

FINAL REPORT

Forest Habitat Networks Scotland Borders and the Lothians Report May 2006

Ecology Division Forest Research

Darren G Moseley and Duncan Ray

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.

© Forestry Commission

FINAL REPORT

Executive Summary

This work continues the Biological and Environmental Evaluation Tools for Landscape Ecology (BEETLE) focal species approach to landscape ecology used in the national and Highland analyses (Ray et al. 2005; Moseley et al. 2005), to determine the functional connectivity of woodland in Scottish Borders, Edinburgh, and the Lothians.

The report provides a detailed analysis of specialised woodland networks in the Lothians and Borders regions of Scotland by incorporating a woodland quality assessment. Particular attention is given to 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 high quality specialists, broadleaved specialists, followed by woodland generalists, enabling targeted improvement and linkage to be undertaken.

The use of habitat quality data provides an added dimension to the analysis, 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 and as such provide the focus for forest habitat network strategies. A common characteristic of woodlands in the Borders and Lothians 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 the high quality woodlands.

The integration of the analyses into climate change strategies is 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. The large urban areas within Edinburgh and the Lothians provided 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.

FINAL REPORT

Contents

EXECUTIVE SUMMARY	2
1. INTRODUCTION	6
2. METHODS	7
2.1. Study area	7
2.2. Data	8
2.3. Data preparation	8
2.3.1. Regional landcover matrix	8
2.3.2. Woodland quality	9
2.4. Analysis and concepts for modelling habitat networks	12
2.4.1. Generic Focal Species and dispersal costs	14
2.5. Woodland in and around communities	15
3. RESULTS & DISCUSSION	16
3.1. Habitat Networks	16
3.1.1. Woodland generalists	20
3.1.2. Woodland specialists	20
3.1.3. Heathland generalists	23
3.1.4. Potential interactions between woodland and heathland networks	25
3.2. Regional application of the analyses	27
3.2.1. Broadleaved networks along valleys	28
3.3. Local application of the analyses	31
3.3.1. Network improvement opportunities	32
3.4. Woodlands in and around communities	39
3.4.1. 2ha woodlands within 500 m	39
3.4.2. 20ha woodlands within 4 km	40
4. DISCUSSION	41
4.1. Determination of habitat quality	41
4.2. Habitat networks	42
4.3. Woodlands in and around communities	43
4.4. Integration of Habitat Networks into LBAP aims	44
5. RECOMMENDATIONS	45
5.1. Data quality	45

FINAL REPORT

5.2. Woodland biodiversity protection	45
5.3. Woodland management	45
5.4. Woodland expansion	45
5.5. Open-habitat management	46
5.6. Woodlands in and around communities	46
References	47
Appendix 1. Metadata for designating woodland type.	48
Appendix 2. Example Species of Wood and Scrub in the Lothians and/or Borders.	50
Appendix 3. Woodland generalist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.	52
Appendix 4. Broadleaved specialist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.	53
Appendix 5. High quality broadleaved specialist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.	54
Appendix 6. High quality mixed / broadleaved woodland specialist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.	55
Appendix 7. Heathland generalist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.	56
Appendix 8 Other potential forest habitat network development sites.	57

Figures

Figure 1. Area of analysis, incorporating a 15 km external buffer around the Lothian and Borders unitary boundaries.	7
Figure 2. Location of lowland zone.	9
Figure 3. Woodland biodiversity quality determined from survey or indicated by the presence of ancient woodland indicator plant species occurring in the woodland.	17
Figure 4. The distribution of ancient and long established woodland within the area of analysis.	17
Figure 5. Comparison of habitat networks for woodland generalists capable of dispersing 250 m, 500 m and 1000 m.	20
Figure 6. Woodland networks, assuming a maximum dispersal distance of 1km, for high quality specialists, broadleaved specialists, and woodland generalists in the regions of Edinburgh, Lothians, and Borders.	22
Figure 7. Heathland generalist networks, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.	23
Figure 8. Potential interactions in Edinburgh, Lothians, and the Borders at a maximum 1000 m dispersal distance between heathland generalists and woodland generalists. The distribution of heathland generalist networks and the area of overlap with the woodland generalist are shown.	26
Figure 9. Potential interactions in Edinburgh, Lothians, and the Borders at a maximum 1000 m dispersal distance between woodland generalists and heathland generalists. The distribution of woodland generalist networks and the area of overlap with the heathland generalist are shown.	26
Figure 10. Potential interactions in Edinburgh, Lothians, and the Borders at a maximum 1000 m dispersal distance between heathland generalists and broadleaved specialists.	27
Figure 11. Broadleaved specialist networks are associated with the riparian areas running through the valleys.	29
Figure 12. Illustration of how species might disperse from the south, via Moffat following Moffat Water and crossing to Ettrick Water to disperse northeast.	30
Figure 13. Illustration of how species might disperse from the south, through Liddesdale following Liddel Water and crossing to Slitrig Water to disperse northwards.	30
Figure 14. Illustration of how dispersal events might occur across an east-west direction, following the riparian woodlands adjacent to the Clyde and Tweed rivers.	31

FINAL REPORT

Figure 15. A selection of Forest Habitat Network development site opportunities.	32
Figure 16. FHN improvement opportunities east of Melrose.	33
Figure 17. A high quality mixed/broadleaved specialist network west of Berwick-upon-Tweed.	34
Figure 18. An example of high quality cleuch woodland sites in the Borders, these are located south of St. Mary's Loch.	35
Figure 19. Semi-natural broadleaved woodland with low canopy cover, but good ground flora, south of Nether Williamston.	36
Figure 20. Illustration of the possibilities for habitat consolidation, buffered expansion, and rehabilitation to improve biodiversity and network connectivity around Pease Dean Glen SSSI.	38
Figure 21. Communities not served by 2 ha woodlands within a distance of 500 m in the regions of Edinburgh, the Lothians, and the Borders.	39
Figure 22. Communities not served by 20 ha woodlands within a distance of 4 km in the regions of Edinburgh, the Lothians, and the Borders.	40

Tables

Table 1. Scoring system used to derive an overall stand quality score from structure, deadwood, and field layer components.	10
Table 2. A selection of ancient woodland indicator plants for Edinburgh, the Lothians, and the Borders.	11
Table 3. The proportion of land cover types in Edinburgh, the Lothians, and the Borders (total area approximately 645,000 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.	13
Table 4. Very high quality (8 ancient woodland indicator plants or more) woods in Edinburgh, the Lothians, and Borders region.	18
Table 5. Landscape metrics for the five generic focal species analyses covering the region of Edinburgh, the Lothians, and the Borders.	23

FINAL REPORT

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 Lothians and Borders regions of Scotland by incorporating a woodland quality assessment. Particular attention is given to broadleaved woodland located along riparian areas and 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) focal species approach to landscape ecology (Watts *et al.* 2005) used in the national and Highland analyses (Ray *et al.* 2005; Moseley *et al.* 2005), to determine the functional connectivity of woodland in Scottish Borders, Edinburgh, and the Lothians.

Attention is also given to the way the expansion of woodland can be incorporated with strategies to increase opportunities for woodland use by communities. The large urban areas within Edinburgh and the Lothians provided 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.

These approaches seek to address the aspirations of the region's Local Biodiversity Action Plans for woodland, which include:

- To maintain, enhance and expand in area the conservation value of woodlands in the Scottish Borders.
- To prevent the loss of existing woodland and extend woodland cover by 1000 hectares to 2500 hectares in total (10% of Edinburgh). To enhance the social and environmental value of Edinburgh's woodland.
- To develop public appreciation and understanding of woodlands, woodland management and wood products, and encourage people to participate in the management of the woodlands in their area.
- To protect woodland from unsympathetic development through the robust use of statutory instruments and the development control process.

FINAL REPORT

2. Methods

2.1. Study area

The study area, defined as the unitary boundaries of Lothian and Borders, with an external 15 km buffer applied to the external boundary (Figure 1), is 1 091 337 ha, of which Edinburgh and the Lothians covers 172 000 ha, the Borders 473 573 ha, and 183 800 ha is in England.



Figure 1. Area of analysis, incorporating a 15 km external buffer around the Lothian and Borders unitary boundaries.

The landscape of the Borders and the Lothians has been highly modified by man, historically by farming practice, and in more recent times by the increasing urban spread. The impact of farming has defined the fragmented wooded landscape, with small wooded areas, occasionally interconnected by strips of woodland boundaries along the fields. Although much of the non-developed land is agricultural, particularly in the Lothians, the regions do have significant areas of woodland.

Woodland constitutes approximately 19.5% of the area of the Lothians and Borders, of which 60% is coniferous woodland, and the remainder broadleaved woodland, mixed woodland, and scrub. The broadleaved component is composed of ancient, cluch, policy, or other semi-natural broadleaved woodlands, with shelter belts, areas of plantation, and ancient trees in parks. Only small remnant ancient semi-natural woodlands remain in the Lothians and Borders, the exact amount is uncertain because the Ancient Woodland Inventory was not completed for the region.

FINAL REPORT

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 datasets 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
- 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)*
- Ancient woodland indicator dataset (derived from Biological Record Centre 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)
- Designated areas: Natura 2000 Special Areas of Conservation (SAC), Special Site of Scientific Interest (SSSI)
- Ordnance Survey® Strategi ®
- Unitary Authority boundaries

* Records of Long established woodland of plantation origin woods are incomplete in the Borders.

2.3. Data preparation

2.3.1. Regional landcover matrix

The landcover matrix 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 Phase 1, NIWT and SSNWI follow the broad habitat type classification: conifer, broadleaved and mixed. SSNWI has additional interpreted classes of canopy cover and semi-naturalness, Phase 1 habitat data provided survey data for the Lothians. WGS3 and SFGS provide updates for new planting, the Scottish Ancient Woodland dataset allows antiquity to be designated to existing woodland.

The lowland zone mask (Figure 2), defined using climate, geology and landuse, (Humphrey *et al.* 2005) was applied to vary the costs for farm and parkland wooded areas. This accounts 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 through coniferous plantation to reflect the relatively more open canopy of pine plantation compared to spruce plantation was applied to the analyses.

FINAL REPORT

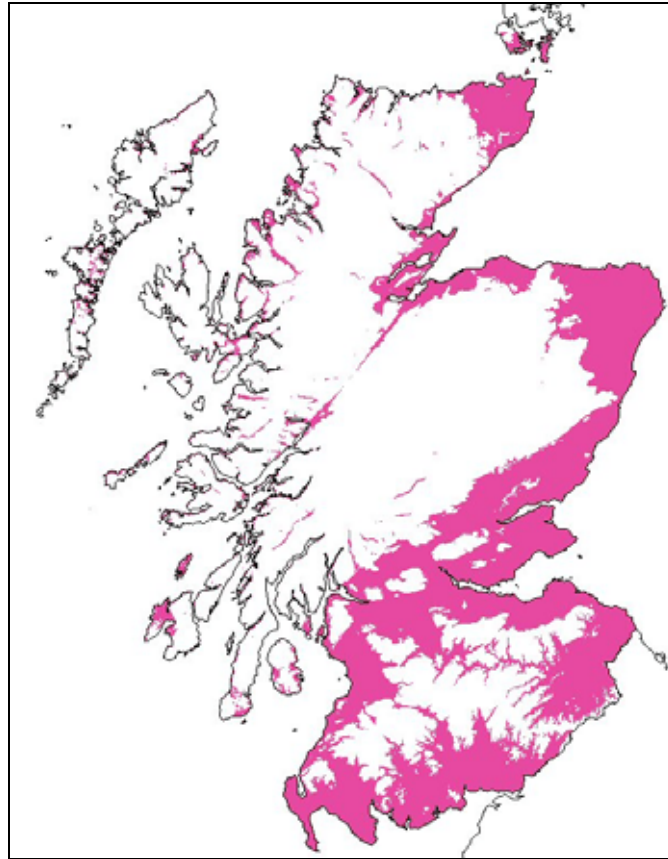


Figure 2. Location of lowland zone (Humphrey *et al.* 2005).

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

2.3.2. Woodland quality

This study attempts to assess the biodiversity contribution made by woodlands and other land cover types at the landscape scale. It was therefore important to establish the quality of woodlands within Edinburgh, Lothian, and Borders regions. Quality assessment of broadleaved and mixed woodland was undertaken to identify areas of high quality woodland and improve the detail of the land cover matrix. Two approaches to quality assessment were undertaken: interview, where local knowledge was available; coincidence mapping, to identify woodlands on the basis of species occurrence.

Quality assessment by interview

The Highland (Moseley *et al.* 2005) and southwest Scotland (Grieve *et al.* 2006) analyses employed a series of interviews with local woodland officers and foresters to 'broadly' categorise woodland quality wherever possible. The scope, scale and resources of the FHN project do not permit a very detailed description of woodlands at the sub-compartment level, therefore the interview and interpretation focused on an overall score for woodland blocks. For the purposes of woodland assessment, areas under 2 ha were not considered as most would be eliminated in the GIS analysis during the removal of the 50 m internal buffer.

Three factors of quality are considered in the survey, and in order for a high quality designation to be ascribed to a woodland block, the area should be well represented in each area. The three factors are: structure, deadwood, and field layer composition. These are combined to provide a surrogate for biodiversity value.

FINAL REPORT

1. Structure

1.a. 'Good' structural composition will include: tree species mix suited to the site, multi-layer canopy, gaps in the canopy. The majority of the trees would be at least 100 years old.

1.b. 'Moderate' composition will include two of the factors described in 1.a.

1.c. 'Poor' composition will include one or none of the factors described in 1.a.

2. Deadwood

2.a. 'Good' deadwood component will include the following elements in varying stages of decay: some standing deadwood – snags (and hung broken branches), sap runs, fallen deadwood.

2.b. 'Moderate' deadwood will include two of the factors described in 2.a.

2.c. 'Poor' deadwood will include one or none of the factors described in 2.a.

3. Field layer

3.a. 'Good' field layer component will include roughly 50% cover or more of the woodland floor, a representative sample (5 or so) of plants associated with that woodland type, evidence of low deer browsing pressure.

3.b. 'Moderate' field layer will include two of the factors described in 3.a.

3.c. 'Poor' field layer will include one or none of the factors described in 3.a.

The assessment is based upon SSNWI and NIWT databases. In addition the ASNWI was used for identifying ancient broadleaved and mixed woodlands.

A single overall quality score is agreed by the woodland officer or forester based upon structure, deadwood, and field layer quality, set out in combinations shown in Table 1.

Table 1. Scoring system used to derive an overall stand quality score from structure, deadwood, and field layer components.

Overall quality	Component Quality		
	High	Good	Average
High	3	-	-
High	2	1	-
Good	2	-	1
Good	1	2	-
Good	1	1	1
Good	-	3	-
Good	-	2	1
Average	1	-	2
Average	-	1	2
Average	-	-	3

Quality assessment using coincidence mapping

The process of interviewing local woodland officers and foresters to confirm woodland type and identify quality information is a time consuming process and does not identify all woodlands as it is restricted to those woodlands the interviewee is familiar with. To supplement information from a woodland surveyor, a procedure for identifying woodlands remotely using coincidence mapping was designed.

This methodology involved making the assumption that the best quality woodlands will contain more organisms associated with ancient woodlands. 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.

FINAL REPORT

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 good quality, whilst eight or more species would represent particularly rich woodlands and would be likely to be high quality woodland.

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

- less than 4 ancient woodland indicator plants = average quality woodlands
- 4 to 7 ancient woodland indicator plants = good quality woodlands
- 8 or more ancient woodland indicator plants = high quality woodlands

Twenty-one ancient woodland indicator plants were selected, and their point data distribution was queried from the digital data held by Lothian Wildlife Information Centre and Scottish Borders Biological Records Centre. Since woodland conditions vary from site to site, the list (Table 2) includes species associated with poor to rich soil nutrient regimes, and very moist to dry soil moisture regimes (Pyatt *et al.* 2001). Table 2 indicates the types of woodland with which the plants are associated.

Table 2. A selection of ancient woodland indicator plants for Edinburgh, the Lothians, and the Borders.

Species (common name)	Species (scientific name)	NVC Woodland type affinity
1. Moschatel	<i>Adoxa moschatellina</i>	8, 9, 19
2. Ramsons	<i>Allium ursinum</i>	8, 9, 12, 21
3. Lord's-and-Ladies	<i>Arum maculatum</i>	8, 9, 12 to 14, 21, 24, 25
4. Giant bellflower	<i>Campanula latifolia</i>	8
5. Pendulous Sedge	<i>Carex pendula</i>	7,8
6. Pignut	<i>Conopodium majus</i>	7-11,25
7. Enchanter's-nightshade	<i>Circaea lutetiana</i>	6-10,12,14,21,25
8. Giant Fescue	<i>Festuca gigantean</i>	8,9,14
9. Woodruff	<i>Galium oderatum</i>	8-10,12,14
10. Bluebell	<i>Hyacinthoides non-scripta</i>	6-12,14-17,21,22,25
11. St. John's-wort	<i>Hypericum pulchrum</i>	11,14,17
12. Hairy wood-rush	<i>Luzula pilosa</i>	10,11,14, 5,17-19
13. Common cow-wheat	<i>Melampyrum pratense</i>	10,11,15,17-19
14. Wood melick	<i>Melica uniflora</i>	8-10,12,14
15. Dog's mercury	<i>Mercurialis perennis</i>	6-10,12-14,19,21,22,24-25
16. Wood millet	<i>Milium effusum</i>	8-10,12,14
17. Wood Meadow-grass	<i>Poa nemoralis</i>	8,10,12,14,15,17
18. Common wintergreen	<i>Pyrola minor</i>	11,19
19. Wood dock	<i>Rumex sanguineus</i>	1,5,6,8,10,12,21,24
20. Sanicle	<i>Sanicula europaea</i>	8-10,12
21. Chickweed-wintergreen	<i>Trientalis europaea</i>	11, 17-19

Data Extraction

Two approaches were undertaken to identify woodland associated with the presence of ancient broadleaved woodland specialists.

