FINAL REPORT – January 2007

A Forest Habitat Network for Edinburgh and the Lothians: the contribution of woodlands to promote sustainable development within the regional Structure Plan

Duncan Ray and Darren Moseley
Ecology Division
Forest Research
Northern Research Station
Bush Estate
Midlothian
EH25 9SY
Contact: duncan.ray@forestry.gsi.gov.uk

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Contents

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Executive summary

This report describes a detailed desk study using digital data on a geographic information system (GIS) to identify Forest Habitat Networks in the Edinburgh and Lothian regions of Scotland, and classify them in terms of biodiversity quality. The analyses used a landscape ecology model from the 'BEETLE' (Biological and Environmental Evaluation Tools for Landscape Ecology) suite of tools to assess the spatial position and extent of functional habitat networks.

Networks were defined, for woodland species and open ground species, as contiguous areas containing functionally connected habitat patches in a matrix. A network is defined as a landscape structure through which focal species can disperse freely between numerous habitat patches. The approach uses several data sets in relation to the occurrence of ancient woodland indicator plants to indicate biodiversity quality, to try and better understand woodland biodiversity and the functional connectivity required for its dispersal, viability and resilience.

A hierarchy of woodland networks is presented, with very high quality woodlands forming the key biodiversity areas within broadleaved networks, which in turn are nested within the larger woodland generalist networks. It is suggested that these quality woodlands constitute fragmented remnants of what was once a more widely distributed woodland cover. Although many woodlands have been intensively managed, often containing a proportion of non-native tree species from past planting, the high quality areas form the focus for Core Woodland Areas of high biodiversity.

The Unitary Authorities included in the Regional Structure plan have, through demographic studies, identified a need to increase housing at a rate of 5,000 unit per year up to 2015. The planning authorities have identified that much of the new housing development should be located within a number of Core Development Areas. So withi this study much attention is given to the way the expansion of woodland can be integrated into urban development and incorporated with strategies to increase opportunities for woodland use by communities. The large urban areas within Edinburgh and the Lothians provide an opportunity for the study to focus on the way in which people and communities might link with woodland and forestry issues at the landscape scale, by determining accessibility to woodland according to accepted standards of the Woodland Trust's "Space for People".

The analyses detail the extent of the current networks and indicate that, while the quality networks are quite widely distributed throughout the region, much can be done to improve their functional connectivity. Recommendations to improve networks are given, with detailed examples for consolidating, expanding, and linking forest habitat networks, based on Core Woodland Areas and Core Development Areas identified from Local Plans. The importance of carefully planning woodland expansion in relation to priority open ground habitat is emphasised. Networks for open ground species are explored using an analysis for heathland generalists, enabling woodland expansion to be planned with consideration to the potential interaction with heathland networks.

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 forest habitat networks contain key woodland areas for biodiversity and as such provide the focus for forest habitat network strategies. A common feature of woodlands in the Lothians are the shelterbelts, characterised by very narrow sinuous stands lacking ‘core’ conditions. It is recommended that selected areas should be buffered with additional woodland to greatly increase the functional connectivity of the networks, providing particular benefit to the high quality woodlands, and maintaining the distinctive landscape character of the region.

1. Background

1.1. Sustainable development is a frequently used concept in planning, and was famously articulated in the Brundtland Report (Brundtland 1987) as development which "seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future". Sustainable development is embedded in UK government policy, and linked to this is the notion of sustainable forest management, a policy to which the UK government committed at the second (Helsinki) Ministerial Conference on the Protection of Forests in Europe (MCPFE). This Helsinki accord supports 'the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality, and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national and global levels, and that does not cause damage to other ecosystems'. This is the policy that underpins and drives the need to take a thorough, holistic and spatial 'landscape view' of planning issues at both a strategic and local level. It is only by evaluating spatial landscape scale scenarios, that we can determine the contribution of individual patches of a land cover mosaic to the function and quality of economic, social, and ecological processes.

1.2. Turning, firstly to ecological issues in land use and planning. It is recognised that changes in the type and pattern of land cover over the last century, particularly the intensification of farming over the last fifty years, and the increase in development and infrastructure in recent decades, have been the main drivers of both fragmentation of rich and diverse ecosystems and the general decline in biodiversity over the wider countryside. In landscape ecology terms individual species require 'habitat' or 'habitat patches', and all non-habitat patches of the landscape mosaic are termed the 'matrix'. Fragmentation occurs as a result of two processes: the loss of habitat area, due to land use change; and the increased isolation of remaining habitat patches, due to a general increase in the resistance of the landscape matrix to species movement. The impact is serious for biodiversity, since the ability of species to respond to stress is weakened. Ecosystems begin to fail at the landscape scale, because further disturbance, whether mechanical or climatic, cannot be absorbed within the spatial patch distribution if species are not able to disperse. Consequently, the resilience of species at the landscape scale is reduced. The result of continued stress being applied to a functionally weakened landscape is likely to be local extinctions.

