <10% canopy (1623)
VARIOUS-bl & mixed? clipped to NWM wet woodland NVC <10% canopy (1624)
VARIOUS-woodland defined as wet (Carr) from survey (1625)
RSPB-Wet bl woodland derived from a number of NESBReC datsets (1630)
RSPB-Wet mixed woodland derived from a number of NESBReC datsets (1631)

Broadleaved woodland on ancient woodland sites

PAWS, LEPO, ASNW that intersect with broadleaved woodland
SSNWI ≥ 80% broadleaved clipped to the Ancient Woodland Inventory (1119)
NIWT broadleaved clipped to the Ancient Woodland Inventory (1119)

Other broadleaved woodland
NIWT Forest type = broadleaf (1001)
SSNWI = excluding farm and parkland categories, with minimum canopy cover of 50% and minimum 80% broadleaf tree type
Sfgs or WGS ≥ 80% broadleaved not on ancient woodland site 1152
Sfgs or WGS < 80% broadleaved not on ancient woodland site 1154

Undesignated ancient mixed woodland
PAWS, LEPO, ASNW that intersects with mixed woodland (1121)

Undesignated ancient conifer woodland
PAWS, LEPO, ASNW that intersects with conifer woodland (1120)

Other conifer woodland
NIWT, conifer (1002)
SSNWI

Data resources used in the Grampian Forest Habitat Network study.

Rank	Resource name	Resolution	Notes
1	Phase 1 habitat data	Mapped at 1:10,000 with 0.25 ha resolution	Surveyed Digitized 2000 Hutcheon Bros.
2	Scottish Semi-Natural Woodland Inventory (SSNWI)	0.1 ha resolution	Interpreted from 1987-88 aerial photograph survey
3	National Inventory of Woodlands and Trees (NIWT)	2 ha minimum patch size	Interpreted from aerial photograph survey and maintained to 2003
4 *	Woodland Grant Scheme 3 (WGS3), Scottish Forestry Grant Scheme (SFGS)	0.1 ha resolution, Qualifying size for schemes is 0.25 ha	Maintained records of species in new woodland areas
5	Land Cover Scotland 1988 (LCS88)	0.1 ha resolution	Interpreted from 1987-88 aerial photograph survey
6	Forest Enterprise (FE) sub-compartment database	0.5 ha resolution in most cases	Database of all Forestry Commission woodlands
7.	Biological records centre data	Variable, 10m to 1 km depending on submission	Locations of species from recording systems and public submissions
8.	Ordnance Survey Pan-Government product portfolio	Variable, dependent on product	Products include: 1) for large scale mapping - OS MasterMap; Land-Line; 1:10 000 Scale Raster; 2) for small scale mapping – 1:50 000 Scale Colour Raster; 1:50 000 Scale Gazetteer; 1:250 000 Scale Colour Raster; Strategi; Meridian 2

These data specifically relate to new planting,** i.e., **all woodland that has been established since the last update of the National Inventory of Woodlands and Trees (NIWT) in 2003.