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, NIWT, Phase 1, WGS3, and SFGS that intersected the ancient woodland polygons were selected.

FINAL REPORT

2. The Ancient Woodland Inventory did not cover woodlands with < 20% canopy cover, and so some parkland with ancient trees may have been missed. To improve data capture, polygons from SSNWI, NIWT, WGS3, and SFGS within an arbitrary 50 m of the ancient woodland indicator points 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 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, good, or average quality 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 good quality, good quality to average quality. 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 found to be of a high quality, the landcover can be amended to reflect this.

If no polygon could be ascribed to a data point within the 1km specified distance, the data point was noted and used to suggest areas where additional woodland or conversion to broadleaved woodland may be appropriate.

Ordnance Survey First Edition mapping was used in one instance to determine that an area of conifer woodland had originally been broadleaved woodland, even though it did not appear on the ancient woodland inventory.

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 BEETLE 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 non-habitat patches of the landscape (the matrix). This modelling approach cannot be based upon empirical data, since

FINAL REPORT

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 non-habitat patches. The BEETLE approach taps into this knowledge, by setting within the model a matrix of, 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 Edinburgh, the Lothians, and the Borders (total area approximately 645,000 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 Edinburgh, Lothians & Borders	Woodland generalist	Broadleaved specialist
Forest and woodland*	Coniferous woodland	11.6%	0	3
	Mixed woodland	3.7%	0	1.5
	Broadleaved woodland	4.1%	0	0
	Scrub**	<0.1%	1	1
Total		19.5%***		
Open land	Bracken	1.5%	3	4
	Heath	10.8%	7	8
	Unimproved grassland	10.9%	3	5
	Improved grassland/arable	49.5 %	15	20
	Wetlands	0.7%	15	15
	Bog	2.9%	25	50
	Dunes and bare ground	0.5%	30	30
Total		77.0%***		
Developed land and water	Urban/roads/rail	3.0%	50	50
	Inland water	0.5%	50	50
Total		3.5%***		

*figures for woodland types include an equal division of general land cover classes, such as 'young trees'

**scrub considered good surrogate habitat

***note small rounding errors in total values

FINAL REPORT

2.4.1. Generic Focal Species and dispersal costs

The analysis undertaken for the Borders and Lothians 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 landcover. These were associated with specific woodland types: broadleaved woodland specialists; high quality broadleaved woodland specialists; and high quality broadleaved and mixed woodland specialists. The high quality broadleaved and mixed woodland specialists were chosen as much of the mixed woodland in the Lothians and Borders was considered to have a high broadleaved component, *e.g.* Roslin glen, and would have the many of the characteristics of a broadleaved woodland. 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 the Lothians and Borders 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 crane fly, *Dicrostema gracilicornis* – a sawfly.
- High quality broadleaved woodland specialist – representing those species only associated with ancient and long established woodlands. The species may additionally be present in conifer plantations on ancient woodland sites (PAWS), but PAWS have not been classified as habitat in the analysis. The important issue is antiquity which provides a long period of woodland cover. Species in this category might be less mobile than broadleaved specialists and include: bluebell, dog's mercury, saproxylic fungi.
- High quality mixed / broadleaved woodland specialists – representing species requiring woodlands of antiquity, but not as exacting in their need for only broadleaved species. These woods would normally have a relatively high broadleaved tree component (30% or more). Again the species may additionally be present in conifer plantations on ancient woodland sites (PAWS), but PAWS have not been classified as habitat in the analysis. Examples include: ramsons, nuthatch.

Habitat for each of the GFS was defined as follows:

Broadleaved woodland specialists

SSNWI = 80 to 90% broadleaved or broadleaved, with a minimum canopy cover of 10%, excluding farm/parkland; NIWT = Broadleaved; Phase 1 = Broadleaved.

High quality broadleaved woodland specialists

As for broadleaved specialists, but including farm/parkland and in addition the sites have either been qualified by an expert or they spatially correspond to sites with at least 8 ancient woodland indicator plants (Table 2).

FINAL REPORT

High quality mixed woodland and broadleaved woodland specialists

SSNWI = 80 to 90% broadleaved or broadleaved, mixed broadleaf/conifer, with a minimum canopy cover of 10%; NIWT = Broadleaved or mixed; Phase 1 = Broadleaved or mixed, where the sites have either been qualified by an expert or they spatially correspond to sites with at least 8 ancient woodland indicator plants (Table 2).

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.

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. 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). A 50 metre internal buffer was removed from the habitat layer where it bordered non-woodland. Although the 50 metre edge was not considered as source habitat, it was 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 15 permutations for analysis. The focal species profiles were derived from the broadleaved woodland specialist costs previously agreed by the FHN Scotland Steering Group.

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.

FINAL REPORT

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 Edinburgh, Lothians, and Borders did not meet the requirements for woodland accessibility. The analysis extended to 5 km outside the unitary boundary of the Lothians & Borders to allow woodlands outside this area, but accessible to residents of the Lothians & Borders, to be included.

Woodland area was defined as broadleaved or mixed woodland, with a minimum 10% canopy cover. It was assumed that much of the mixed woodland in the Lothians will be policy woodlands associated with estates and as such will have good recreational access. Semi-natural conifer woodland was included, as it was thought that this category would be comprised mostly of Scots pine, much of which was likely to be relatively open. Unless other conifer woodland had attributes suggesting it was likely to be Scots pine, e.g. conifer plantation defined by the upland zone (Humphrey et al. 2005), it was deemed to be too difficult to assess openness, and hence recreational attractiveness. New planting areas and young trees were not considered to possess the attributes (structure and historical use) to attract recreational use. Similarly, areas classified as felled or prepared for planting were also not considered.

The two main data sources showing the distribution of urban areas are:

- the vector OS Strategi® resource
- digitised local plans from each of the four unitary authorities

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

Five GFS analyses were undertaken for the region of Edinburgh, Lothians, and Borders, using individual profiles and working with a specially prepared spatial database of land cover types and GFS profiles.

Woodland quality (in terms of biodiversity) was assessed using expert knowledge and ancient woodland indicator plants. Figure 3 shows the distribution of quality woodlands according to the three classes, defined by the number of ancient woodland indicator plants present. It is clear that, with the exception of the far west of the Borders, each area has some high quality, rich and diverse woodland, based on the occurrence of ancient woodland indicator plants. To illustrate the difference in this method of assessing the quality of woodland compared to a method which places a high value on all woodlands of some antiquity, compare Figure 3 with Figure 4. Figure 4 shows all woodland classified as ancient or long established. It is clear that there are many more candidate woodlands with a potential high biodiversity value, by virtue of their antiquity than demonstrated by ancient woodland indicator plants in Figure 3.

Those areas identified as being of high or good quality represent some of the key areas where conservation management should be undertaken and the networks linking the areas

FINAL REPORT

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.

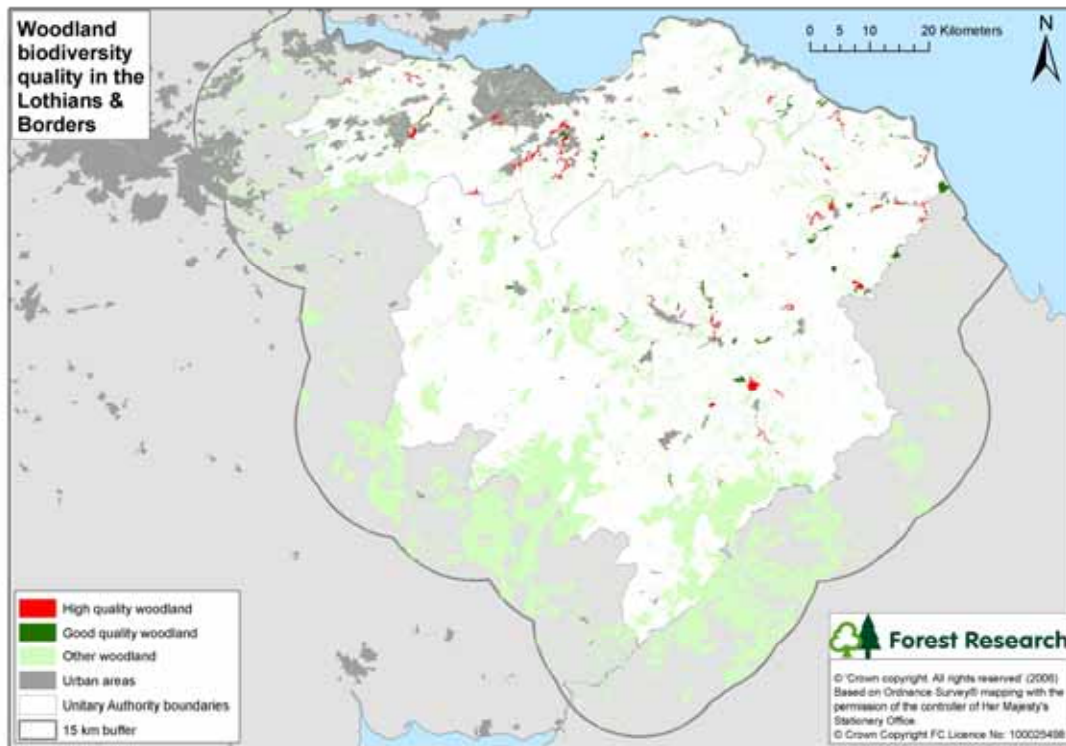


Figure 3. Woodland biodiversity quality determined from survey or indicated by the presence of ancient woodland indicator plant species occurring in the woodland. High quality woodland has 8 or more species present, good quality 4 to 7 species.

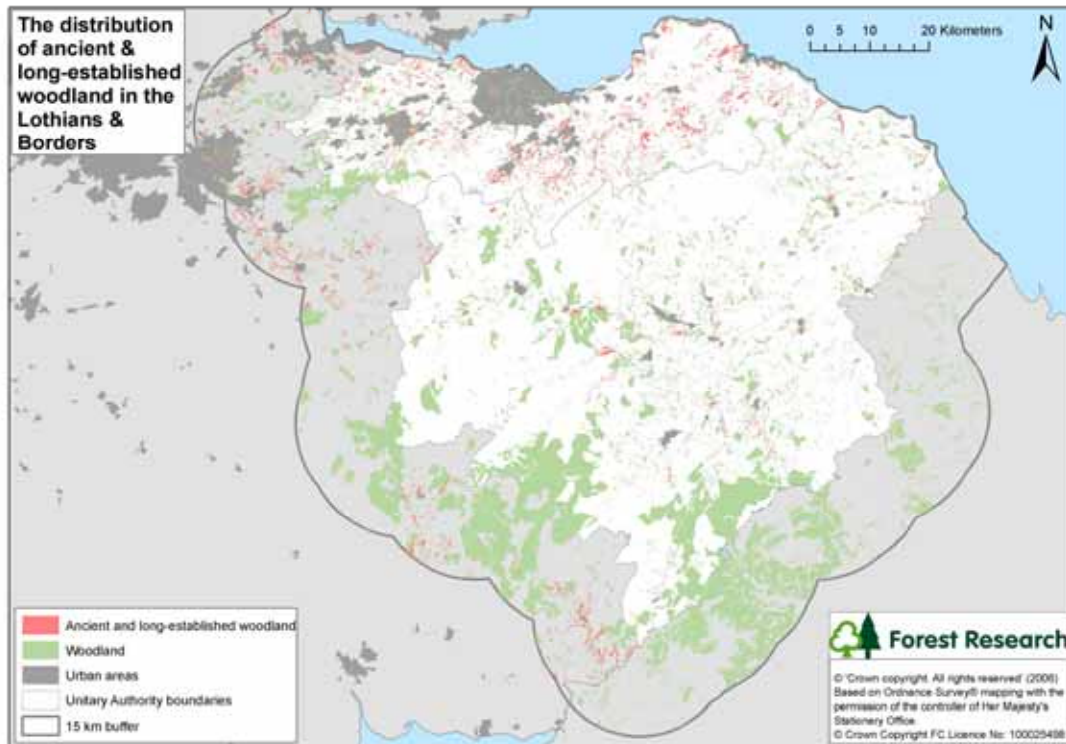


Figure 4. The distribution of ancient and long established woodland within the area of analysis.

FINAL REPORT

Table 4. Very high quality (8 ancient woodland indicator plants or more) woods in Edinburgh, the Lothians, and Borders region.

Unitary Authority	Woodland name	Grid reference
West Lothian	Philipstoun	NT070763
	Avon gorge	NS969751
	Oakbank - Almond	NT076665
	Mid Calder	NT089690
	Bellsquarry	NT058646
Edinburgh	Dreghorn	NT223683
	Craigmillar Castle	NT284710
	Hermitage of Braid	NT250703
	Colinton Dell	NT213694
Midlothian	North Esk (Penicuik-Polton)	NT274627
	South Esk (Temple-Bonnyrigg)	NT330610
	Eskbank	NT308669
	Gowkeshill - Gorebridge	NT351630
East Lothian	Whitecraig	NT347703
	Saltoun	NT468665
	Nunraw	NT599704
	Woodhall	NT677727
	Hailes Castle	NT576759
Borders	Newhall Glen SSSI	NT175564
	Harlamuir burn north	NT178563
	Cadonbank wood	NT340362
	Glenkinnon burn SSSI	NT420334
	Krikhope Linns SSSI	NT384240
	Helmburn	NT390242
	Lower Prison Linns	NT386239
	Plover plantation	NT428127
	Whitlaw wood	NT500132
	Whitlaw bank railway cutting	NT504128
	Cleuchhead & Minto Craigs	NT578207
	Wolfhopelee burn	NT594079
	Dod hill	NT688125
	Kiln burn	NT668132
	South of Cock Cleuch	NT673142
	Mossburnford bank – Glendouglas to Earlsheugh	NT654175 to NT677140
	Sunnybrae Scaur woods	NT653190
	Harestanes woods	NT648240
	Fox Dean woods	NT690228
	Leader water woods –Redpath to Dryburgh Abbey	NT575360
	Blackadder House	NT855545
	Hutton Castle Scaur and Edington Mill	NT891548
	Broadmeadow woods	NT912544
Bastle Dean	NT920547	
Chesterfield – Edington wood	NT935546	
Edrington Castle woods	NT940532	
Paxton House	NT932520	
Clarabad wood	NT926542	

FINAL REPORT

Chesterfield wood, south of Whiteadder	NT937541
Hirsel Country Park	NT828407
West Dunglass wood	NT817414
Gavinton, west to Choicelee and north to Raeclaugh head	NT752530
Duns castle	NT779542
Langon Lees Cleuch SSSI	NT740523
Gavinton	NT758582
Choicelee	NT746518
Shannabank wood east	NT763621
Butterwell wood north	NT767615
Abbey St Bathans woodlands SSSI	NT773608
Cockburn	NT771582
Cockburn Mill	NT776580
Pease Dean SWT Reserve	NT790704
Pease Bridge Glen SSSI	NT792701
Maggie Reikie's Well	NT935625
Leet Water woodlands	NT825413
Leaderfoot – Hallidean Mill wood	NT580342
Gledswood	NT590345
Drygrange community woodland	NT577356
Tweedwood – Gateheugh SSSI	NT572348
Newtown St Boswells wood SSSI	NT581322
Ellwynd wood	NT525357
Lowood	NT516354
Huntleyburn	NT527336
Tweed horizons – St. Boswells wood	NT587313
Woodland by Gala Water, Torwoodlee	NT475378
Woodland by Gala Water, Torwoodlee	NT474374

For each of the 5 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 (land cover types not classed as habitat) 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

FINAL REPORT

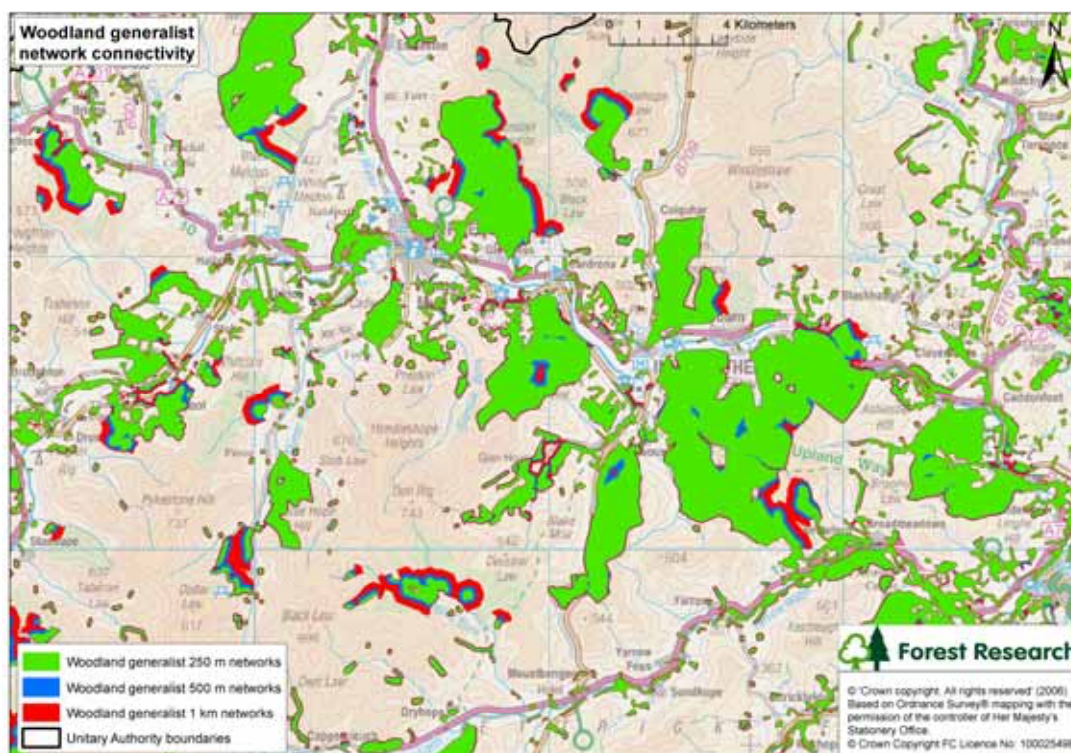


Figure 5. Comparison of habitat networks for woodland generalists capable of dispersing 250 m, 500 m and 1000 m. The networks have been overlaid with the greatest dispersal underneath and the least dispersal network on top.