1.3. It has been suggested that the development of ecological networks will be a valuable approach to maintain functional linkages in the landscape, and to help prevent the general biodiversity decline at the landscape scale. At a local level, it has been suggested that areas of high biodiversity may in the longer term be protected by an improvement in the quality of the matrix for generalists. The specialists that are often associated with high biodiversity habitat are, by definition, less able to disperse, and have a more specialised habitat requirement. However efforts to identify, create and maintain ecological networks, will in time benefit specialists, as low frequency high magnitude dispersal events do occur over longer time frames, and the quality of generalist habitat will therefore improve in time.

1.4. The concept of green space (see - http://www.greenspacescotland.org.uk/), or urban greening, has received considerable attention as a means to attract people into their local natural environment by improving community access, recreation opportunities and environmental and ecological quality close to, and within, communities. In terms of the way in which people and communities link with woodland and forestry issues at the landscape scale, this policy has been interpreted as identifying and protecting green space, for people to: retreat from the 'hustle and bustle' of urban life, engage in more activity through walking and cycling, improve their health and well being, and engage in environmental awareness and learning. Through these activities people will begin to identify and value the green space in their neighbourhood. It is expected that this will transform environmental quality in former run down urban areas, with a corresponding increase in the economic value of the area and a stimulation of economic activity and investment (Anon 2005).

1.5. The Edinburgh and the Lothians Structure Plan 2015 (Anon 2004) was approved by Scottish Ministers on 17 June 2004. The structure plan is a 10 year strategic planning vision for the region to maintain sustainable economic and social growth. It has been developed by drawing together information from the spatially explicit detail shown in the Local Plans from the four unitary authorities, and applying this information within a broad framework context to specify the policy issues required to maintain sustainable development of the region. The structure plan and local plans together comprise the statutory development plan which is the basis and foundation for planning applications and the future development in Edinburgh and the Lothians. Land-use planning and transport are key issues at the heart of strategic planning, in which the aspirations and rules are set for determining how and where new development areas will be, how the population distribution will adjust, and how people will move through the region, between the expanding urban areas to places of work and to retail locations.

1.6. Recently, Geographical Information System (GIS) technology has been widely adopted, as a means of dynamically storing and retrieving spatially referenced information. The information held in a spatial database can be represented in the form of maps. However, GIS systems also provide powerful analysis tools, which enable many types of data to be combined and used in models to help provide support for decision making. This study brings together three types of spatial information - the urban distribution and local plans; the types and quality of woodland; and the functional woodland habitat network. The resultant models reveal how woodlands should be considered, protected and expanded within the context of the Edinburgh and the Lothians structure plan, as a pivotal component of sustainable development for the region.

1.7. Central to the modelling approach we have adopted, is a landscape ecology habitat network analysis model. This is one component in a range of methods called Biological and Environmental Evaluation Tools for Landscape Ecology (BEETLE). The approach is well documented (Watts et al. 2005) and has been used to determine the habitat network extent and distribution in the Scottish Borders, West Lothian, Wales, and now across the whole of Scotland (see

www.forestresearch.gov.uk/habitatnetworks). The BEETLE analysis has also been used in this study to determine the functional connectivity of woodland in Edinburgh and the Lothians.

2. Approach and analyses

2.1. Data

All Ordnance Survey® (OS) data used in this study is licenced 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.

2.2. Study area

The region of Edinburgh and the Lothians (Figure 1) covers an area of approximately 171,500 ha with a population of about 778,000 (Table 1). The region is divided into 4 unitary authorities for the purposes of local government: Edinburgh City Council; East Lothian Council; Midlothian Council; and West Lothian Council. Each authority provides local plans that are linked by a regional structure plan. The structure plan has recently been reviewed up to 2015. A review was urgently required as the region has changed demographically due to renewed economic growth, and this in turn has resulted in the housing requirement growing at a rate of 5,000 per annum (Anon 2004a). The structure plan also reviews the infrastructure of the region, highlighting plans to develop new rail and tram links between Edinburgh and the Lothians.

Table 1. Regional population and area statistics. Woodland area is based on a minimum 10% canopy cover, excluding farm and parkland categories in the Scottish Semi-Natural Woodland Inventory.

Local Government Authority	Population 2001 census	Size (ha)	Woodland area (ha)	Woodland area as a percentage of land area
Edinburgh	448,624	26,067	3,288	12.6
East Lothian	90,088	67,024	6,909	10.3
Midlothian	80,941	35,519	4,151	11.7
West Lothian	158,714	42,826	8,088	18.9
Regional Total	778,367	171,509*	22,432*	13.1

*Subject to rounding errors.