Data hierarchy

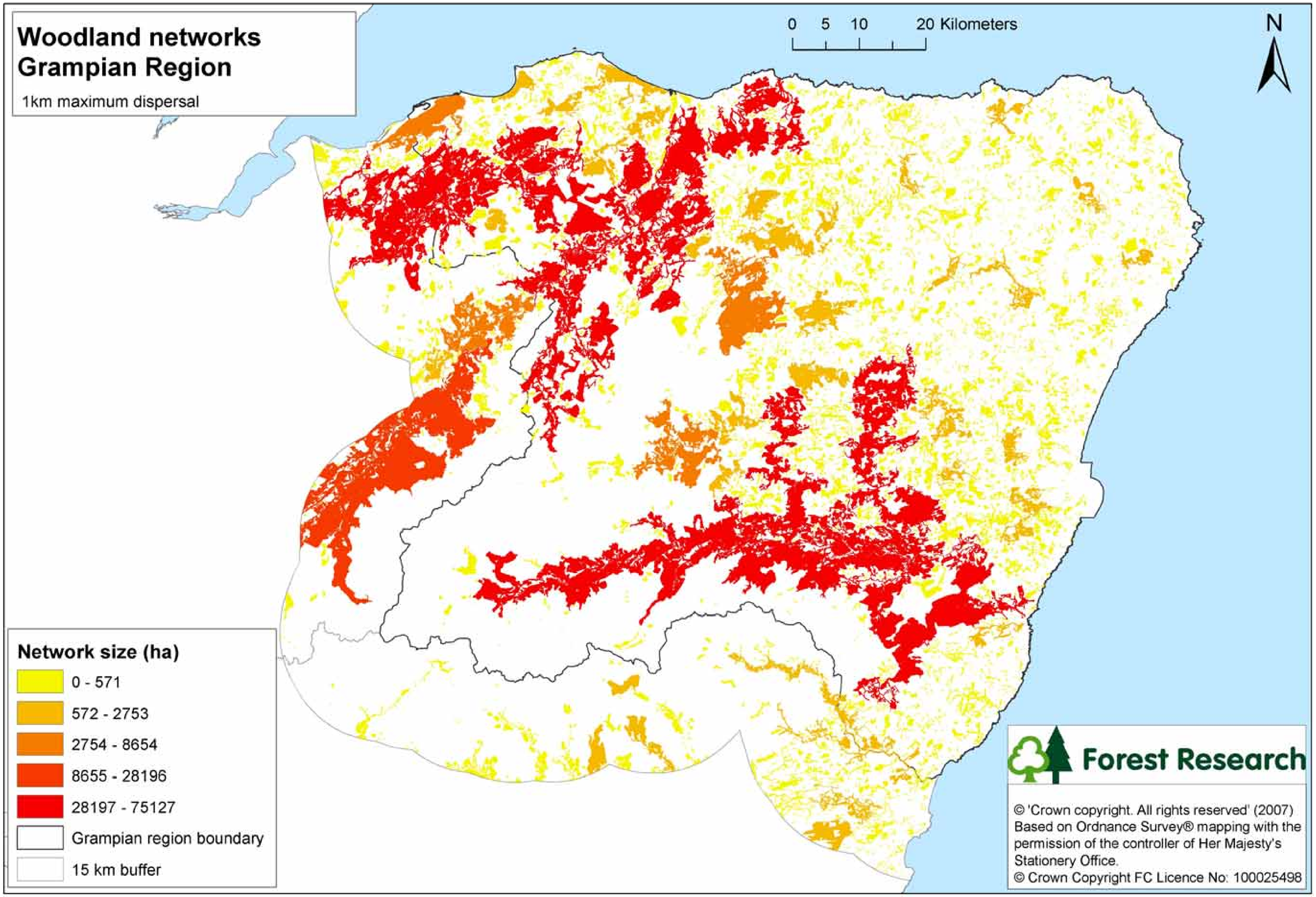
The land cover matrix was built using the following data hierarchy (highest importance at top):

Land cover type	File names
Removed buffers	Wet (Carr)_20m_buffer Riparian_20m_buffer AP_50m_buffer Pine_50m_buffer Broadleaved_50m_buffer
Survey data	WetWood_region
Coincidence mapping data	Ssnwi_grampian_within_500m_8_indicators_not_watercourse_selected
SSNWI watercourse	Ssnwi_grampian_watercourse_woodland
Derived wet woodland	Flood_risk_bl_mixed_semi_nat_non_watercourse
NWM wet woodland	Nwm_ssnwi_wet_woodland_bl_mbl_clip
Qualified pinewood	Highland_pinewood_clipped_to_grampian
FE pine	Fe_pinewoods_favourable_sssi Fe_pinewoods_favourable_sac Fe_scots_pine
CPI pinewood	Ssnwi_caledonian_planted_over10canopy Ssnwi_caledonian_over10canopy
FE alder	Grampian_fe_alder
PAWS/LEPO/AW	Aw_ssnwi_grampian
FE other	Grampian_comps_no_open_ground
SFGS	Sfgs_grampian_wland_only
WGS	Wgs_grampian_over60_percent_paid
Open areas within fe estate	Lcs_open
SSNWI reclass	Ssnwi_grampian_reclass
NIWT reclass	Niwt_grampian_reclass
LCS88/LCM2000/OS Strategi	Grid – lcov_grampian