3.1.1. Woodland generalists

The analysis shows there are a large number of small woodland generalist networks, with the largest networks being centred on the conifer plantations extending to the south of the Borders (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 smaller habitat area than woodland generalists, but more extensive areas of more moderate (better) permeability. Also in contrast, in the BEETLE model 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 38%, indicating increased networks connectivity, while increasing the network area 1.3 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 4 to 6) with few networks over 118 ha. However, many of the larger networks are of high quality, indicating there are some relatively robust areas from which to initiate expansion. Figure 6 shows four distributions of networks for specialists of high quality broadleaved woodland, high quality mixed woodland, other broadleaved woodland and woodland generalists. The map provides a spatially referenced index of a range of woodland networks of varying biodiversity value in Edinburgh, Lothians, and Borders. In particular, the map provides an estimate of the degree of linkage of high quality woodland with adjacent woodland of lower quality. It can be used as a reference for estimating where high quality woodlands should be protected and expanded,

FINAL REPORT

and how woodland expansion might seek to link existing structures, to form stepping stones between two or more networks. This will be explored in detail in section 3.3. Because the matrix is not permeable to woodland specialist species dispersal, Figure 6 tends to re-emphasise the distribution of quality woodlands shown in Figure 3.

The metrics (Table 5b-d) show 1 329 broadleaved networks covering 34 888 ha. Within these structures are 64 high quality mixed / broadleaved woodland networks covering 4 754 ha, and 62 high quality broadleaved networks covering 2 565 ha. The 250 m to 1000 m dispersal sensitivity analysis shows that the number of high quality mixed woodland specialist networks is reduced by 46% with a 1.7 times increase in network size (Table 5c). Networks of this type constitute small sections of the woodland generalist networks, they are slightly less fragmented than, for example high quality broadleaved specialist networks (reduction in networks - 31%, size increase 1.9 times), and can be more easily connected through existing woodland corridors. 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 non-habitat in the specialist networks compared to the generalists, suggesting that the matrix is much less permeable to specialists than to generalists.

However, 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 non-habitat woodland (including the 50 m buffer), 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 quality woodlands, is a reflection of how they are distributed within the woodland matrix.

FINAL REPORT

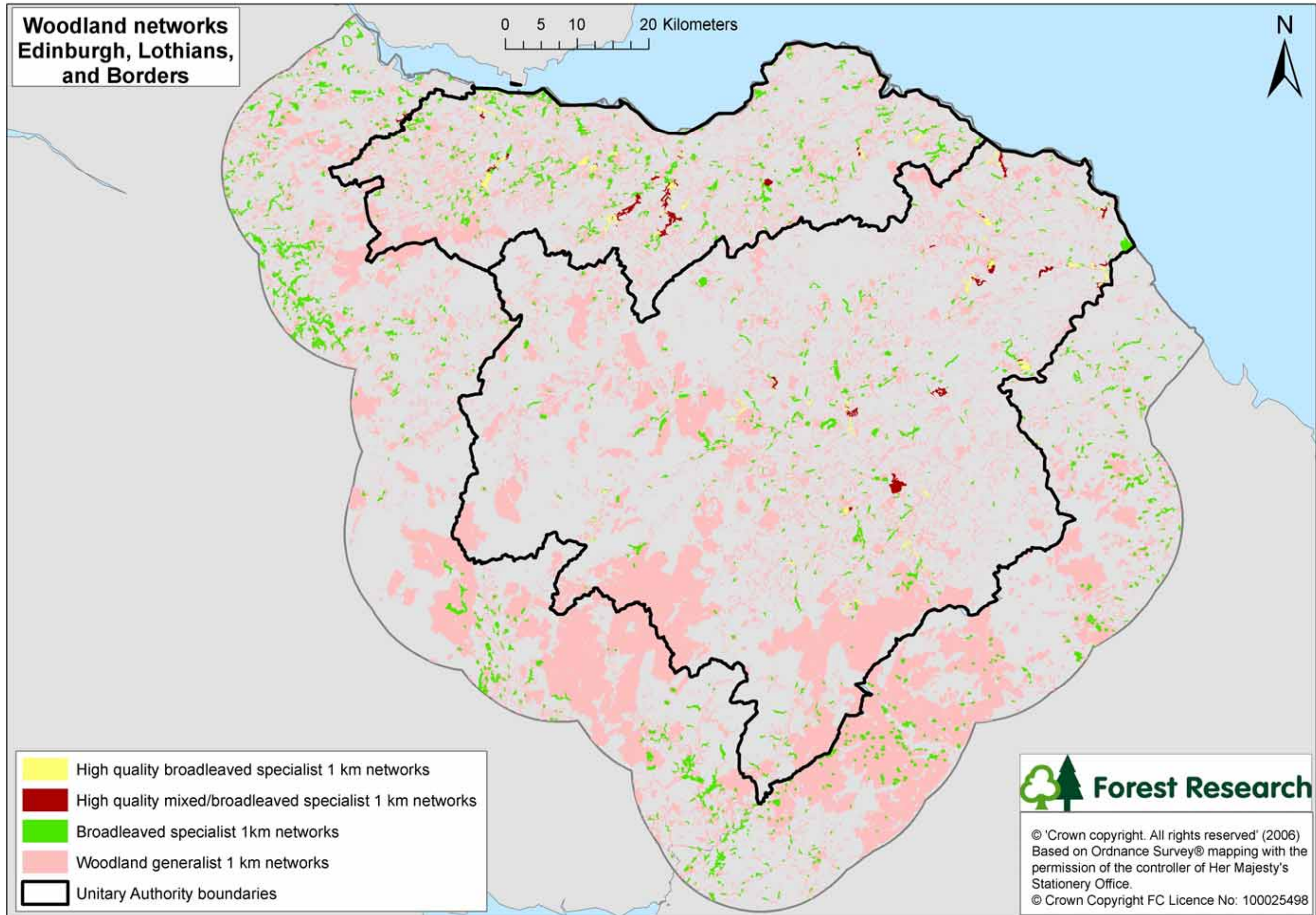


Figure 6. Woodland networks, assuming a maximum dispersal distance of 1km, for high quality specialists, broadleaved specialists, and woodland generalists in the regions of Edinburgh, Lothians, and Borders.

FINAL REPORT

3.1.3. Heathland generalists

An assessment of the Lothians and Borders landscape permeability was undertaken for heathland generalists to indicate the extent of networks for open habitats (Figure 7). Figure 7 shows clearly the heathland habitat occurring in the Pentland, Moorfoot, Lammermuir, Upper Tweeddale, Lowther, and the northern Cheviot Hills.

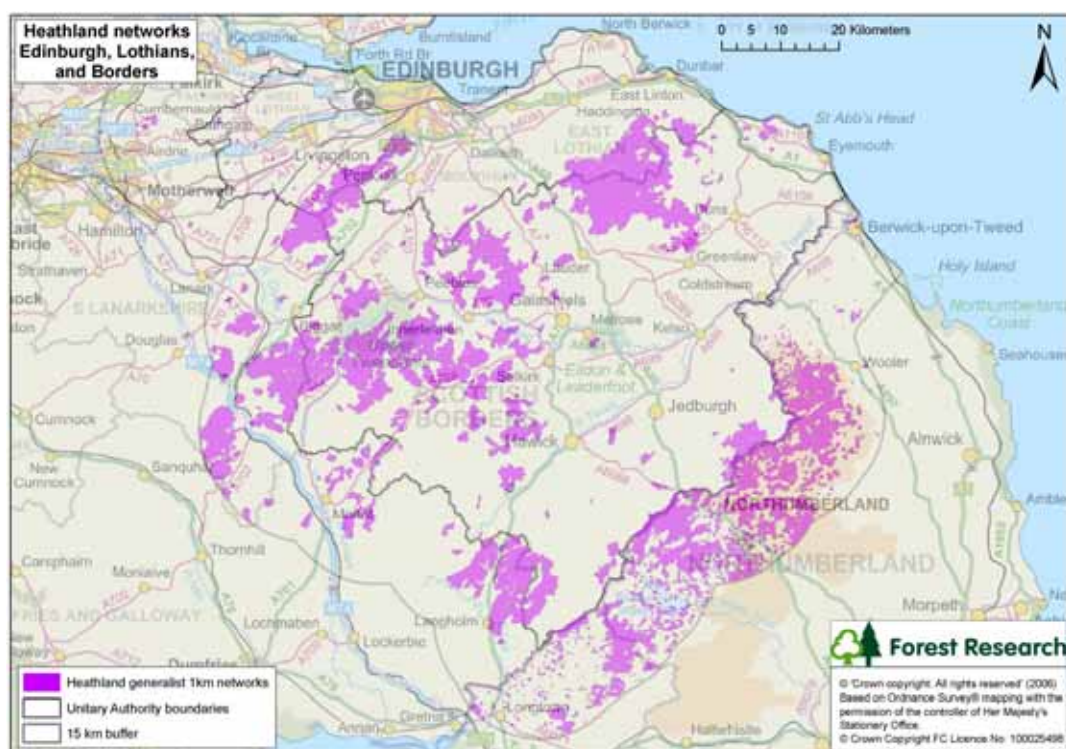


Figure 7. Heathland generalist networks, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.

The analysis indicates that most of the heathland generalist networks are relatively large (Appendix 7). 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 52% when the dispersal distance is increased from 250 m to 1000 m, while the network area increases by 1.3 times. This is slightly better response to the sensitivity analysis than for woodland generalists (38% reduction in network size, increase in network area 1.3 times), indicating that the heathland generalist networks are less fragmented at the higher dispersal distance (Table 5a). The total area of heathland networks is less extensive than woodland networks, but more consolidated as is apparent in the lower number of networks and higher mean network size.

FINAL REPORT

Table 5. Landscape metrics for the five generic focal species analyses covering the region of Edinburgh, the Lothians, and the Borders.

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 non-habitat network (ha)	Percentage non-habitat in network (ha)
250	12 768	231 453	18.1	33 492	42 640	18
500	11 005	256 683	23.3	36 834	67 870	26
1000	7 876	311 824	39.6	62 485	123 011	39

b) Broadleaved woodland specialists

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 non-habitat network (ha)	Percentage non-habitat in network (ha)
250	1 915	15 907	8.3	227	11 835	74
500	1 613	22 857	14.2	328	18 785	82
1000	1 329	34 888	26.3	433	30 816	88

c) High quality mixed woodland and broadleaved woodland specialists

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 non-habitat network (ha)	Percentage non-habitat in network (ha)
250	119	2 879	24.2	242	1 792	62
500	80	3 642	45.5	324	2 559	70
1000	64	4 754	74.3	398	3 672	77

d) High quality broadleaved woodland specialists

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 non-habitat network (ha)	Percentage non-habitat in network (ha)
250	90	1 336	14.8	104	950	71
500	71	1 798	25.3	119	1 405	78
1000	62	2 565	41.4	145	2 158	84

e) 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 non-habitat network (ha)	Percentage non-habitat in network (ha)
250	1 664	140 342	84.3	21 225	21 000	15
500	1 270	156 361	123.1	22 307	37 019	24
1000	793	184 950	233.2	24 003	65 608	35

FINAL REPORT

3.1.4. 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 8 to 10). There is very little overlap (12 ha) between the high quality mixed / broadleaved specialist networks and heathland generalists (Table 6), which is unsurprising as the former habitat tends to be located in lowland areas. The interaction between heathland generalist and broadleaved specialist networks is larger, representing approximately 5% of the broadleaved specialist network, but only 0.4% of the heathland generalist network. Many of the overlapping areas occur along steep sided ravines bordering moorland. The largest network overlap is between the woodland and heathland generalists, although a large proportion of this is occurs in the conifer plantations across the English border, which are located on high ground, adjacent to the largest areas of heathland. If the 15 km buffer is removed from the analysis, the areas of overlap are greatly reduced, indicating that woodland networks do not have a large impact of heathland generalist networks (Table 7).

Table 6. The overlap of the heathland generalist networks with high quality mixed / broadleaved specialist, broadleaved specialist, and woodland generalist networks at a maximum 1000 m dispersal distance within Edinburgh, Lothians, and Borders, 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
High quality mixed / broadleaved specialist	4 611	12	< 0.01	0.3
Broadleaved specialist	34 888	1 764	0.4	5.1
Woodland generalist	311 824	28 384	15.3	9.1
Heathland generalist	184 950			

Table 7. The overlap of the heathland generalist networks with broadleaved specialist, and woodland generalist networks at a maximum 1000 m dispersal distance within Edinburgh, Lothians, and Borders, excluding 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
Broadleaved specialist	18 078	449	0.5	2.5
Woodland generalist	165 524	7 404	7.7	4.5
Heathland generalist	95 668			

The analyses indicate that there is a small amount of overlap between woodland networks and open ground 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.

FINAL REPORT

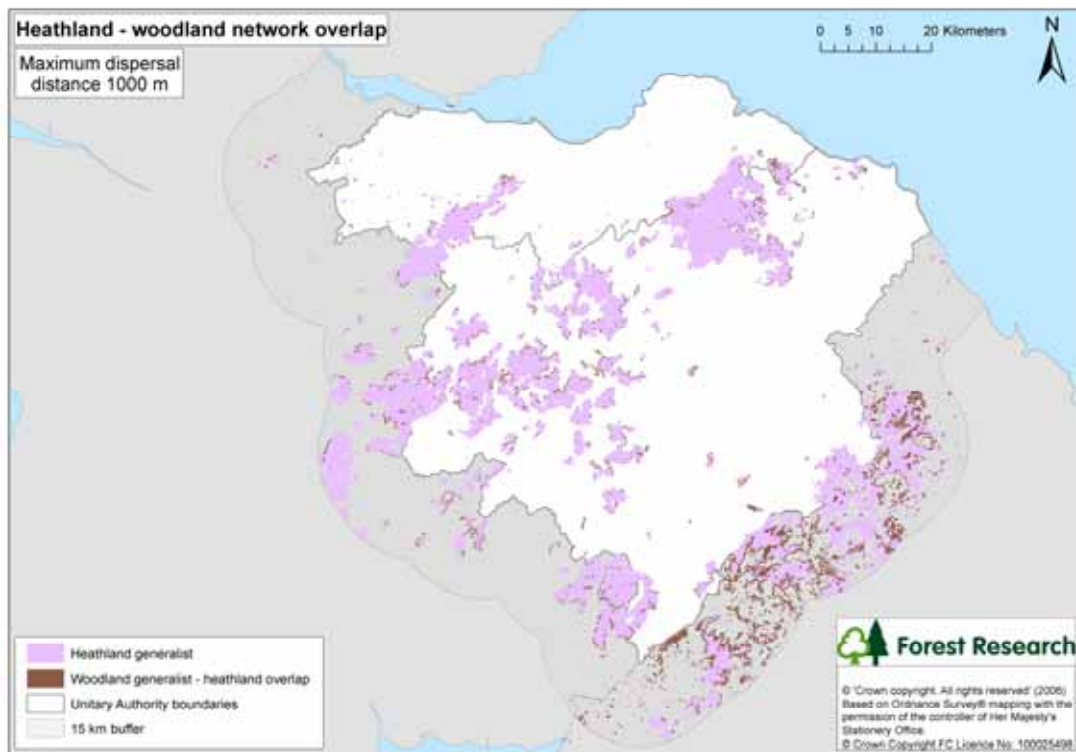


Figure 8. Potential interactions in Edinburgh, Lothians, and the Borders at a maximum 1000 m dispersal distance between heathland generalists and woodland generalists. The distribution of heathland generalist networks and the area of overlap with the woodland generalist are shown.