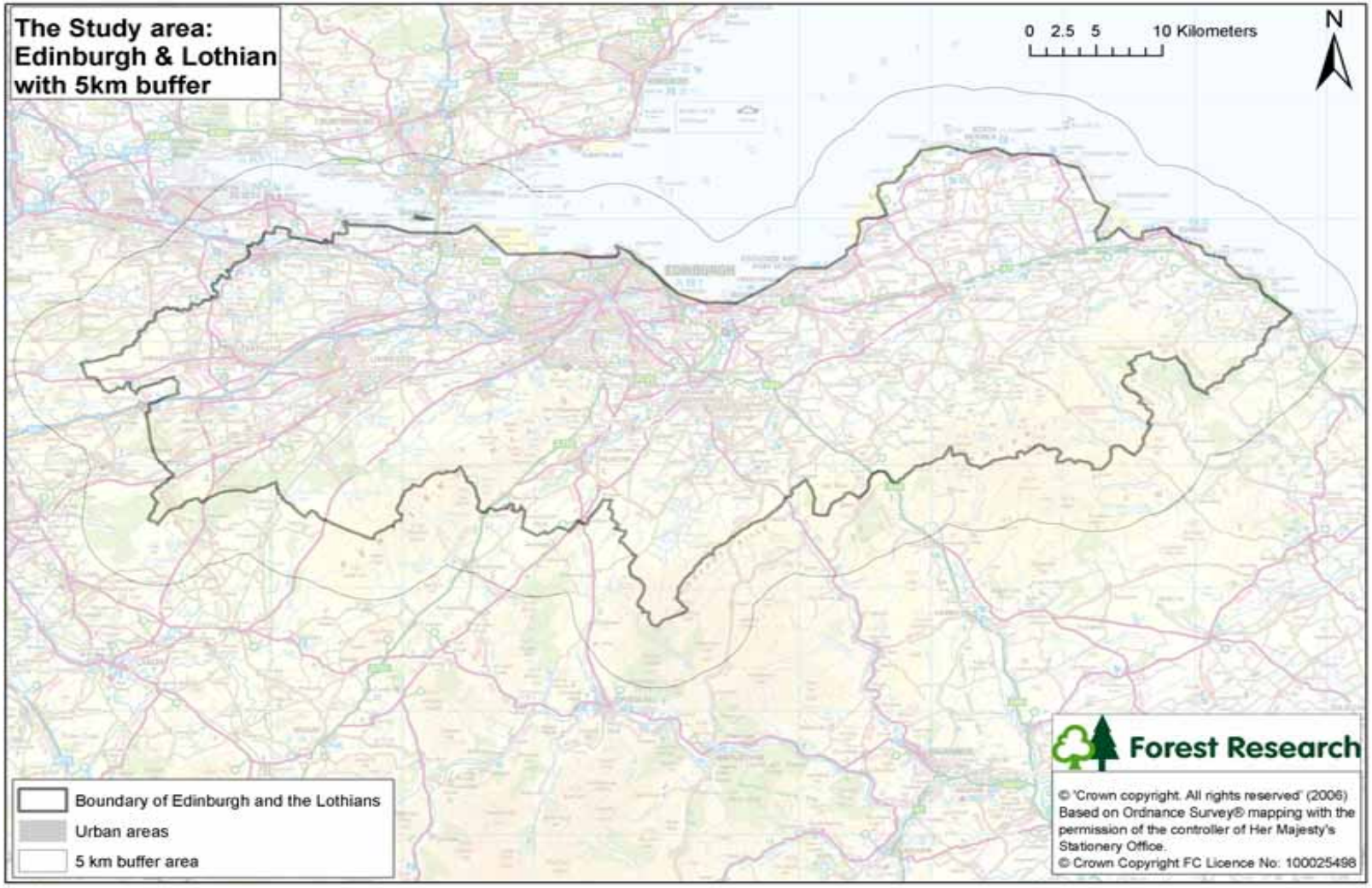

Figure 1. The region of Edinburgh and the Lothians, showing the lowland setting with the Lammermuir Hills, Moorfoot Hills and Pentland Hills to the south, and the urban areas and infrastructure of the region.

The region is bounded by the sea (Firth of Forth) to the north and by hills to the south. It is characterised geologically, with sediments of carboniferous age underlying West Lothian, Edinburgh and Midlothian, and rising to the south and west, with intrusions of basalt forming the Pentland Hills and Arthur's Seat. The carboniferous lithology gives way to greywackes of Ordovician and Silurian age and outcrops of the Old Red Sandstone south of Dunbar in East Lothian.

Although much of the non-developed land is agricultural, the region does have significant areas of woodland, particularly in West Lothian and Midlothian. Much of it is in the form of shelter belts of broadleaved species, a few older estate woodlands, ancient woodland remnants in river gorge settings, and a few more recent conifer plantations.

2.2.1. Land cover type

Woodland types were classified by combining some or all of the resources shown in Table 2 (Table 2 also defines the acronyms and abbreviations).

Table 2. Data resources used in the habitat network study for Edinburgh and the Lothians.