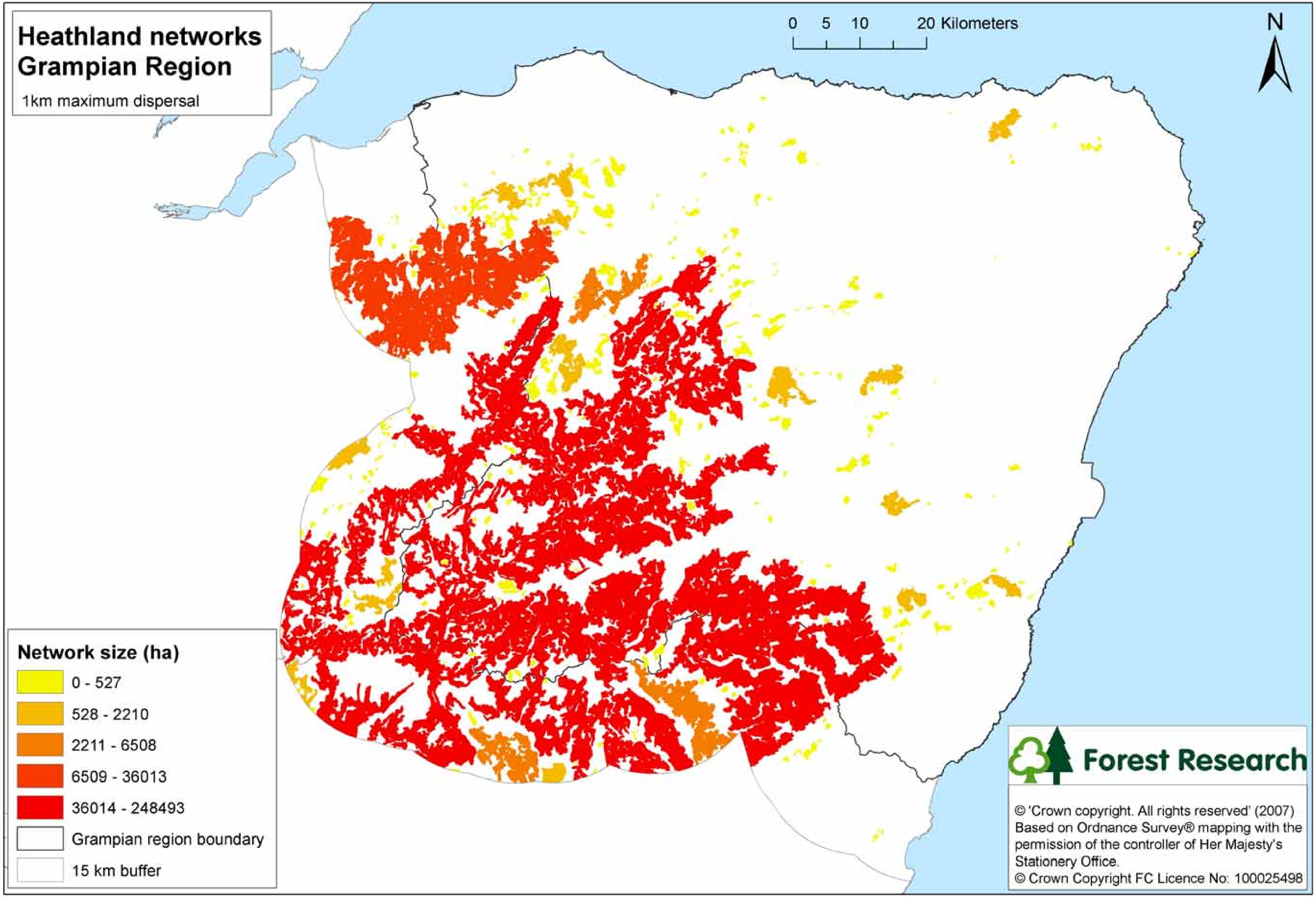
Appendix 2. Example species of broadleaved, riparian, and wet woodland habitat in Grampian Region.

Species	Common name	Habitat requirements	Dispersal ability	Area requirement	Woodland Specialist or Generalist
Vascular plants					
Adoxa moschatellina	Moschatel	Woodland	low	small	G
Anemone nemoralis	Wood Anemone	Woodland	low	small	S
Corallorhiza trifida	Coral-root orchid	Damp woodlands, especially wet birch and willow woodland and wet (Carr).			
Hyacinthoides non-scripta	Bluebell	Broadleaf woodland	low	small	G
Linnaea borealis	Twinflower	Woodland			
Melampyrum sylvaticum	Small Cow-wheat	Wetland, birch woodland in ravines and glens.	low	small	S
Mercurialis perennis	Dog's mercury	Broadleaf woodland	low	small	G
Scirpus sylvaticus	Wood Club-rush	Woodland	low	small	G
Lichens/fungi/ liverworts/mosses					
Amanita submembranacea	a fungus	Woodland	low	small	G
Lobaria pulmonaria	Tree lungwort	Established broadleaved woodland, particularly oak	low	small	G
Insects					
Acrotrichis lucidula	a featherwing beetle	Wet moss by spring water seepages and trickles in woodland. Also found in fens, in Alder wet (Carr) and other damp places.	medium	small	G
Brachyptera putata	Stonefly	Slower reaches of rivers.			
Curculio villosus	a weevil	Broadleaved woodland - A parasite of oak gall wasps	medium	medium	S
Dicrostema gracilicornis	a sawfly	Larva on *Adoxa moschatellina*	low	small	S
Lampronia fuscatella	a longhorn moth	Ancient birchwood on peat with a continuous history of regeneration (trees < 10 years old)	medium	medium	S
Limnophila verralli	a cranefly	Near small streams, usually in the shade of alders. Larvae aquatic.	medium	small	S
Limonia trivittata	a cranefly	Wet woodland on calcareous soils, especially near rivers.	medium	small	S
Lipsothrix ecucullata	a cranefly	Wet woodland	medium	small	S
Luperus flavipes	a leaf beetle	Broadleaved woodland (BLW), parkland, scrub, heath and disused railway lines.	medium	small	G
Margaritifera margaritifera	Freshwater Pearl Mussel	Fast flowing rivers with a stony bottom. Dependent on salmonids as larval host.	medium	small	S
Parasyrphus nigritarsis	Alder Hoverfly	Wet deciduous woodlands, beside rivers, containing alder, willow and aspen.			
Stiroma bicarinata	a planthopper	Vegetation in woodland.	low	small	S
Tipula pseudovariipennis	a cranefly	Mainly calcareous woods.	medium	small	S