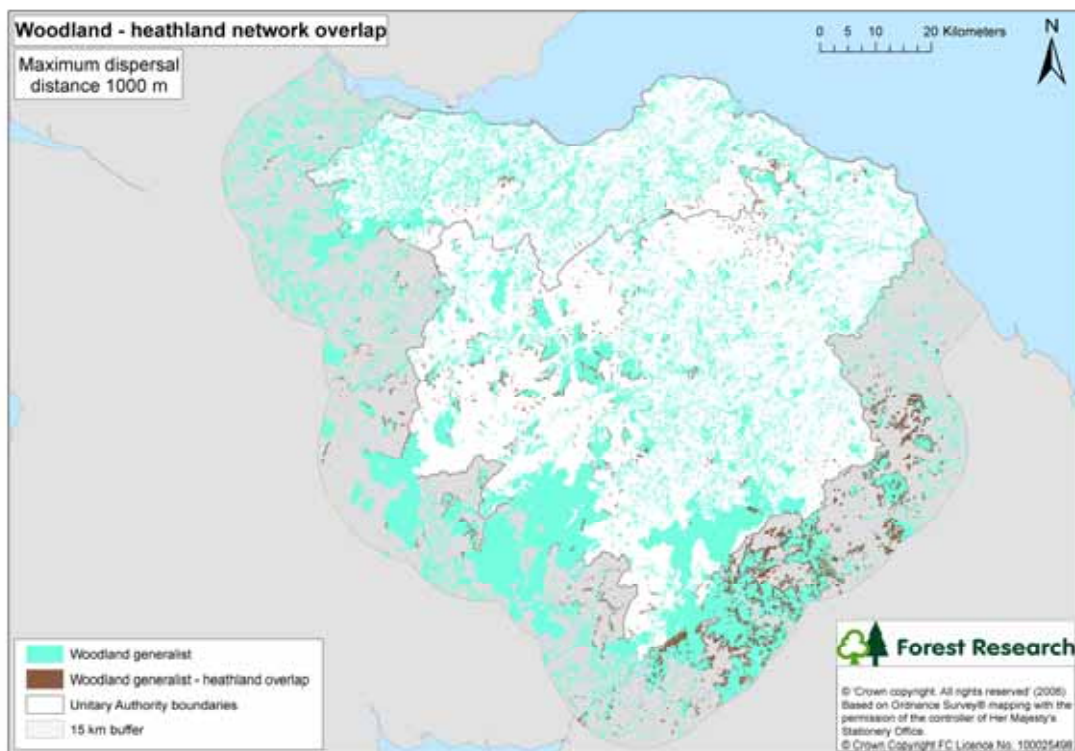


Figure 9. Potential interactions in Edinburgh, Lothians, and the Borders at a maximum 1000 m dispersal distance between woodland generalists and heathland generalists. The distribution of woodland generalist networks and the area of overlap with the heathland generalist are shown.

FINAL REPORT

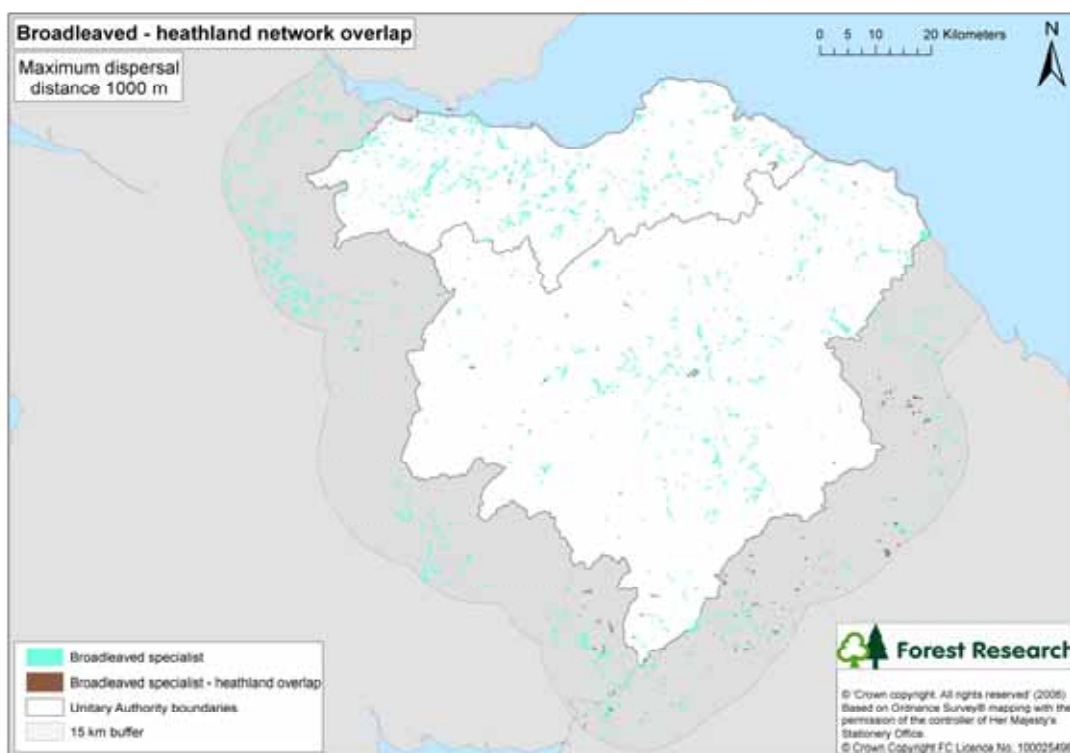


Figure 10. Potential interactions in Edinburgh, Lothians, and the Borders at a maximum 1000 m dispersal distance between heathland generalists and broadleaved specialists. The distribution of heathland generalist networks and the area of overlap between the heathland generalist and broadleaved specialist networks are shown.

3.2. Regional 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 **restoration** 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 containing **High quality woodland specialist networks** (identified by the presence of at least 8 ancient woodland indicator species or identified in the Borders by an expert as 'high' quality) should be designated for **consolidation** and **buffered expansion**.
- Those woodlands containing **good quality woodland** (identified by the presence of 4 to 7 Ancient woodland indicator species or identified by an expert in the Borders as 'good' quality) should be designated for **restoration**, to improve the condition of the woodland to encourage a greater number of ancient woodland indicator species. This would then bring these areas into the **high quality broadleaved woodland category**. Management should concentrate on approaches that maintain and enhance the existing ground flora. **Structural management** of broadleaved woodland of undesignated quality can be undertaken to improve quality.
- **Broadleaved specialist networks** can be placed on top of woodland generalist networks to indicate where broadleaved specialist networks can be **expanded** through **restructuring** of

FINAL REPORT

other woodland, *i.e.* conversion to broadleaved, removal of conifers from mixed woodland (Figure 6).

- **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** (Figure 6).
- 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.

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.
- Determine how forest plans can be developed to **minimise disruption** to existing FHNs.
- Identify **open ground** areas where forest expansion is not appropriate.

3.2.1. Broadleaved networks along valleys

The analyses gave an opportunity to examine the broadleaved woodland specialist networks in relation to the criteria set for the Borders Locational Premium Scheme, which was launched with the aim “to encourage planting of native woodlands and riparian woodlands, particularly where it will reduce the isolation of existing native woodlands or significantly improve riparian habitat.”

Under the scheme, native woodland planting proposals should be within 500 m of existing native source woodland occupying at least 0.1 ha to contribute to FHNs. Source woodlands need to be predominantly native species (or non-native species on ancient woodland sites that are to be restored) that occupy at least 0.1 ha.

The criteria for riparian woodland proposals specify that:

- they must adjoin watercourses greater than 1 m wide, except where we agree that important habitat linkages can be made along a watercourse close to its source.
- Average width of planting should be between 25 m and 100 m from the edge of the watercourse or water body on each side. Possibly wider on some flood plains.
- they maximise opportunities for linking with existing riparian and native woods where possible.

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 landcover permeability will result in network connectivity. The networks produced focus on broadleaved networks (with detailed analysis of woodlands with higher biodiversity value) and it is likely that future planting will be biased towards the creation of broadleaved native woodlands. The locational premium may help consolidate existing areas of native woodland, particularly small ones as the minimum area is 0.1 ha although it is hard to determine whether dispersal events will occur between new and existing woodland, particularly if the distance between is at the limit of the 500 m maximum. The BEETLE analysis takes into account variation in the landcover 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 (< 110 m width) woodlands not being classified as ‘core’ habitat (instead being given a very low resistance to dispersal in the landcover), it provides a focus on those habitats that are more likely to support viable species populations.

The broadleaved specialist network analysis (Figure 11) indicates that many of the broadleaved networks are associated with valleys, in particular around riparian areas. Consolidation and

FINAL REPORT

expansion of these areas sits well with the Borders Locational Premium riparian woodland criteria, but also requires that the width of the woodland be at least 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.

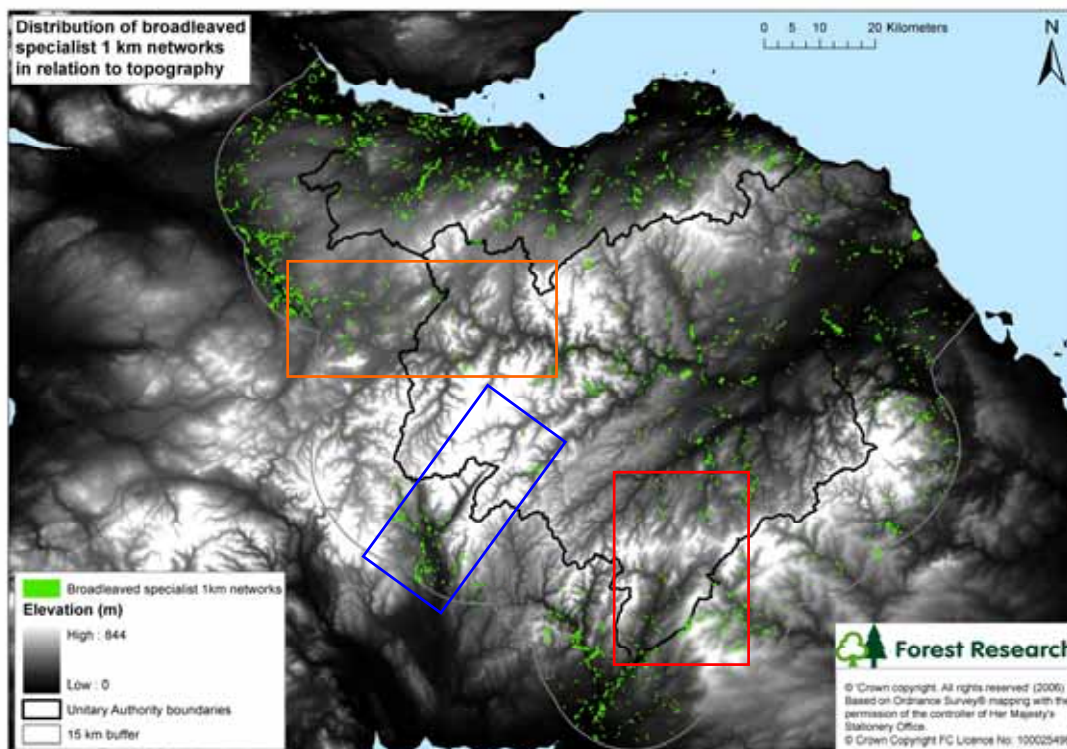


Figure 11. Broadleaved specialist networks are associated with the riparian areas running through the valleys. The blue box refers to figure 12, the red box figure 13, and the orange box figure 14.

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 route could be along the valleys of Moffat Water and Ettrick water, with dispersal via cleuch woodlands running up the fells separating the two valleys (Figure 12). Other potential routes run through Liddesdale, on the west side of Kielder forest towards Hawick with its established broadleaved woodlands, and via the River Rede towards Jed water on the east of Kielder (Figure 13). Although Kielder is largely situated within England, liaison with forest planners could help in the development of forest restructuring plans that increase the broadleaved component, thereby helping to develop broadleaved specialist networks.

FINAL REPORT

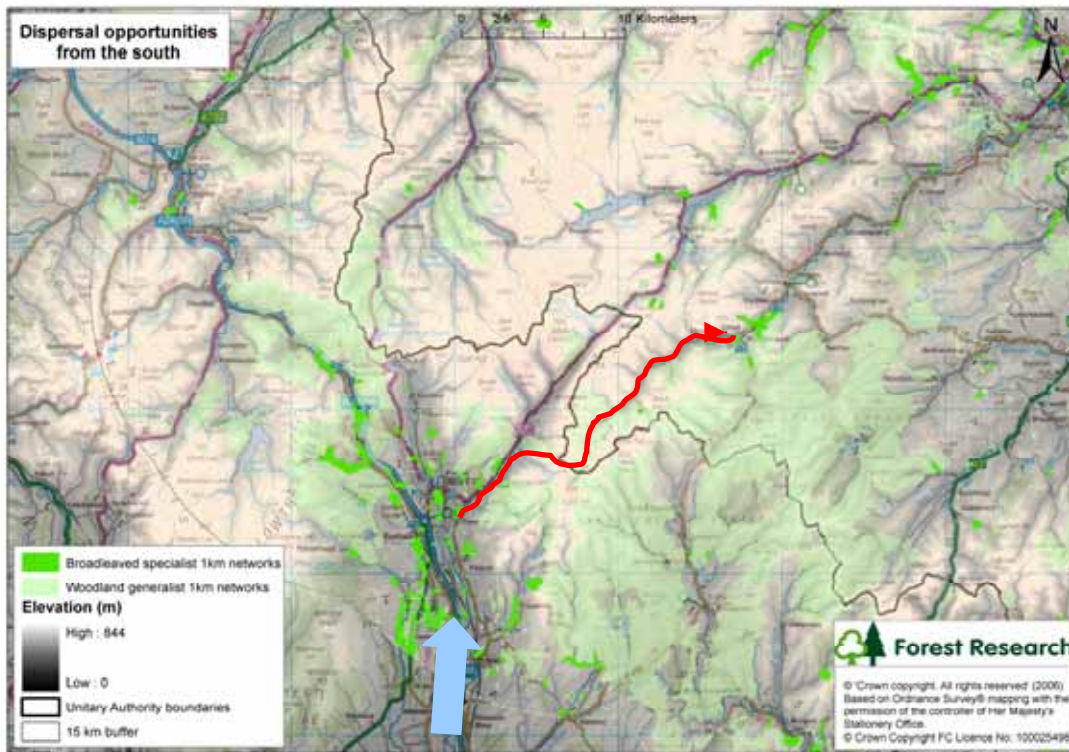


Figure 12. Illustration of how species might disperse from the south (blue arrow), via Moffat following Moffat Water and crossing to Ettrick Water to disperse northeast (indicated by red arrowhead).

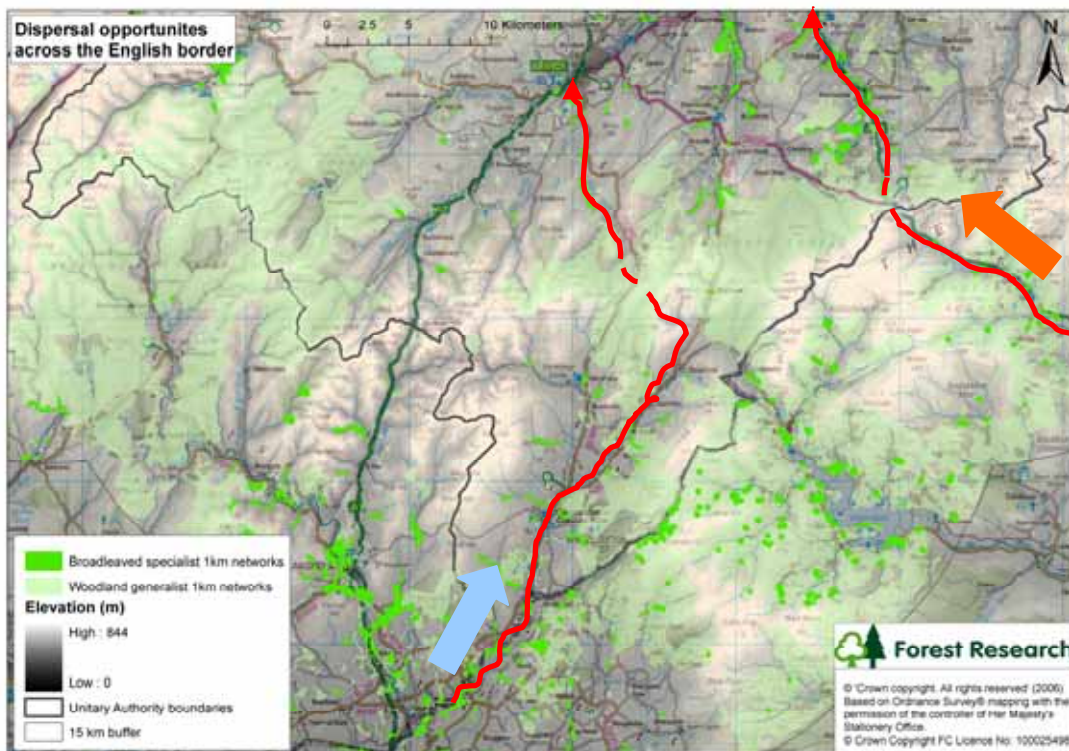


Figure 13. Illustration of how species might disperse from the south (blue arrow), through Liddesdale following Liddel Water and crossing to Slitrig Water to disperse northwards (indicated by red arrowhead). Another dispersal route is indicated from the southeast (orange arrow), following the River Rede and crossing to Jed Water through Kielder forest.