Rank	Resource name	Resolution	Notes
1	Phase 1 habitat data	Mapped at 1:10,000 with 0.25 ha resolution	Surveyed Digitized 2000 Hutcheon Bros.
2	Scottish Semi-Natural Woodland Inventory (SSNWI)	0.1 ha resolution	Interpreted from 1987-88 aerial photograph survey
3	National Inventory of Woodlands and Trees (NIWT)	2 ha minimum patch size	Interpreted from aerial photograph survey and maintained to 2003
4 *	Woodland Grant Scheme 3 (WGS3), Scottish Forestry Grant Scheme (SFGS)	0.1 ha resolution, Qualifying size for schemes is 0.25 ha	Maintained records of species in new woodland areas
5	Land Cover Scotland 1988 (LCS88)	0.1 ha resolution	Interpreted from 1987-88 aerial photograph survey
6	Land Cover Map 2000 (LCM2000)	0.1 ha resolution	Developed from Landsat thermal imagery and a supervised classification technique

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

It should be noted that this study was a desk exercise, and so no new surveys or fieldwork were conducted. Consequently the quality of data is the same as set by the original Phase 1 habitat surveyors in 1996, the interpreted forest types set in 1987-88 for SSNWI (Caledonian Partnership 1999) and NIWT (Smith and Gilbert 2003), and other land cover types not mentioned by the Phase 1 survey have

reverted to the value given by the LCS88 (MLURI 1993). 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.

2.2.2. Woodland quality

This study attempts to assess the biodiversity contribution made by woodlands and heathland at the landscape scale. It was therefore important to establish the biodiversity quality of woodlands within Edinburgh and the Lothians region. The method involved making the assumption that the woodlands of the best quality will contain a greater diversity of woodland organisms, as demonstrated by many 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. 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. Our use of these plants was to indicate specifically, woodlands of high biodiversity quality, not necessarily antiquity.

The presence of one ancient woodland indicator species might occur by chance, or have been introduced, and would therefore not necessarily reflect biodiversity quality. The presence of additional species will strengthen the quality argument (Peterken 2000). As an arbitrary threshold, a minimum of four species was taken to indicate an area of “good quality” in terms of biodiversity; this allows the identification of quality woodlands on less fertile sites which are naturally less species rich. Woodlands with eight or more species were taken to represent “high quality” in terms of biodiversity, and which are naturally species rich. This leads to three standards of woodland quality. Woodland that contained:

- less than 4 ancient woodland indicator plants = low quality woods
- 4 to 7 ancient woodland indicator plants = good quality less fertile woods and moderate quality fertile wood
- 8 or more ancient woodland indicator plants = high quality fertile woodlands

Twenty-one ancient woodland indicator plants were selected, and their point data (Grid Reference) distribution was extracted from the digital data held by the Biological Records Centre for Edinburgh and the Lothians. Since woodland conditions vary from site to site, the list (Table 3) includes species associated with poor to rich soil nutrient regimes, and very moist to dry soil moisture regimes (Pyatt et al. 2001). Table 3 indicates the types of woodland with which the plants are associated.

Table 3. A selection of ancient woodland indicator plants for Edinburgh and the Lothians.

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

*Although beech wood NVC communities are not considered native to Scotland, they do occur as plantations in Edinburgh and the Lothians, and as such may contribute to a forest habitat network.

2.3. Analysis and concepts for modelling habitat networks

2.3.1. 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 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).

2.3.2. Central to the use of BEETLE for evaluating habitat networks is the concept of focal species. In a habitat network analysis, the focal species can be a real or 'virtual' species or a range of species that use the habitat, e.g. woodland. As an example, specific focal species of broadleaved woodland could include a great spotted woodpecker, red squirrel, wood anemone, or 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 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.

2.3.3. The solution requires the adoption of a generic class of focal species, which does not need to consider any species in particular. 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 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 experience 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.

2.3.4. The BEETLE model identifies habitat networks by analysing the ability of the GFS to disperse through each land cover patch surrounding the habitat patches, modified by the weights of resistance for the GFS. As an example, if the GFS maximum dispersal distance is 1000 m, then the actual dispersal of the GFS would be: 1000m through a land cover class with a dispersal resistance weight of 1, but only 100m through a land cover with a dispersal resistance weight of 10, or 50m through a land cover with a 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. 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.

2.3.5. Table 4 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 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. 1-5), whereas land cover types less suitable for dispersal have a higher weighting factor (5-50).

Table 4. The proportion of land cover types in Edinburgh and the Lothians (total area approx 171,000 ha), and examples of the relative dispersal resistance weights attributed to a selection of land cover types for woodland generalists and broadleaved woodland specialists.