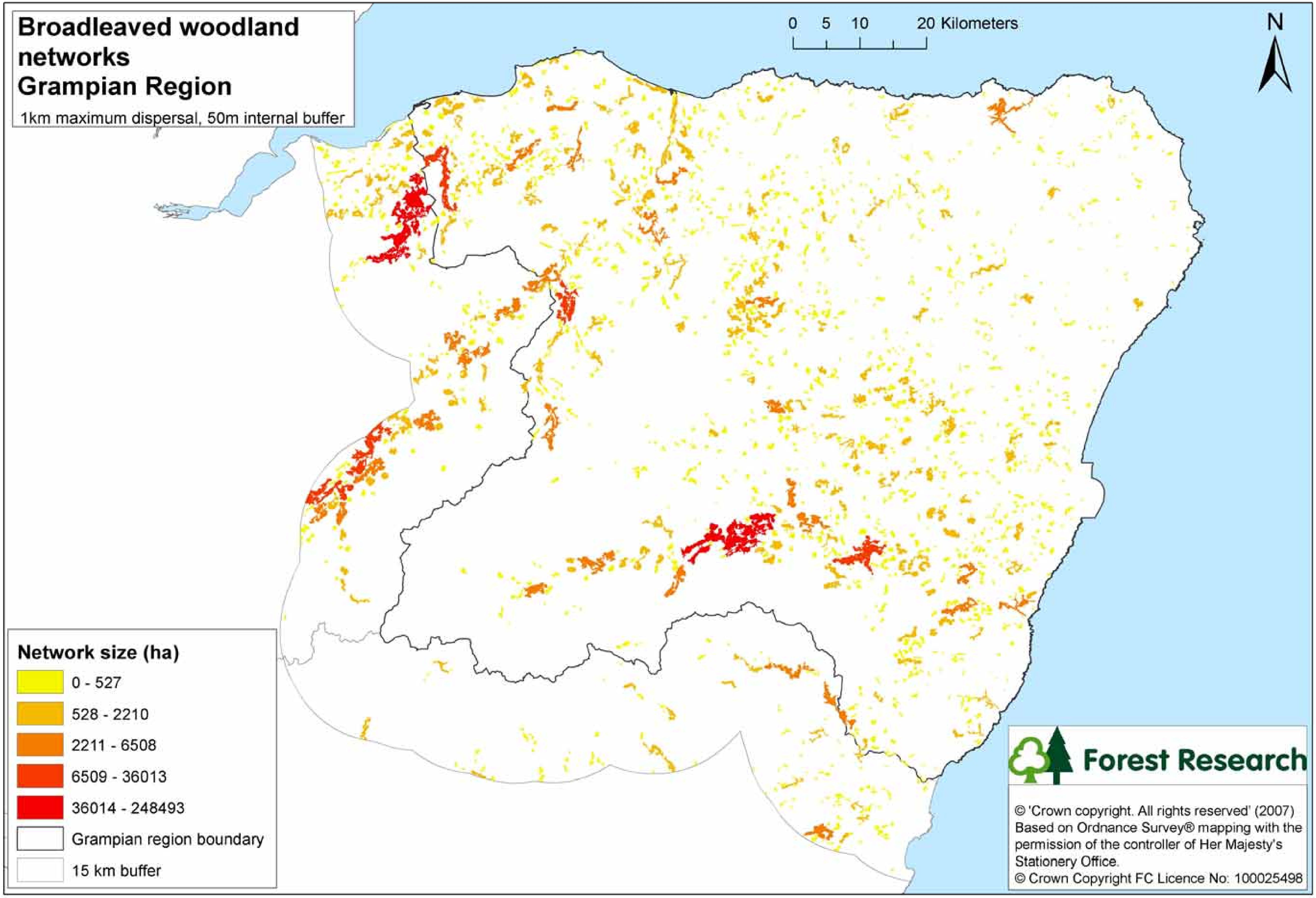
Birds					
Asio otus	Long-eared Owl	Woodland and neighboring open country	high	large	S
Bucephala clangula	Goldeneye	Coastal and freshwater (rivers and lochs). Riparian trees for roosting and nesting sites.			
Muscicapa striata	Spotted Flycatcher	Woodland, broad-leaved & mixed	high	medium	G
Parus palustris	Marsh Tit	Deciduous woodland, especially extensive beech and oakwoods. Also orchards, mature gardens & parkland.	high	medium	G
Passer montanus	Tree Sparrow	Tree-lines	high	medium	G
Picus viridis	Green Woodpecker	Open deciduous woodland	high	medium	G
Pyrrhula pyrrhula	Bullfinch	woodland, broad-leaved & mixed	high	medium	G
Sitta europaea	Nuthatch	Mature deciduous woods, especially large oakwoods, wooded parks and gardens	high	medium	G
Tetrao tetrix	Black Grouse	Woodland edge	high	medium	G
Turdus philomelos	Song Thrush	Woodland, broad-leaved & mixed	high	medium	G
Mammals					
Meles meles	Badger	Mostly lowland, lightly wooded countryside. Setts most often in woods and copses, hedgerow and scrub	medium	medium	G
Lutra lutra	Otter	Alongside rivers, burns, ditches and lochs. Riparian woodland stabilises banks, providing breeding sites.			
Pipistrellus pipistrellus	Pipistrelle Bat	Rivers bordered by riparian woodland.			
Sciurus vulgaris	Red Squirrel	Mainly large blocks (>50ha) of mature coniferous forest, particularly Scots Pine	medium	medium	G