FINAL REPORT

Biodiversity can also benefit from dispersal events across the breadth of Scotland, with the valleys providing important linkage between the Tweed and the Clyde (Figure 14). Linking these areas would allow species to disperse from the Borders region, through central Scotland, and towards the Highlands.

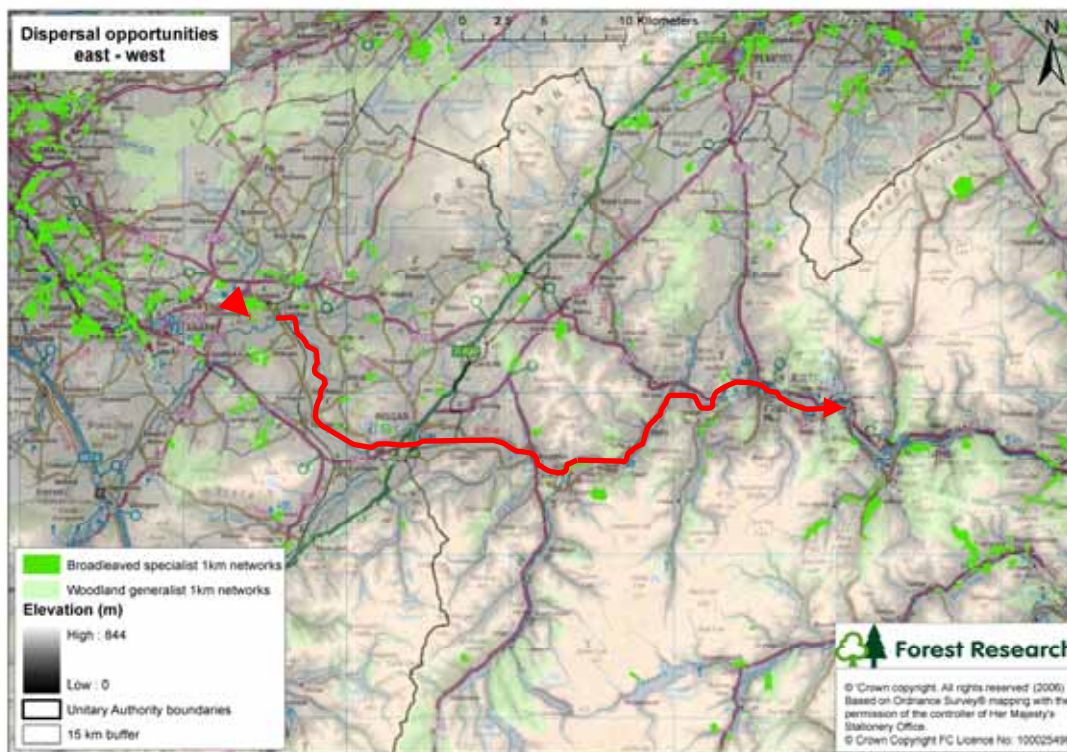


Figure 14. Illustration of how dispersal events might occur across an east-west direction (indicated by the red arrowheads), following the riparian woodlands adjacent to the Clyde and Tweed rivers.

3.3. Local application of the analyses

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 **restoration** 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.

Figure 15 shows the location of five examples that we have focussed on to demonstrate how the analyses may be applied to local situations:

1. Improvement using habitat quality
2. Linkage based on quality improvement
3. Cleuch woodland restoration
4. Use of quality identifiers to restore degraded woodland
5. Multiple approaches for Forest Habitat Network development

FINAL REPORT



Figure 15. A selection of Forest Habitat Network development site opportunities. 1) Improvement using habitat quality; 2) Linkage based on quality improvement; 3) Cleuch woodland restoration; 4) Use of quality identifiers to restore degraded woodland; 5) Multiple approaches for FHN development.

3.3.1. Network improvement opportunities

Network Improvement using habitat quality

Figure 16 demonstrates how network can be improved by using habitat quality information to direct local scale FHN management. In this example, high quality woodlands have been identified but they do not currently contribute to networks as they are too narrow to contain core habitat. These areas could be buffered by either new planting or encouraging natural regeneration. The high quality broadleaved specialist networks are currently fragmented, but could be linked by restructuring or removal of conifers in the woodland box separating them (blue box). It would also be possible to start linking smaller fragments into the larger network (orange boxes).

FINAL REPORT

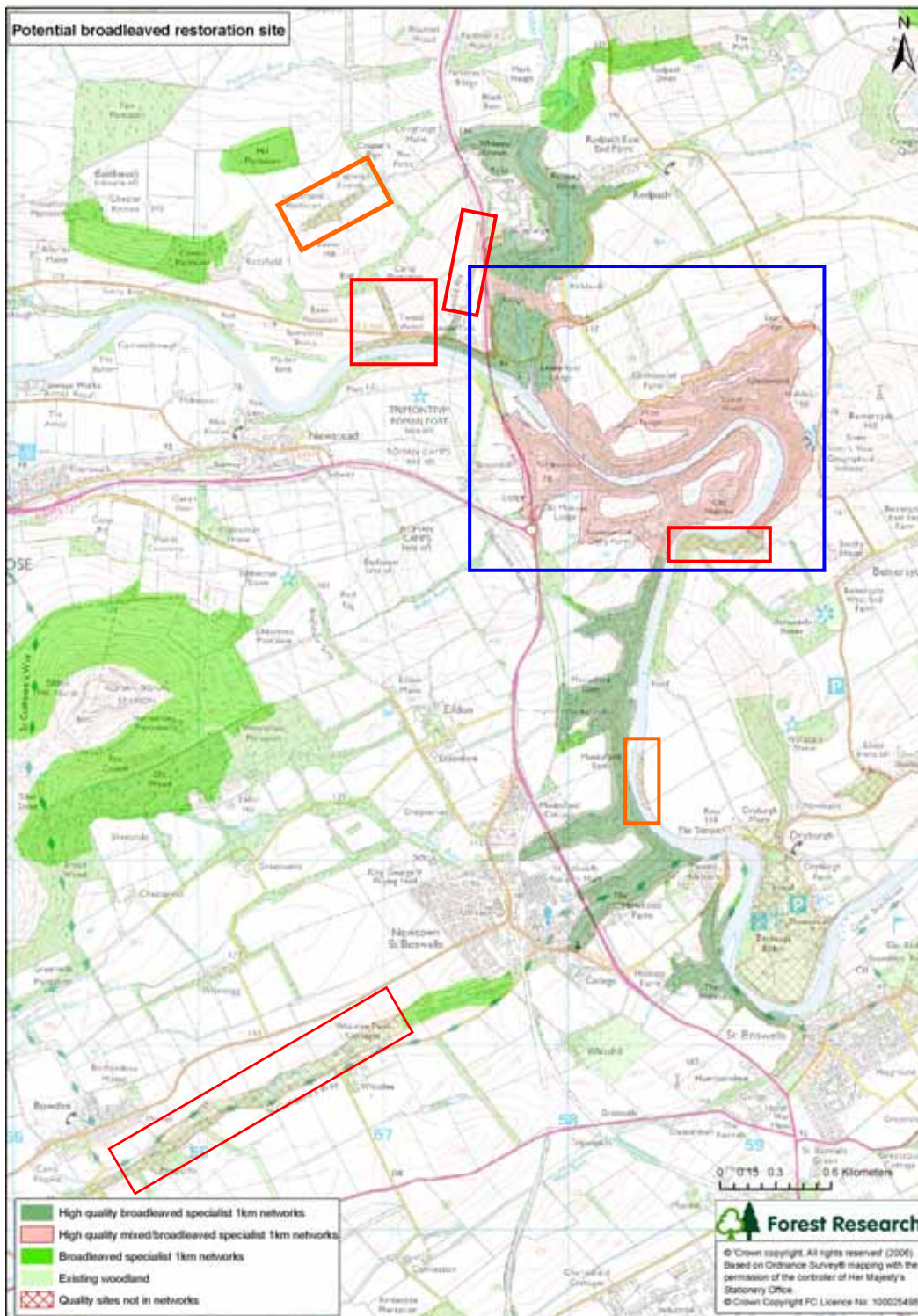


Figure 16. FHN improvement opportunities east of Melrose. High quality woodlands that currently do not contribute to networks (red hatching), indicate that a potentially extensive habitat network could be developed by: 1) buffering existing high quality woodland (red boxes); 2) management of existing sites to improve habitat – e.g. removal of conifer, or restructuring (Blue box), 3) linking smaller fragments into larger network (orange boxes).

FINAL REPORT

Management to improve quality – good to high quality

The high quality network analyses require high quality woodlands from which to disperse to other high quality woodlands. A very effective approach to expanding networks is to improve the good quality woodlands so that they contribute to the high quality networks. Figure 17 indicates that a network along Whiteadder water, west of Berwick-upon-Tweed, could be extended by increasing the quality of the woodlands, highlighted by the red boxes. There is an opportunity to further link the network by buffering existing high quality woodlands so they provide 'core' habitat (dashed orange box), and adding small amounts of new broadleaved woodland (purple boxes). Conversion of existing woodland to higher quality broadleaved woodlands (blue boxes) will further link and consolidate a potentially excellent riparian network.

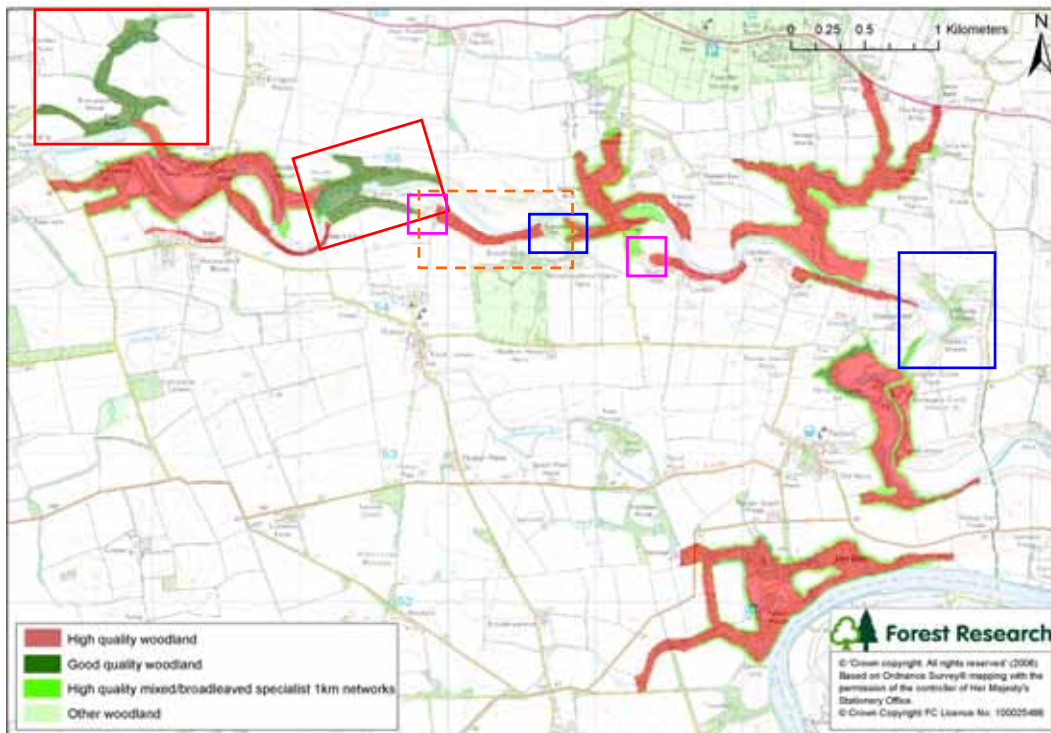


Figure 17. A high quality mixed/broadleaved specialist network west of Berwick-upon-Tweed that may be linked by: 1) increasing the quality of the good quality woodlands to high quality (red boxes); 2) buffering existing high quality woodlands so they provide 'core' habitat (dashed orange box); 3) converting existing woodland to broadleaved woodland, which can in time be developed into high quality woodlands (blue boxes); 4) planting new, native broadleaved, woodland (purple boxes).

Cleuch woodland restoration

The Borders are well known for rich cleuch woodland. However, many sites are isolated and would benefit from consolidation and buffered expansion, as demonstrated in figure 18. Here, the high quality broadleaved specialist networks are restricted due to lack of core habitat in many of the woodlands. The networks are fragmented and could be consolidated by firstly improving the quality of the adjoining woodland, then ensuring that native broadleaved woodland is planted along the riparian areas to link

FINAL REPORT

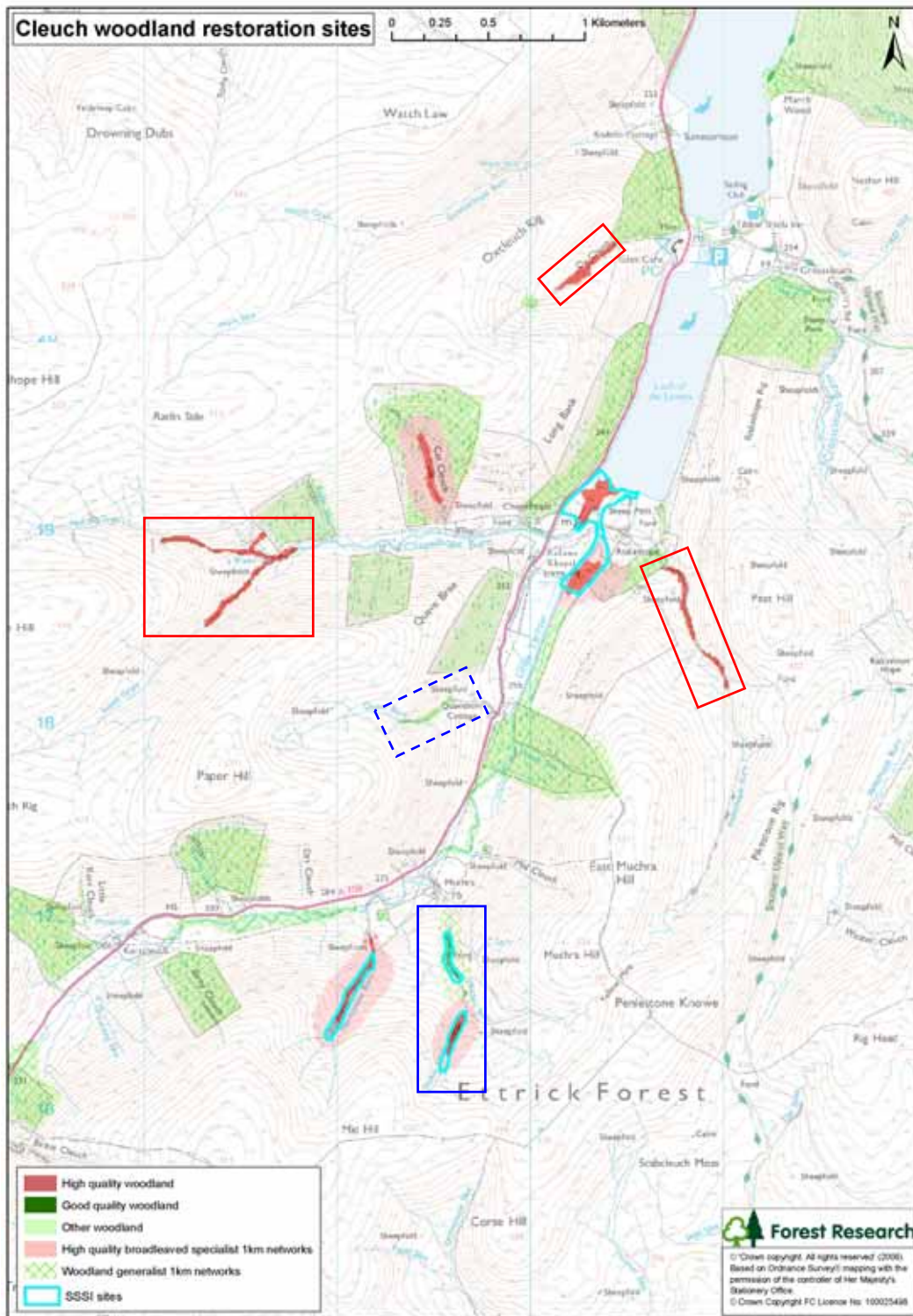


Figure 18. An example of high quality cleuch woodland sites in the Borders, these are located south of St. Mary's Loch. The woodlands highlighted by the red boxes lack sufficient core woodland and should be expanded. Improving the quality and size of adjoining woodland (blue box) can expand existing high quality networks, or create new networks (dashed blue box).

FINAL REPORT

Use of quality identifiers to restore degraded woodland

A number of areas were identified as having 4 or more ancient broadleaved 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 ancient broadleaved woodland indicator species suggests that, at some time, high quality broadleaved woodlands were present. These areas present ideal opportunities for:

1. Restoration to bring the quality of woodland to a higher standard. The resultant woodland may then form part of a high quality broadleaved 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.

Figure 19 focuses on one opportunity for restoration, other locations are suggested in Appendix 8.