	Land Cover Description	Percent area of Edinburgh & Lothians	Woodland generalist	Broadleaved specialist
Forest and woodland	Coniferous woodland	5.0%	0	3
	Mixed woodland	3.3%	0	1.5
	Broadleaved woodland	6.0%	0	0
	Scrub*	0.7%	1	1
	Total	**15.0%****		
Open land	Bracken	0.7%	3	4
	Heath	5.0%	7	8
	Unimproved grassland	3.0%	3	5
	Improved grassland/arable	61.7 %	15	20
	Wetlands	2.0%	15	15
	Bog	3%	25	50
	Total	**75%****		
Developed land and water	Urban/roads/rail	9.3%	50	50
	Inland water	0.6%	50	50
	Total	**10%****		

**scrub considered good surrogate habitat*
***note small rounding errors in total values*

2.3.6. Five separate GFS profiles were developed for the combined data resources for:

- Woodland Generalist GFS – species for which all woodland represents habitat, and also species which 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 Generalist GFS – species for which heathland is habitat, but which may be found in (open) woodlands or glades and rides in woodlands on poor soils. Sites may be recognised by a significant presence of heather. Other examples include: bracken, purple moor-grass, curlew, brown hare.
- Broadleaved specialist GFS – species specifically associated with broadleaved woodland, may be found in mixed woodland to a lesser degree and occasionally in conifer. The term specialist signifies a rather reduced dispersal and a more exacting habitat requirement. Examples include: *Limnophila pulchella* – a cranefly, *Dicrostema gracilicornis* – a sawfly.
- High quality broadleaved woodland specialist GFS – 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 specialist GFS – 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.

2.3.7. Each of the 5 GFS were assessed at 3 dispersal distances of 1000m, 500m, and 250m. This provides the basis for assessing the permeability of the matrix immediately surrounding each GFS, and provides a sensitivity analysis of the model within the landscape. These are explored more fully in the results section.

2.4. Use of urban data

2.4.1. 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.

2.4.2. Following recognition of the value of woodlands to communities, the Woodland Trust has developed the 'Space for People' standards for woodland access for communities and people (Anon 2004b). 'Space for People', 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 500m 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 (8km round-trip) of people's homes.

Forestry Commission Scotland's 'Woodlands In and Around Towns' (WIAT) (Anon 2005) initiative aims to increase the development of urban woodlands close to where people live and work by managing existing woodlands and planting new ones.

2.4.3. 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.

2.4.4. Distance calculations 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 in Scotland. Access issues related to paths, fences, etc., should be dealt with by the local authority through the Local Access Forum.

2.4.5. We assumed that provision of new woodland to meet these criteria should not impinge on open-ground habitat, ecologically valuable brown field land or archaeological sites. The Woodland Trust's access standard suggests that at least one accessible woodland within each distance threshold should be available throughout an urban area, to deal with areas of high population density where usage is likely to be high.

2.5. Planning considerations

Three planning guidance notes also make recommendations on the role and benefit of woodlands in delivering sustainable development.

2.5.1. National Planning Policy Guideline (NPPG) 14: Natural Heritage (Scottish Executive 1999) has particular relevance to Forest Habitat Networks. It recommends that:

- Local Authorities have a responsibility to protect existing woodlands and identify opportunities to extend native woodland cover, particularly where this creates or reinforces links between wooded areas. Ancient and semi-natural woodlands are thought to have the greatest value for nature conservation.
- Indicative Forestry Strategies should be used to identify suitable areas for new forestry and identify environmental sensitivities, which may impose constraints on new planting.
- Opportunities should be taken to secure new woodland planting in development schemes and local authorities have a duty to ensure, whenever appropriate, planning permissions make adequate provision for the preservation or planting of trees.

2.5.2. Planning Advice Note 60 – Planning for Natural Heritage (Scottish Executive 2000) states that the planning and development process can provide important opportunities for improving the environment and achieving landscape, biodiversity, and earth heritage objectives. The note also highlights the importance of open ground habitat considerations when planning woodland expansion.

2.5.3. Planning Advice Note 65 – Planning and Open Space (Scottish Executive 2003) highlights the importance of woodlands in promoting biodiversity, and in the control of air and water pollution. Trees and woodlands also enable the movement of wildlife and people through networks in both urban and rural environments. Trees can also help to soften the impact of new developments, making green and civic spaces more appealing.

3. Results

3.1. Habitat Networks

Five GFS analyses were performed for the region of Edinburgh and the Lothians, using individual profiles and working with a specially prepared spatial database of land cover types and GFS profiles, which had been discussed and agreed by a group of forest ecologists and open habitat ecologists as part of the development of habitat network analysis throughout Scotland (see - www.forestresearch.gov.uk/habitatnetworks).

3.1.1. Woodland quality (in terms of biodiversity) was assessed using ancient woodland indicator plants. Figure 2 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 each unitary authority 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 2 with Figure 3. Figure 3 shows all woodland classified as ancient or long established. There are many more candidate woodlands indicated by virtue of their antiquity than demonstrated by ancient woodland indicator plants in Figure 2. However, additional ancient woodland indicator data or a site survey of candidate woodlands would enable the land cover dataset to be amended.