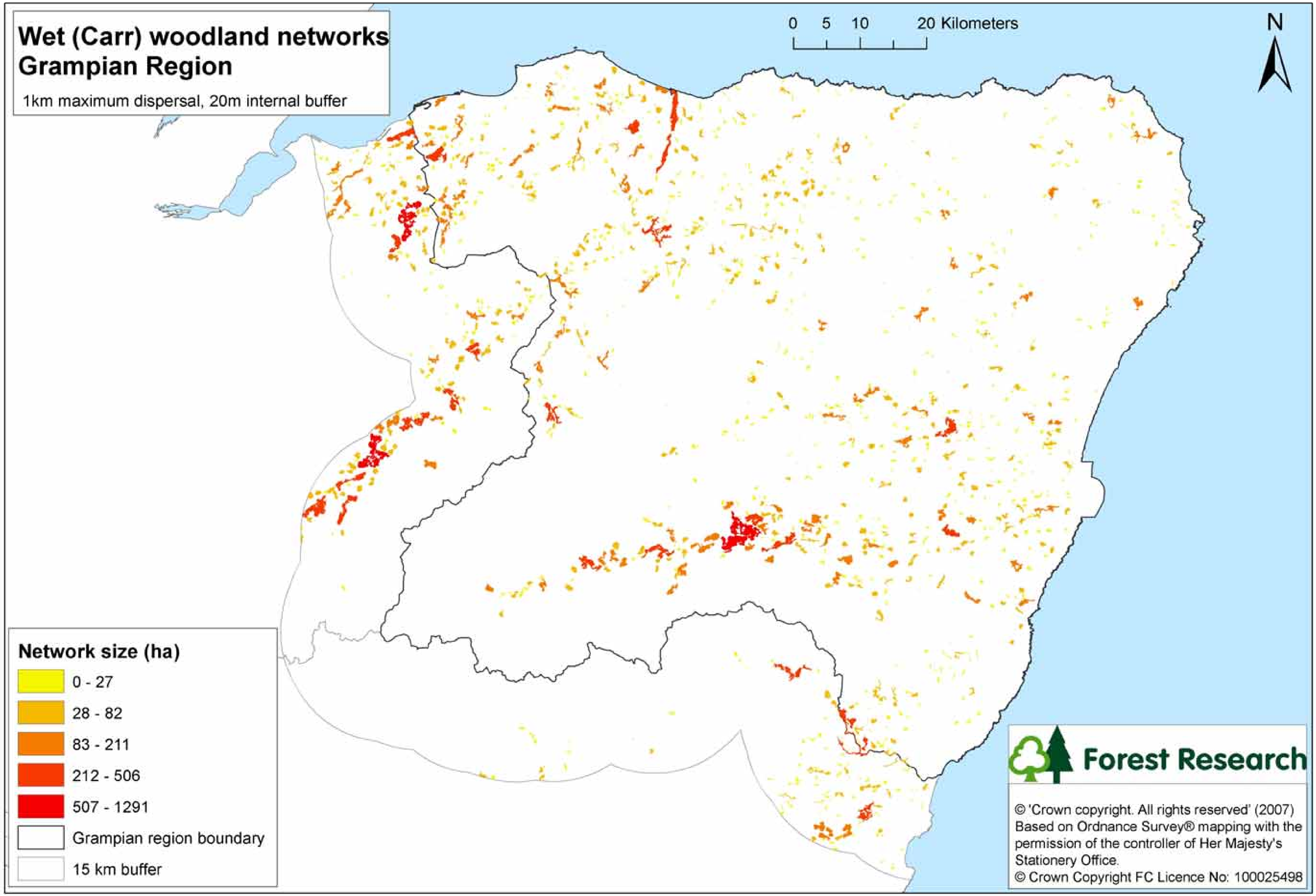
Appendix 3. Woodland networks organised by network size, assuming a maximum dispersal distance of 1km, in Grampian Region.