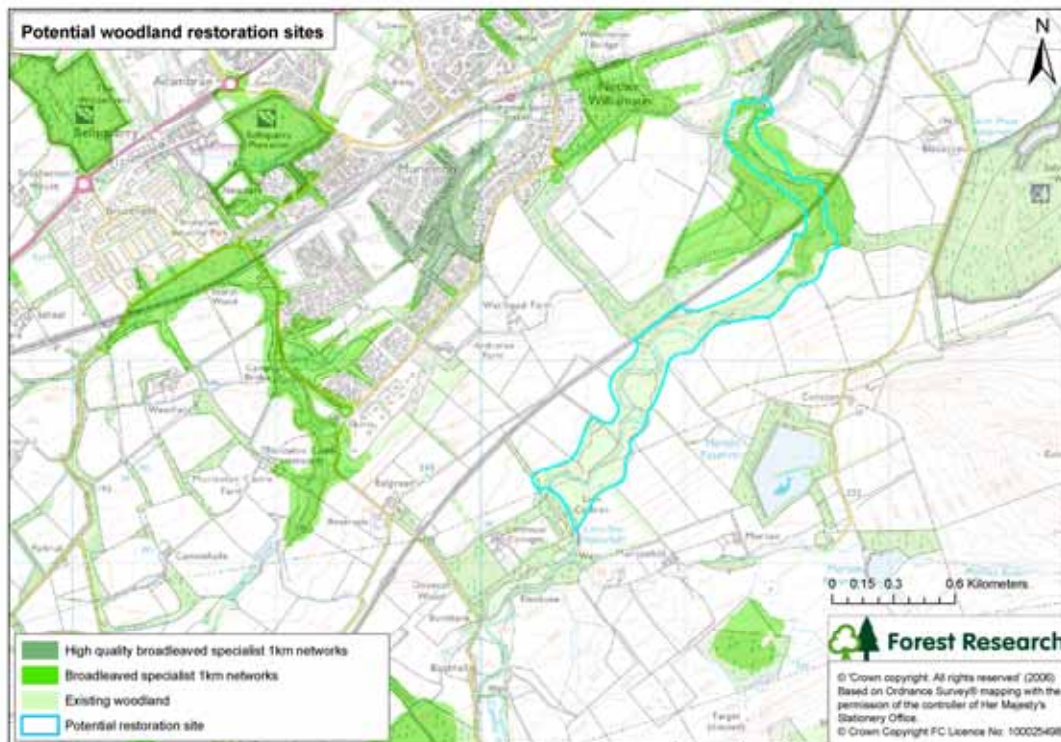


Figure 19. Semi-natural broadleaved woodland with low canopy cover, but good ground flora, south of Nether Williamston (indicated by blue outline).

Nether Williamston (NT069640)

This site corresponds with a semi-natural broadleaved woodland with 1 to 10% canopy cover and is classified as a Long-established plantation in the ancient woodland inventory. There is also an adjacent area nearby which contains scrub, that may include scattered trees. The site, indicated by the blue outline (Figure 19) contains 7 species, so almost has the ground flora component required to classify it as a high quality broadleaved woodland. Increasing the tree cover element and encouraging deadwood would help to develop a relatively large high quality broadleaved specialist

FINAL REPORT

network, with the possibility of linking to the fragment to the northeast. Additionally, it would expand the broadleaved network towards the conifer plantations to the southwest, which may be future targets for conversion to mixed or broadleaved woodland.

Multiple approaches for Forest Habitat Network development

Pease Dean Glen, Edmond's Dean, and Blackburnrig woods provide a good illustration of the multiple approaches may be taken to consolidate, expand, and link high quality forest habitat networks (Figure 20).

Pease Dean Glen (NT792701)

Pease Dean Glen SSSI (hatched area) runs along the northern part of the high quality mixed/broadleaved specialist network, linked to the Scottish Wildlife Trust reserve which incorporates the high quality broadleaved specialist networks. Restoration work may allow the extension of these designated areas, but the analysis also shows that the surrounding woodland provides both a larger habitat patch to reduce the risk of species extinction, and provides opportunities for recolonisation should local extinction occur.

Edmond's Dean (NT760679)

The upper part of this small woodland, highlighted in blue in the centre of the map, is composed of semi-natural broadleaved trees with <50% canopy cover running along a lowland watercourse. The site has 4 of the listed ancient woodland species recorded, indicating 'good' quality woodland. It should be possible to link this woodland to the small cleuch woodland to the south, and extend to link to the broadleaved network to the southeast.

To the north is a relatively large broadleaved woodland specialist network which, with a little buffered to increase the width of the broadleaved woodland to the west, would extend across from east to west. High quality broadleaved specialist networks are nested within the broadleaved woodland, suggesting that the high quality woodland may extend across the whole broadleaved network.

The northern and southern networks are linked by a high quality mixed/broadleaved specialist network, which is comprised of semi-natural broadleaved trees underplanted with conifers. These woodlands are particularly rich in ancient woodland indicator species, suggesting that at one time they formed a large ancient broadleaved woodland network. Removal of conifer may be appropriate for returning the some of the mixed woodlands to broadleaved woodlands, thus increasing the high quality broadleaved specialist networks. Recreation is also an important issue as the Southern Upland Way runs through these woodlands.

Blackburnrig wood (NT789665)

This burnside woodland is planted conifer (10 to 50% canopy) but has historically been broadleaved, as indicated by the first edition maps, and by the ecological evidence of the base enriched (W9) ancient woodland indicators.

FINAL REPORT

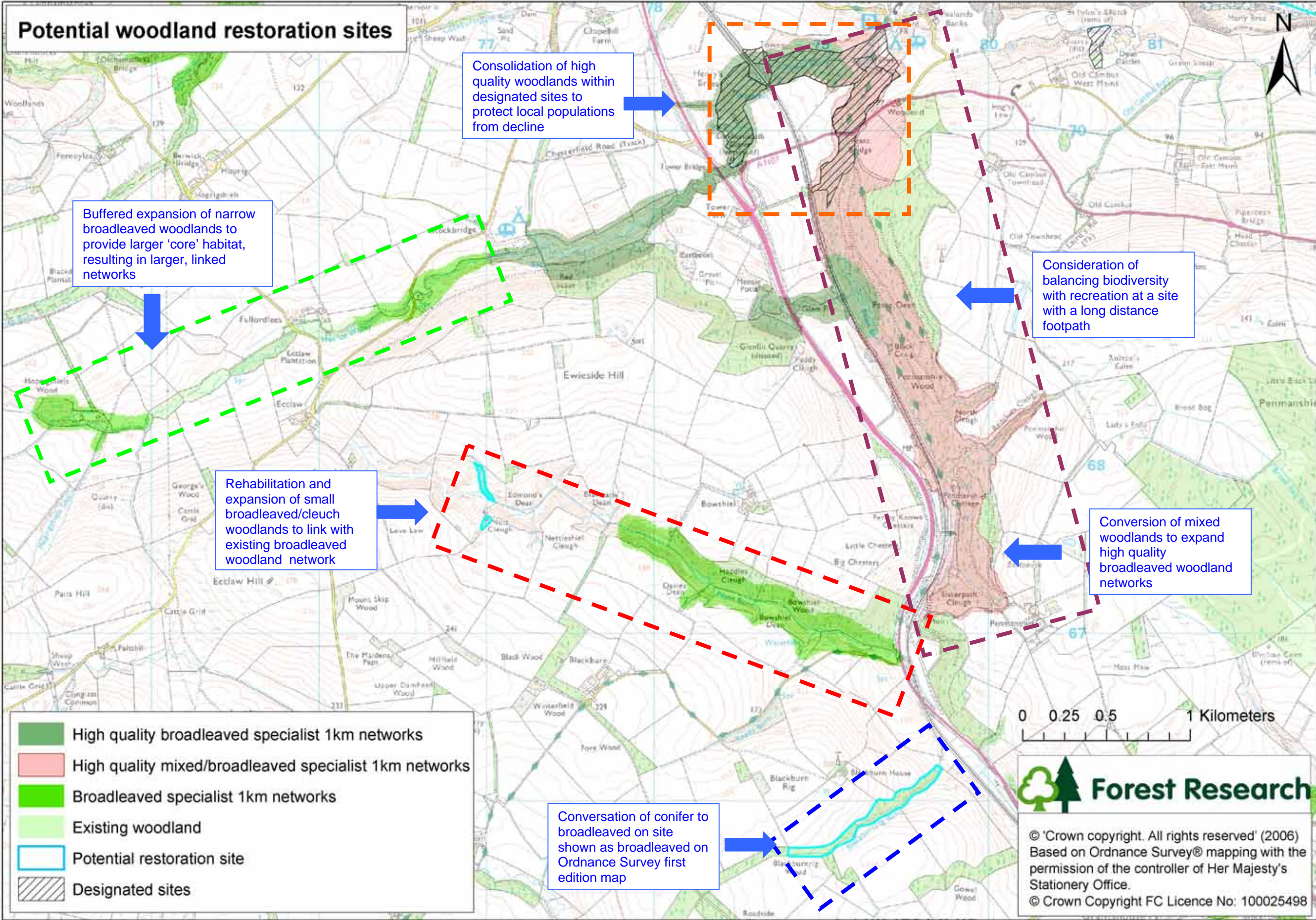


Figure 20. Illustration of the possibilities for habitat consolidation, buffered expansion, and rehabilitation to improve biodiversity and network connectivity around Pease Dean Glen SSSI (Grid reference NT792701).

FINAL REPORT

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 there are a substantial number of existing communities not served by small woodlands within a few minutes walking distance, in Edinburgh and the Lothians. The largest areas are the western waterfront of Edinburgh; from Meadowbank north to the Port of Leith, and the housing estates of Granton and Pilton to the west of Granton Harbour. A second large area runs from Saughton through Sighthill north to central Corstorphine. A third smaller area in Edinburgh extends south of the west end and south through the area to the west of Lothian Road as far as Bruntsfield.

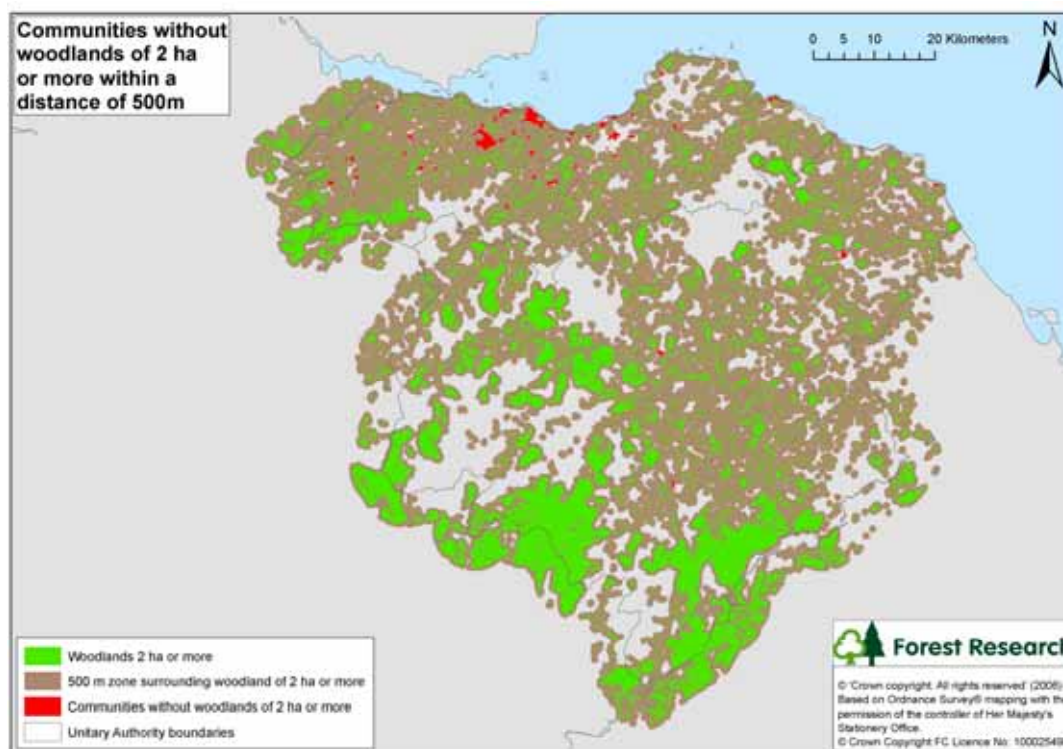


Figure 21. Communities not served by 2 ha woodlands within a distance of 500 m in the regions of Edinburgh, the Lothians, and the Borders.

Away from Edinburgh to the east, Prestonpans, Tranent, Elphinstone and Macmerry have no small accessible woodlands, neither does the northern side of Dunbar. In Midlothian, the southern area of Dalkeith, south Bonnyrigg, and southern area of Newtongrange have no accessible woodlands within easy walking distance. Other areas include the western part of Loanhead and central Penicuik.

In West Lothian, areas without accessible woodland include Broxburn, parts of north Livingston, East Calder and Kirknewton, Deans, Dodridge, West Calder, Bathgate, Seafield, Blackburn, Addiewell, Loganlee, Whitburn, Greenburn, Armadale, Eastfield, Blackridge and eastern Linlithgow.

FINAL REPORT

Although the Borders has smaller urban areas than Edinburgh and the Lothians, a number of existing communities do not have access to woodlands of at least 2 ha within 500 m. The largest area lacking nearby woodland is the south part of Duns, with smaller areas at northern Chirnside, north Eyemouth and southeast Coldingham. Communities lacking woodland access in the south of the Borders region are central Hawick and Denholm, whilst central Galashiels and southwest Greenlaw lack sufficient woodland in central Borders.

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 very small gap in the distribution in north western waterfront of Edinburgh at the Port of Leith.

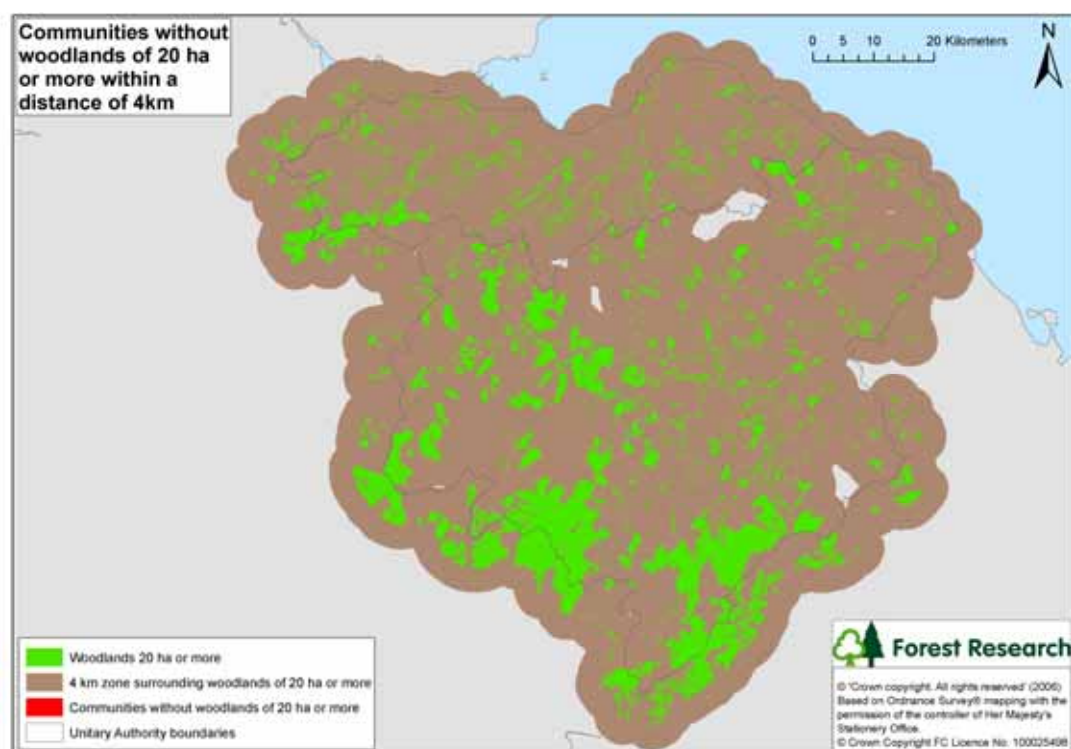


Figure 22. Communities not served by 20 ha woodlands within a distance of 4 km in the regions of Edinburgh, the Lothians, and the Borders.

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 be 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.

FINAL REPORT

4. Discussion

4.1. Determination of habitat quality

This is a desk study to identify extant Forest Habitat Networks of the Borders and the Lothians, and classify them in terms of biodiversity quality. 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 ancient woodland indicator plants can also be used to indicate biodiversity quality.

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 in the vicinity of urban areas, human disturbance and intervention can cause a structural and biological decline e.g. plantations on ancient woodland sites (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), and in this study we follow this principle 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 local BRCs have supplied the ancient 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 21 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 ancient woodland indicator plant criteria thresholds of 4 or more plants to identify 'good 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, and approaches using the ancient woodland inventory to identify high quality woodland, assume 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 landcover is increasingly restricted and woodlands increasingly fragmented.