3.1.2. Three core woodland areas are prominent in West Lothian (Avon Valley, Hopetoun, and Almond Valley). Within the Edinburgh city area there are: 4 woodlands of very high quality, Hermitage of Braid, Colinton Dell, Dreghorn, and Craigmillar Castle; and 9 woodlands of high quality, Nether Liberton (Cameron Toll), Drum at Gilmerton, Merchiston, Riccarton, Balerno, Currie, Clifton Hall, and Newbridge. In Midlothian, there are extensive gorge woodlands of very high quality in the North Esk and South Esk, Eskbank, Redside Burn, Edglaw Reservoir, and Gowkeshill near Gorebridge, forming three prominent core woodland areas centred on the rivers North Esk, South Esk and Gore/Tyne. East Lothian contains 5 very high quality woodlands: Whitecraig, Saltoun, Nunraw, Woodhall, and Hailes Castle. Good quality woods in East Lothian include: Lammermuir Deans woods, Bolton Muir wood, Petersmuir wood, Oxenfoord Castle woods, Railway walk near Ormiston, and Spittal woods. The locations of these woods are summarised in Table 5 and indicated in Figure 4. These woods form high quality components of 17 core woodland areas, centred on: 1) Avon Valley, 2) Hopetoun, 3) Almond Valley, 4) Currie, 5) North Esk, 6) Tyne Water, 7) Saltoun, 8) Bolton Muir wood, 9) Nunraw, 10) Woodhall, 11) Lammermuir Deans, 12) Belvidere wood, 13) Gosforth House, 14) East Linton, 15) South Esk, 16) Craigmillar Castle, and 17) Hermitage of Braid (Table 5, Figure 4).

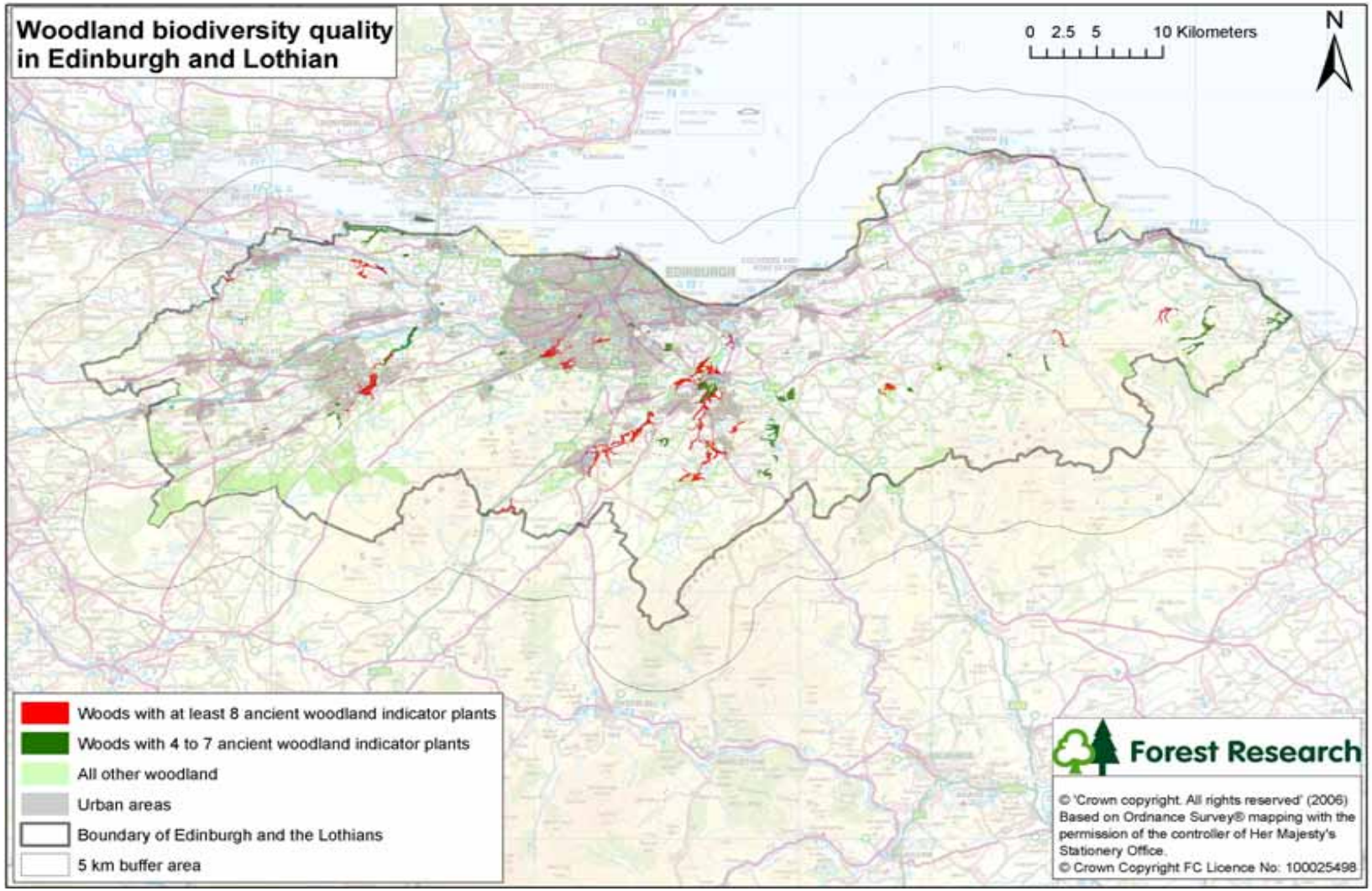

Figure 2. Woodland biodiversity quality, indicated by the number of species of ancient woodland indicator plants occurring in the woodland.