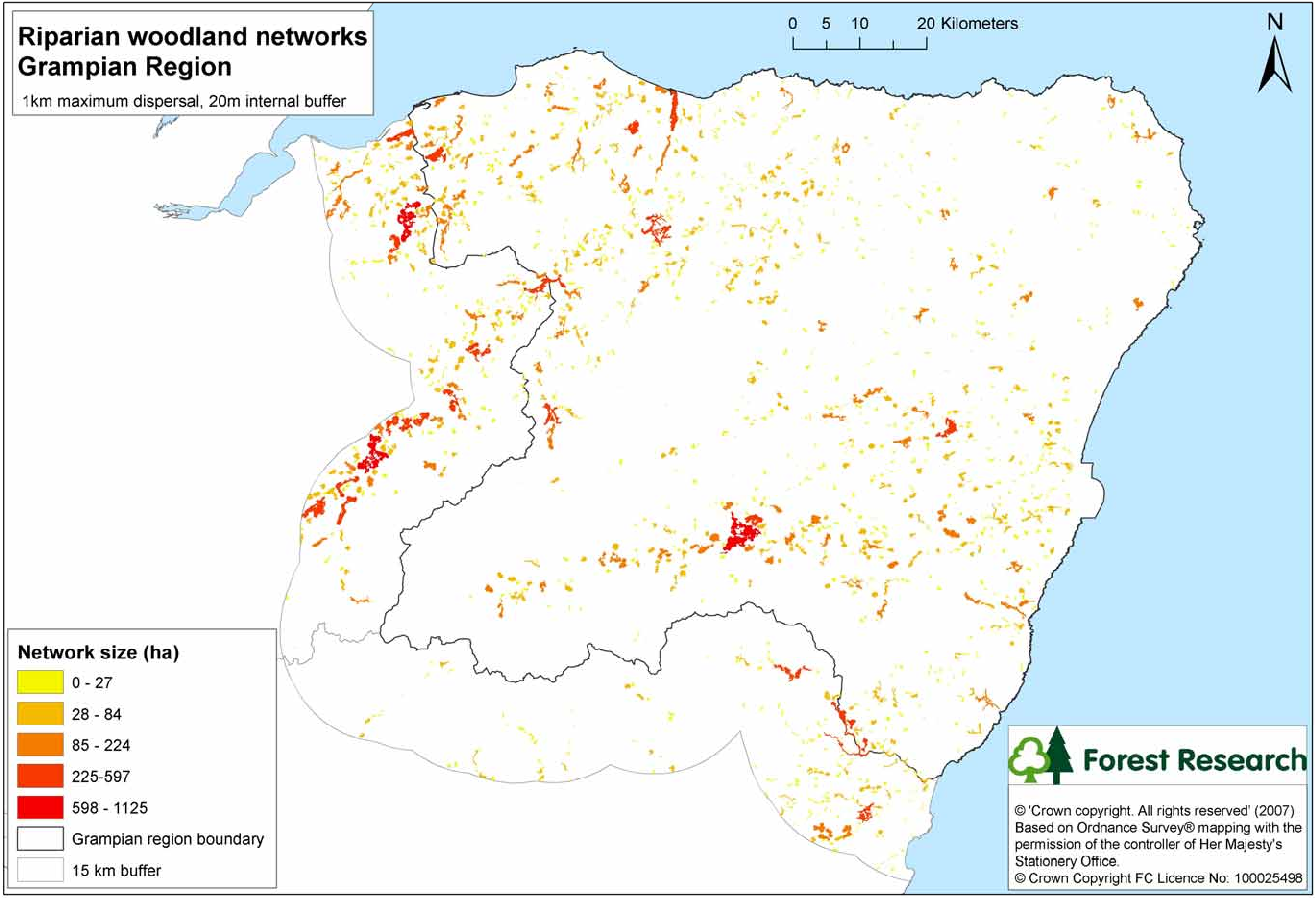
Appendix 4. Heathland networks organised by network size, assuming a maximum dispersal distance of 1km, in Grampian Region.