FINAL REPORT

4.2. Habitat networks

The very high and high quality woodlands are fragmented remnants of what was once a more widely distributed woodland cover. Although of high quality, the woodlands have been heavily managed, and often contain a proportion of non-native tree species from past planting. The tree species component is not an overly important issue, it is more important to continue 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. High quality 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 vital that we try to maintain the landscape structural framework in a way that will provide a range of habitats to protect the biological diversity of Edinburgh, Lothians, and Borders.

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.

Three classes of woodland quality have been used in the study. We have deliberately set the standard high for assessing biodiversity quality. The assumption is founded on the premise that excellent quality woodlands 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 each of the 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, 'low quality' ancient 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 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. Cleuch 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 east to west dispersal, which may be achieved by improving linkage across the central belt.

Improvements in data quality, e.g. 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 datasets to be incorporated. For example, the Borders contains approximately 20% of the species rich hedgerows in Scotland (Anon. 2001). Mapping these

FINAL REPORT

areas would allow further analyses to determine whether such landcover types could be used as surrogate habitat for broadleaved specialists.

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 landcover 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).

The development last century, and the 19th century, of the mining villages in the Lothians, occurred at a similar rate, scale and extent to the current wave of urban expansion. The Lothians have numerous examples of housing that sit in an incongruous way within the landscape. Usually, because little attempt has been made to link the urban setting in the landscape. In many areas, and certainly in the Lothians 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

FINAL REPORT

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:

- **Maintaining, enhancing and expanding in area the conservation value of woodlands** – The analyses have demonstrated the importance of consolidating, buffering, and connecting the highly fragmented woodlands of the Regions, particularly on previously wooded ancient woodland sites. 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.
- **Exclusion of grazing in woodlands** should be encouraged, as this will increase the biodiversity value of woodlands by allowing the understory to regenerate. This is particularly important on ancient woodland sites where the strategy would allow an increase in the number of ancient broadleaved woodland nodes, increasing overall network extent and connectivity.
- **To enhance the social and environmental value of woodlands and develop public appreciation, understanding, and participation of local woods** – Use of the woodlands in and around communities analysis will help identify where the criteria for public use of woodlands cannot be met. It also provides suggestions on how woodlands should be transformed to open up access.
- **To protect woodland from unsympathetic development through the robust use of statutory instruments and the development control process** – Core development areas provide opportunities to accommodate woodland in a way that will enhance sustainable development, either in: maintaining the functional connectivity of high quality ancient woodland networks; providing woodlands in and around existing as well as new communities, or both.

The protection of all of the high quality woodland remaining in the landscape is crucial. Without these remaining patches, the source of woodland biodiversity will disappear in the landscape. The high quality woodlands are the reservoir, the 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. Research has shown that an edge effect occurs within a distance of 2 tree heights from the edge of woodland (50 m) (Murica 1995). The buffered expansion of existing high quality woodland with new woodland, by planting or natural regeneration, is the best way of protecting the existing woodland biodiversity.

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). In planning the opportunities for woodland in core development areas, these issues should be considered.

FINAL REPORT

5. Recommendations

5.1. Data quality

- This desk study has only made use of digital spatial datasets, 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.

5.2. Woodland biodiversity protection

- All woodlands, but particularly high quality woodland should be expanded by planting contiguous patches as the majority of woodlands in Lothians and Borders 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.
- All high quality 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.

5.3. Woodland management

- Woodlands containing high quality 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.
- Woodlands occurring on ancient woodland sites, but not indicated as high/good quality should be actively managed to improve the quality of the woodland. Steps taken may include livestock exclusion, deer management or removal of exotic species.
- Areas indicated by the ancient woodland inventory as having had ancient or long-established woodland; where woodland no longer exists, or another woodland type is now present (conifer plantation), and which still have 4 or more ancient woodland indicators species present, should be targeted for restoration.

5.4. Woodland expansion

- Tree species planted should be suited to the habitat type, e.g. native broadleaved species to be selected for high quality broadleaved networks. Use ESC (Ray 2001) to assess site types and inform species choice.
- Those woodlands designated as having lower quality biodiversity quality broadleaved woodland compartments should be designated 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 higher quality broadleaved woodland categories. Management should concentrate on approaches that maintain and enhance the appropriate woodland ground flora (see NVC for details).
- High quality broadleaved, mixed 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 barriers to grey squirrel incursions around red squirrel reserves.

FINAL REPORT

5.5. 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.

5.6. 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 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.

FINAL REPORT

References

- Anon. (2001) *Scottish Borders Local Biodiversity Action Plan*. Scottish Borders Council. 44pp
- Anon. (2004) *Edinburgh and the Lothians Structure Plan 2015*. Edinburgh, East Lothian, Midlothian & West Lothian Councils.
- Anon. (2005) *WIAT: Woodlands in and Around Towns*. Forestry Commission and Scottish Executive, Edinburgh, Scotland.
- Anon (2006) *Draft Scottish Forestry Strategy 2006: Forest for Scotland - The Scottish Forestry Strategy*. Forestry Commission Scotland, Scottish Executive, Edinburgh. 70 pp.
- Farina, A. (1998) *Principles and Methods in Landscape Ecology*, Chapman and Hall.
- Gergel, S. E., and Turner, M. G. (2002). *Learning Landscape Ecology: A practical Guide to Concepts and Techniques*, Springer.
- Grieve, Y., Sing, L., Ray, D., Moseley, D. (2006) *Forest Habitat Networks*, Broadleaved Woodland Specialist Network for SW Scotland (Draft report March 2006). 25pp
- Humphrey, J., Watts, K., McCracken, D., Shepherd, N., Sing, L., Poulson, L. and Ray, D. (2005) *A Review of Approaches to Developing Lowland Habitat Networks in Scotland. Contract report to Scottish Natural Heritage, Contract AB (02AA102/2)040549*.
- MLURI (1993) *The Land Cover of Scotland 1988: Final Report. A report to the Scottish Office Environment Department*. Macaulay Land Use Research Institute, Aberdeen. 81 pp.
- Moseley, D.G., Sing, L. and Ray, D. (2005) *Forest Habitat Networks Scotland - Highland Conservancy Report September 2005. (Draft Report 220905)*. 32pp.
- Murcia, C. (1995) Edge effects in fragmented forests: implications for conservation. *Trends in Ecology and Evolution*. 10, 58-62.
- Peterken, G. F. (2000) "Identifying ancient woodland using vascular plant indicators." *British Wildlife*, 11, 153-158.
- Pyatt, D. G., Ray, D., and Fletcher, J. (2001) *An Ecological Site Classification for Forestry in Great Britain :Bulletin 124*, Forestry Commission, Edinburgh.
- Ray, D. (2001) *Ecological Site Classification Decision Support System V1.7*, Forestry Commission - Edinburgh.
- Ray, D., Sing., Humphrey, J. and Watts, K. (2005) *Forest Habitat Networks Scotland – Project Progress Report March 2005*, 32pp.
- Rose, F. (1999) "Indicators of ancient woodland: the use of vascular plants in evaluating ancient woods for nature conservation." *British Wildlife*, 10, 241-251.
- Scottish Executive (1999). National Planning Policy Guideline (NPPG) 14. <http://www.scotland.gov.uk/Publications/1999/01/nppg14>
- Scottish Executive (2003) Planning Advice Note: PAN 65: Planning and Open Space.
- Sing, L. (2005) Report on forest habitat networks across Scotland, Forest Research Internal Project Report March 2005. 21pp.
- Smith, S., and Gilbert, J. (2003) "National Inventory of Woodlands and Trees." Forestry Commission, Edinburgh.
- The Woodland Trust. (2004) *Space for People: Targeting action for woodland access*. <http://www.woodland-trust.org.uk/publications> 47 pp.
- Watts, K., Humphrey, J., Griffiths, M., Quine, C., and Ray, D. (2005) "Evaluating Biodiversity in Fragmented Landscapes: Principles." 77, Forestry Commission, Edinburgh.
- Worrell, R., Taylor, C., and Spittal, J. (2003) "Highland Perthshire Forest Habitat Network." *Scottish Forestry*, 57(3), 151-157.

FINAL REPORT

Appendix 1. Metadata for designating woodland type.

Rules for woodland designation and codes assigned.

High quality broadleaved woodland

SSNWI woodlands identified by expert as high quality (1131)
SSNWI \geq 80% broadleaved associated with 8 or more ancient woodland indicators. (1134)
NIWT broadleaved associated with 8 or more ancient woodland indicators. (1136)
Phase 1 broadleaved associated with 8 or more ancient woodland indicators. (1138)
SFGS, WGS, or Fplan associated with 8 or more ancient woodland indicators. (1147)

Good quality broadleaved woodland

SSNWI and NIWT woodlands identified by expert as good quality (1132)
SSNWI \geq 80% broadleaved associated with 4 to 7 ancient woodland indicators. (1135)
NIWT broadleaved associated with 4 to 7 ancient woodland indicators. (1137)
Phase 1 broadleaved associated with 4 to 7 ancient woodland indicators. (1139)
SFGS, WGS, or Fplan associated with 4 to 7 ancient woodland indicators. (1148)

Poor quality or undesignated ancient broadleaved woodland

SSNWI and NIWT woodlands identified by expert as average quality (1133)

Broadleaved woodland on ancient woodland sites

PAWS, LEPO, ASNW that intersect with broadleaved woodland
SSNWI \geq 80% broadleaved clipped to the Ancient Woodland Inventory (1119)
NIWT broadleaved clipped to the Ancient Woodland Inventory (1119)
SFGS, WGS, Fplan \geq 80% broadleaved on ancient woodland site 1151
SFGS, WGS, Fplan $<$ 80% broadleaved on ancient woodland site 1153

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, WGS, Fplan \geq 80% broadleaved not on ancient woodland site 1152
Sfgs, WGS, Fplan $<$ 80% broadleaved not on ancient woodland site 1154

Designated ancient mixed woodland

SSNWI Mixed woodland associated with 8 or more ancient woodland indicators. (1141)
SSNWI Mixed woodland associated with 4 to 7 ancient woodland indicators. (1142)
NIWT Mixed woodland associated with 8 or more ancient woodland indicators. (1143)
NIWT Mixed woodland associated with 4 to 7 ancient woodland indicators. (1144)
Phase1 Mixed woodland associated with 8 or more ancient woodland indicators. (1145)
Phase1 Mixed woodland associated with 4 to 7 ancient woodland indicators. (1146)

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

FINAL REPORT

Data hierarchy

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

Expert qualified data
Sites with at least 8 ancient woodland indicators
Sites with 4 to 7 ancient woodland indicators
Sites clipped to Ancient woodland inventory sites
Phase 1
SSNWI
NIWT
SFGS
WGS3
Fplan
SSNWI <10% canopy cover
SSNWI Lowland farm/parkland
SSNWI Upland farm/parkland
LCS88
LCM2000

FINAL REPORT

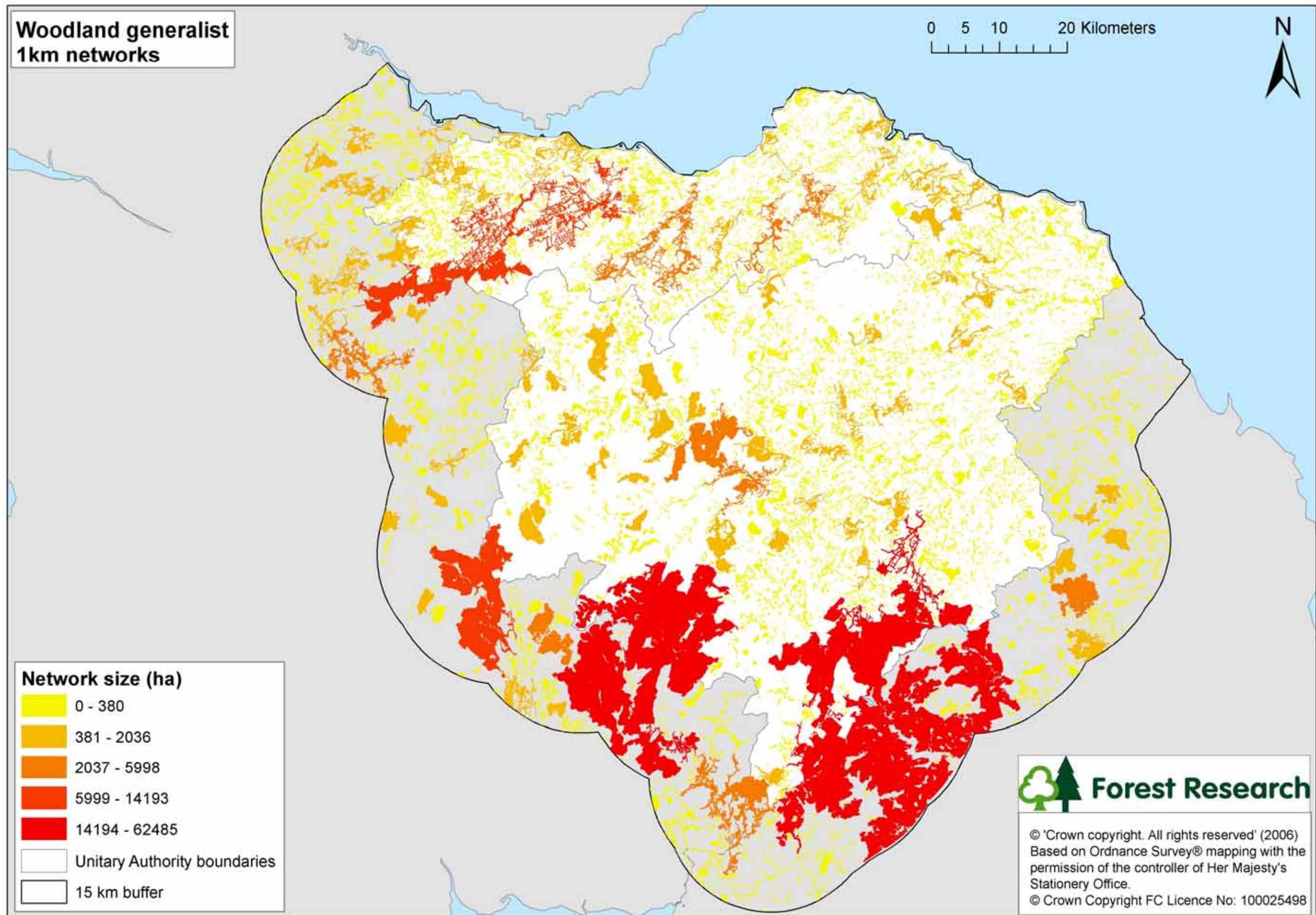
Appendix 2. Example Species of Wood and Scrub in the Lothians and/or Borders.

Species	Common name	Habitat requirements	Dispersal ability	Area requirement	Woodland Specialist or Generalist
Vascular plants					
<i>Adoxa moschatellina</i>	Moschatel	Woodland	low	small	G
<i>Anemone nemoralis</i>	Wood Anemone	Woodland	low	small	S
<i>Hyacinthoides non-scripta</i>	Bluebell	Broadleaf woodland	low	small	G
<i>Melampyrum pratense</i>	Common Cow-wheat	Open woodland	low	small	S
<i>Mercurialis perennis</i>	Dog's mercury	Broadleaf woodland	low	small	G
<i>Scirpus sylvaticus</i>	Wood Club-rush	Woodland	low	small	G
Lichens/fungi/liverworts/mosses					
<i>Amanita submembranacea</i>	a fungus	Woodland	low	small	G
<i>Lobaria pulmonaria</i>	Tree lungwort	Established broadleaved woodland, particularly oak	low	small	G
Insects					
<i>Acrotrichis lucidula</i>	a featherwing beetle	Wet moss by spring water seepages and trickles in woodland. Also found in fens, in Alder carr and other damp places.	medium	small	G
<i>Curculio villosus</i>	a weevil	Broadleaved woodland - A parasite of oak gall wasps	medium	medium	S
<i>Dicrostema gracilicornis</i>	a sawfly	Larva on <i>Adoxa moschatellina</i>	low	small	S
<i>Lampronia fuscata</i>	a longhorn moth	Ancient birchwood on peat with a continuous history of regeneration (trees < 10 years old)	medium	medium	S
<i>Limnophila verralli</i>	a cranefly	Near small streams, usually in the shade of alders. Larvae aquatic.	medium	small	S
<i>Limonia trivittata</i>	a cranefly	Wet woodland on calcareous soils, especially near rivers.	medium	small	S
<i>Luperus flavipes</i>	a leaf beetle	Broadleaved woodland (BLW), parkland, scrub, heath and disused railway lines.	medium	small	G
<i>Stiroma bicarinata</i>	a planthopper	Vegetation in woodland.	low	small	S
<i>Tipula pseudovariipennis</i>	a cranefly	Mainly calcareous woods.	medium	small	S
Birds					
<i>Asio otus</i>	Long-eared Owl	Woodland and neighboring open country	high	large	S
<i>Muscicapa striata</i>	Spotted Flycatcher	Woodland, broad-leaved & mixed	high	medium	G
<i>Parus palustris</i>	Marsh Tit	Deciduous woodland, especially extensive beech and oakwoods. Also orchards, mature gardens & parkland.	high	medium	G
<i>Passer montanus</i>	Tree Sparrow	Tree-lines	high	medium	G
<i>Picus viridis</i>	Green Woodpecker	Open deciduous woodland	high	medium	G