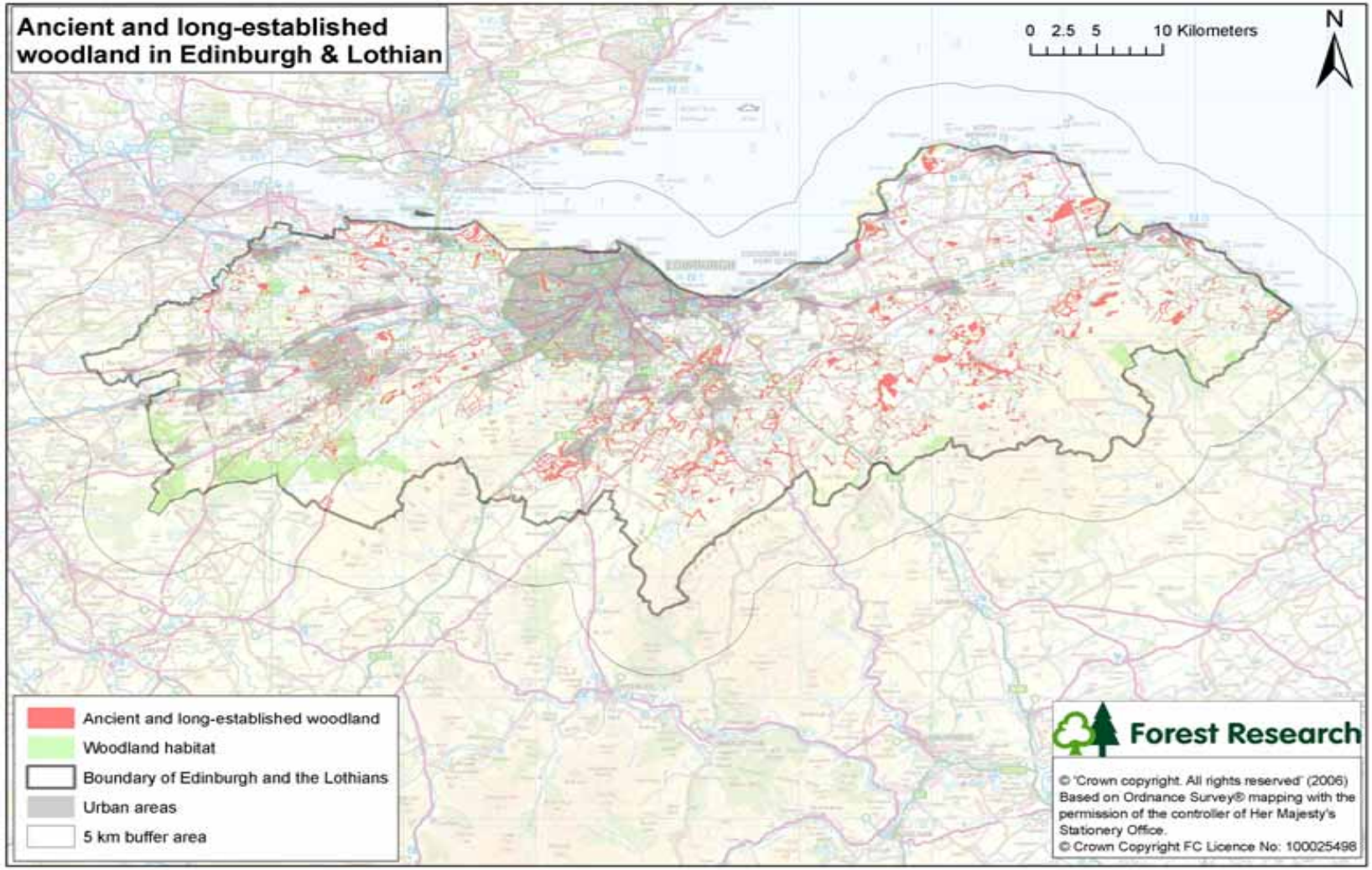

Figure 3. The distribution of ancient and long established woodland in the region of Edinburgh and the Lothians.