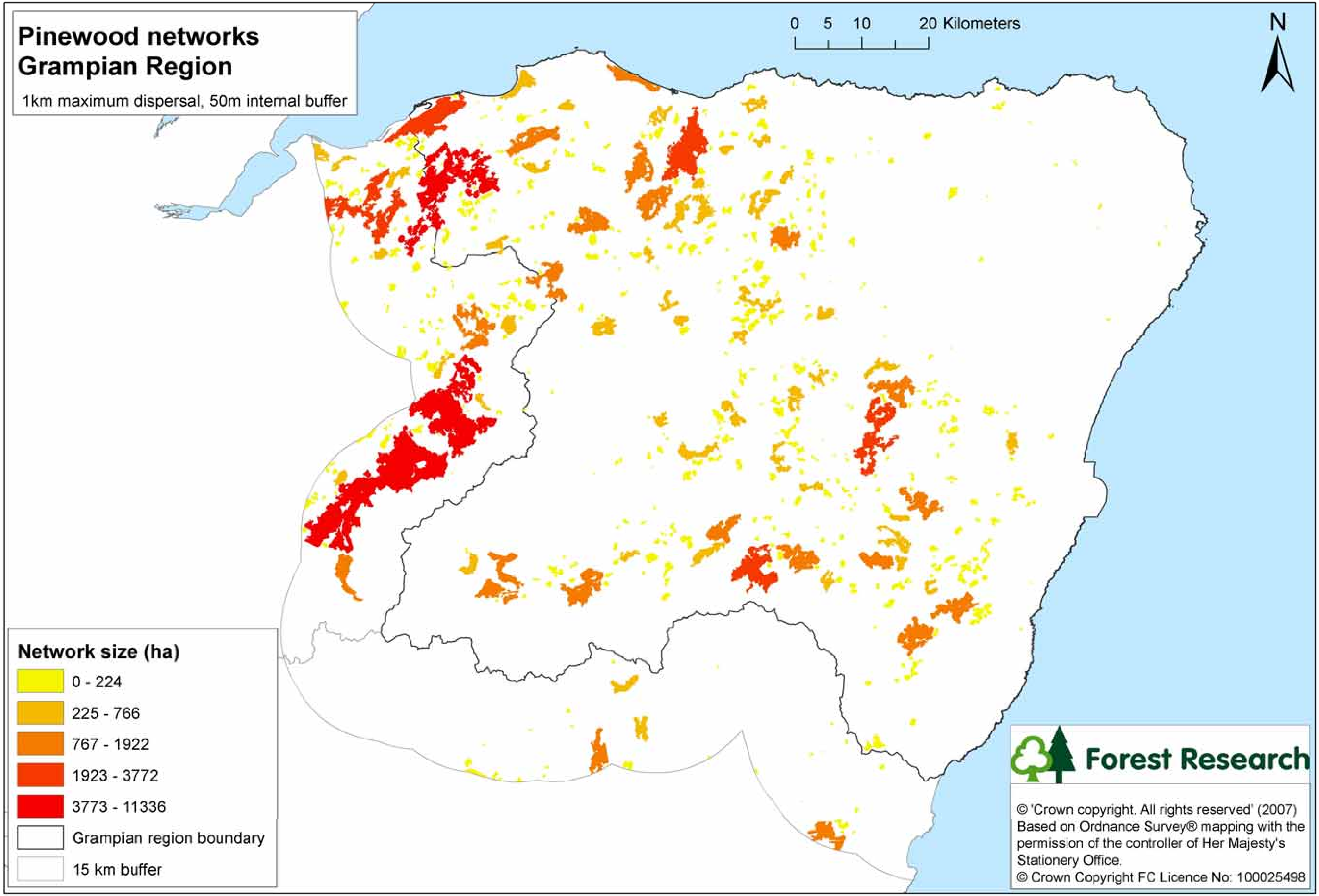
Appendix 5. Broadleaved woodland networks organised by network size, assuming a maximum dispersal distance of 1km and a 50m internal buffer, in Grampian Region.