FINAL REPORT

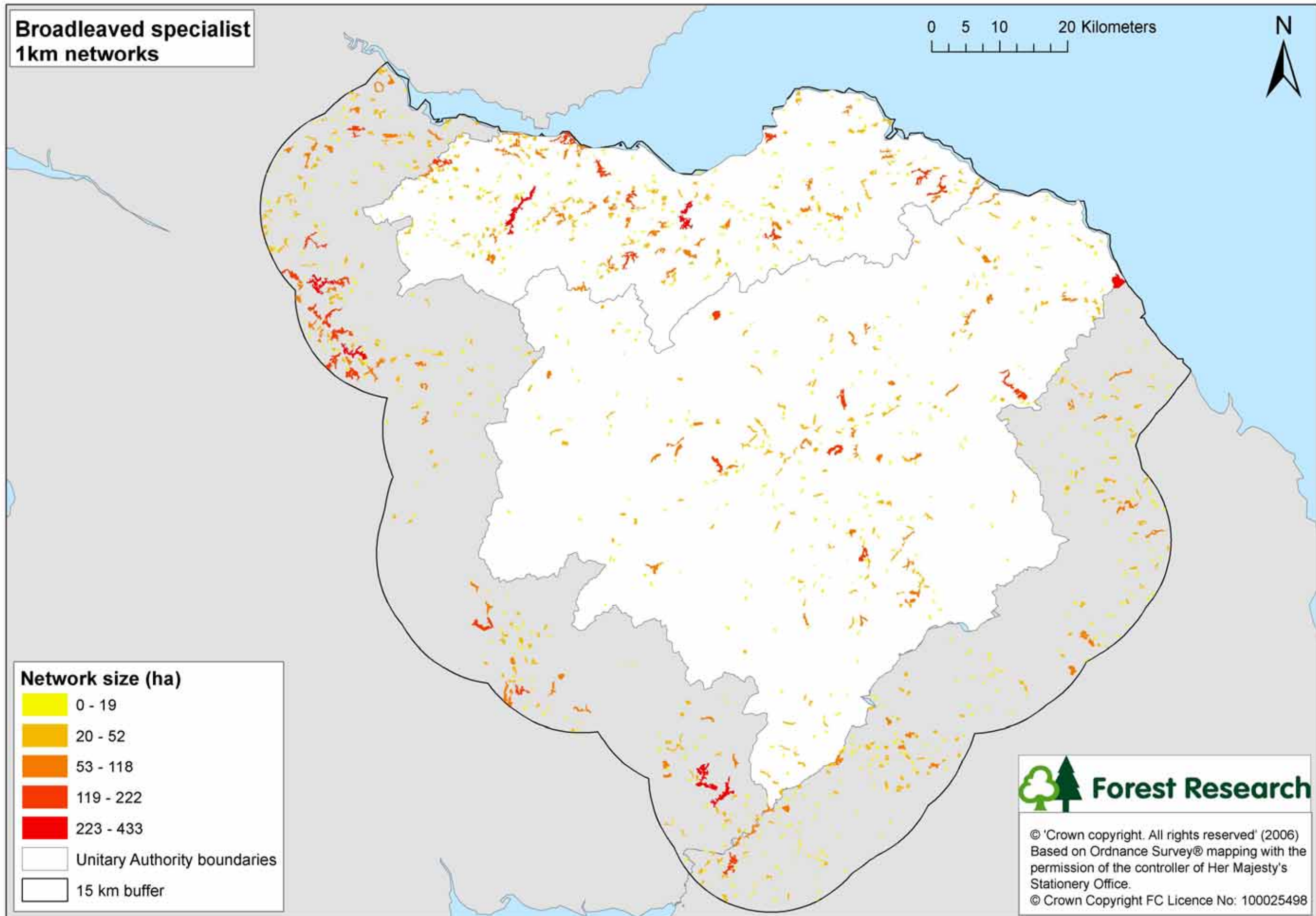
<i>Pyrrhula pyrrhula</i>	Bullfinch	woodland, broad-leaved & mixed	high	medium	G
<i>Sitta europaea</i>	Nuthatch	Mature deciduous woods, especially large oakwoods, wooded parks and gardens	high	medium	G
<i>Tetrao tetrix</i>	Black Grouse	Woodland edge	high	medium	G
<i>Turdus philomelos</i>	Song Thrush	Woodland, broad-leaved & mixed	high	medium	G
Mammals					
<i>Meles meles</i>	Badger	Mostly lowland, lightly wooded countryside. Setts most often in woods and copses, hedgerow and scrub	medium	medium	G
<i>Sciurus vulgaris</i>	Red Squirrel	Mainly large blocks (>50ha) of mature coniferous forest, particularly Scots Pine	medium	medium	G

FINAL REPORT



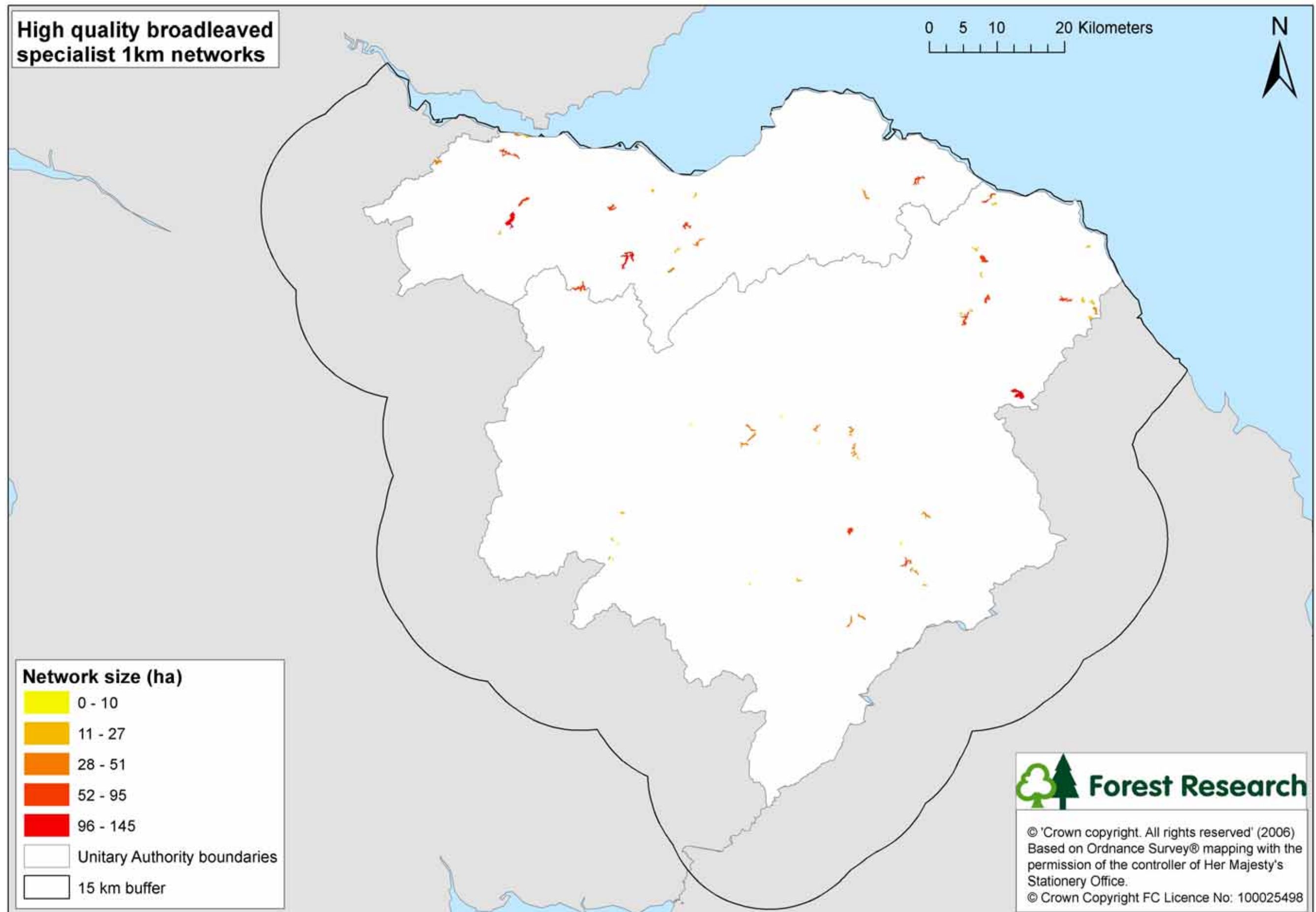
Appendix 3. Woodland generalist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.

FINAL REPORT



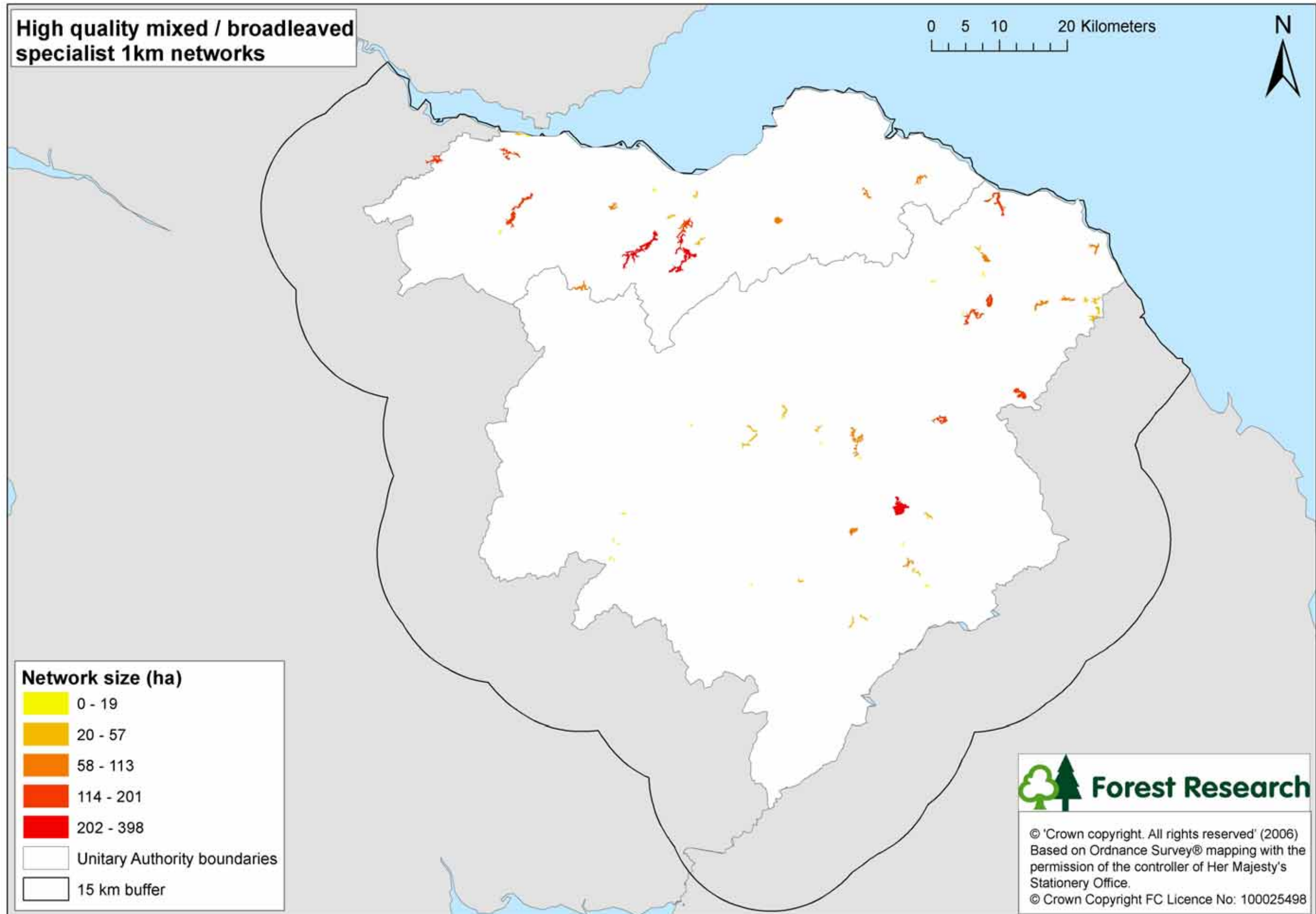
Appendix 4. Broadleaved specialist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.

FINAL REPORT



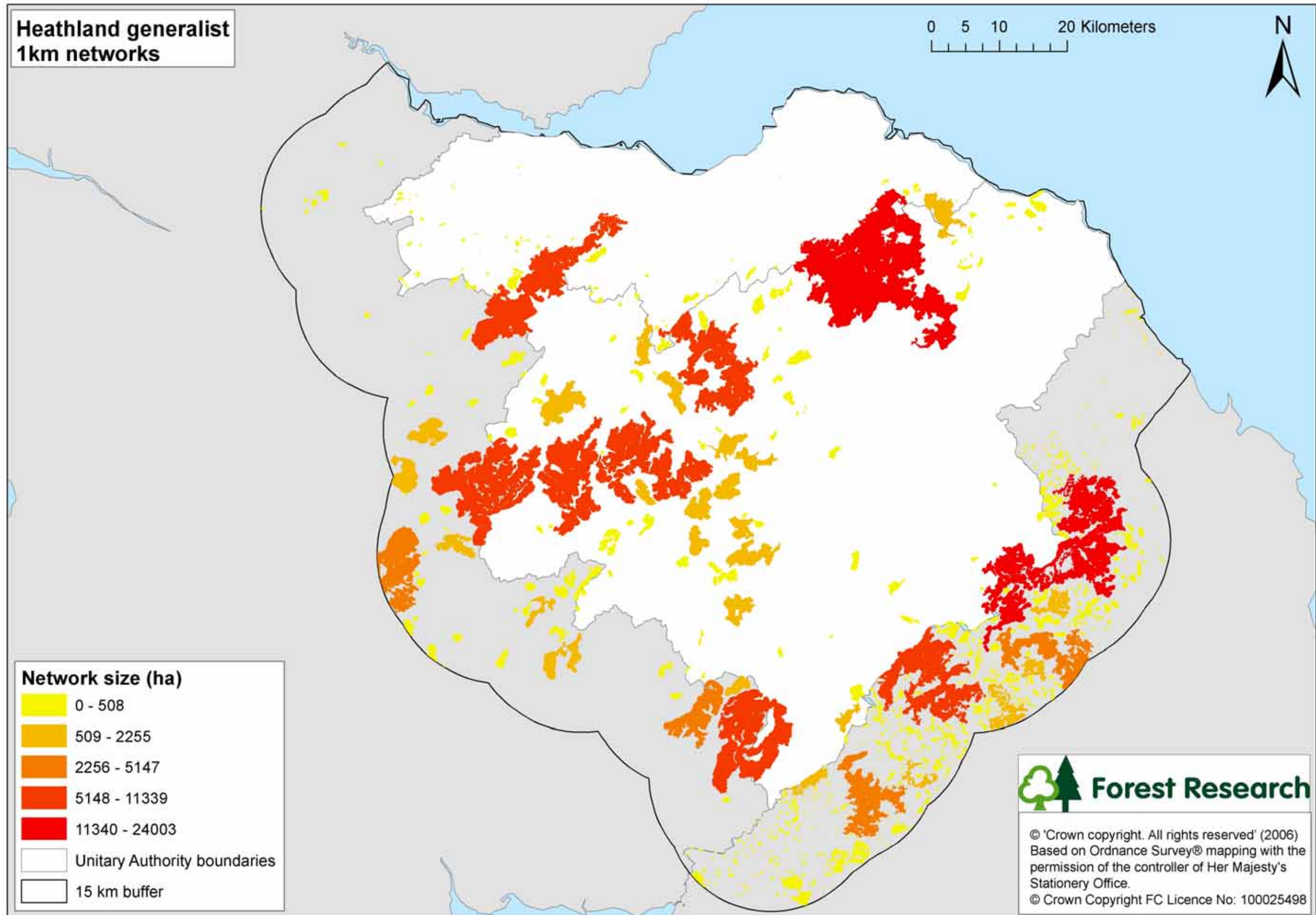
Appendix 5. High quality broadleaved specialist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.

FINAL REPORT



Appendix 6. High quality mixed / broadleaved woodland specialist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.

FINAL REPORT



Appendix 7. Heathland generalist networks organised by network size, assuming a maximum dispersal distance of 1km, in the regions of Edinburgh, Lothians, and Borders.

FINAL REPORT

Appendix 8 Other potential forest habitat network development sites.

Grid reference	Description
NT3814	Alemoor west loch and meadow SSSI. There is only planted conifer in area, but may have potential for restoration
NT122346	Rachan fish pond. A large block of planted conifer, which could potentially be converted.
NT15579	North Esk valley. 6 ancient woodland indicators, but no woodland polygons. Slope woodland restoration may be suitable, but this would not contribute to a network unless extensive planting undertaken.
NT5145	Grid reference Linked to small semi-nat/planted bl woodland to south with over 50% canopy cover. Possibility to rehabilitate & expand, but it is a very small fragment.
NT8147	Probably an area of policy woodland which could form the basis for rehabilitation.
NT8869, NT880699, NT9758, NT9660, NT9661	On Berwickshire coast. No woodland polygons present, but scrub is along these coasts. Although not applicable to the rehabilitation of FHNs, it is worth noting them as potential coastal scrub sites.