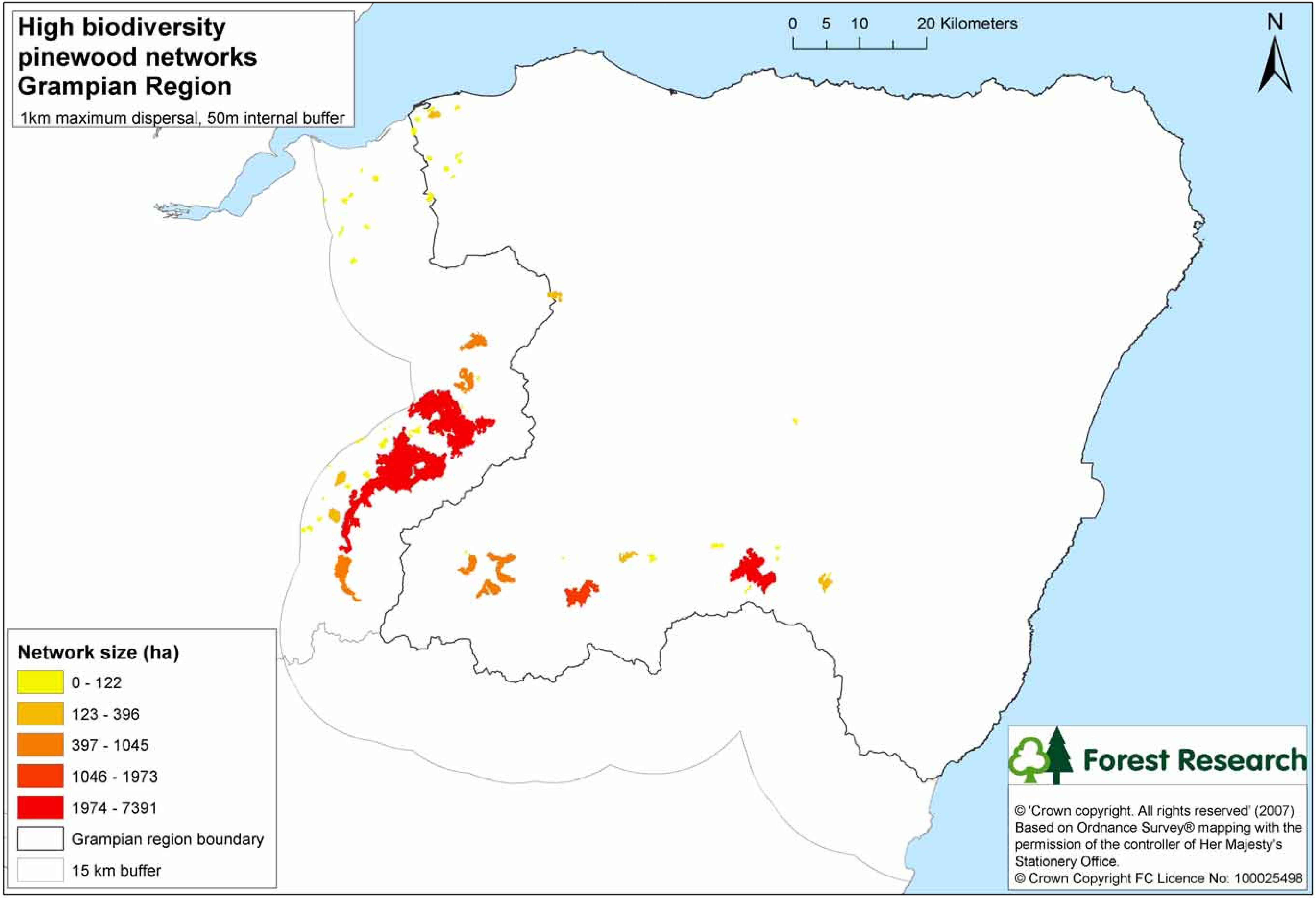
Appendix 6. Wet woodland networks organised by network size, assuming a maximum dispersal distance of 1km, in Grampian Region. A 20m internal buffer applied to wet (Carr) woodland, 50 m to broadleaved woodland, other networks unbuffered.



Appendix 7. Riparian woodland networks organised by network size, assuming a maximum dispersal distance of 1km and a 20m internal buffer, in Grampian Region.



Appendix 8. Pinewood networks organised by network size, assuming a maximum dispersal distance of 1km and a 50m internal buffer in Grampian Region.



Appendix 9. High biodiversity pinewood networks organised by network size, assuming a maximum dispersal distance of 1km and a 50m internal buffer in Grampian Region.