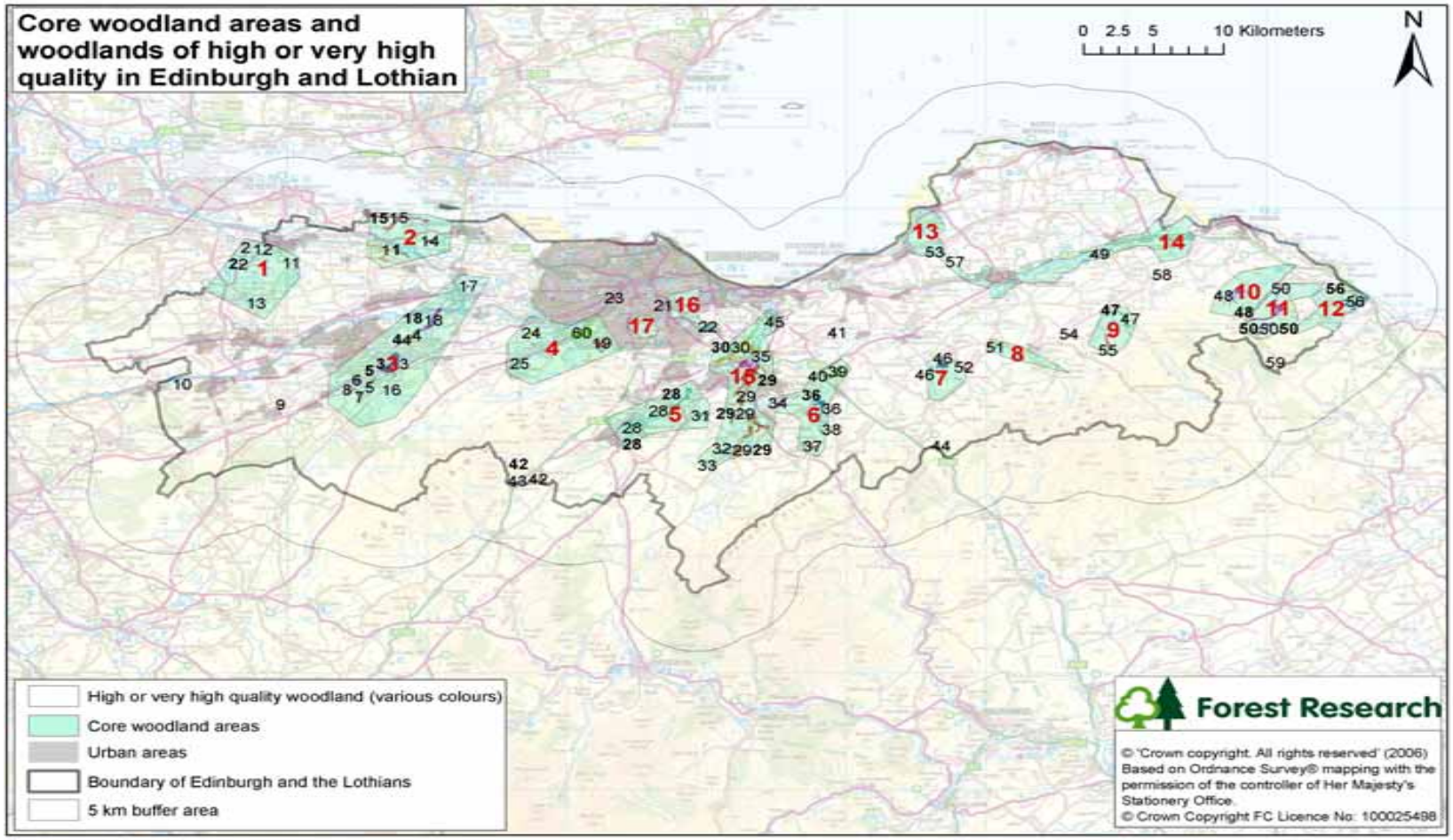

Figure 4. The locations of core woodland areas (individually numbered in red) and very high and high quality woodlands (individually numbered in black) in Edinburgh and Lothian. Woodlands consisting of more than one block are indicated by repeat numbering.

3.1.3. Habitat networks were calculated separately for each of the 5 GFS, and for 3 dispersal distances of: 250m, 500m and 1000m. By overlaying the 500m network onto the 1000m network, and the 250m network onto the 500m network, we can examine the extent of dispersal overlap of larger networks surrounding the smaller dispersal networks. This allows an assessment of the degree of permeability of the matrix (land cover types not classed as habitat) surrounding a woodland generalist network (Figure 5). In areas where there are large differences in the spatial extent of networks representing the dispersal range, the surrounding patches of the landscape matrix are more permeable to woodland species, for example, these might be managed less intensively, or they may be semi-natural open ground patches.

3.1.4. Figure 5 also provides the spatial context for a sensitivity analysis with accompanying metrics in Table 6a. The sensitivity analysis 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 the 1000m dispersal networks compared to 500m networks, but very little difference between the size and distribution of the 500m and 250m networks. This suggests the landscape matrix is generally not very permeable for the dispersal of woodland species.

3.1.5. To graphically illustrate the way in which the BEETLE model was parameterised to express landscape permeability for woodland generalists, broadleaved specialists and heathland generalists, areas of generalised land cover type for the region were used to proportionally divide the charts of Figure 6 a-c). Each chart is colour coded to reflect the relative degree of permeability in classes described as ‘very permeable’ to ‘extreme barrier’. The analysis shows 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 (similar to woodland specialists), 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 ‘slight barrier’ to dispersal, compared to the ‘extreme barrier’ for woodland species in farmland.

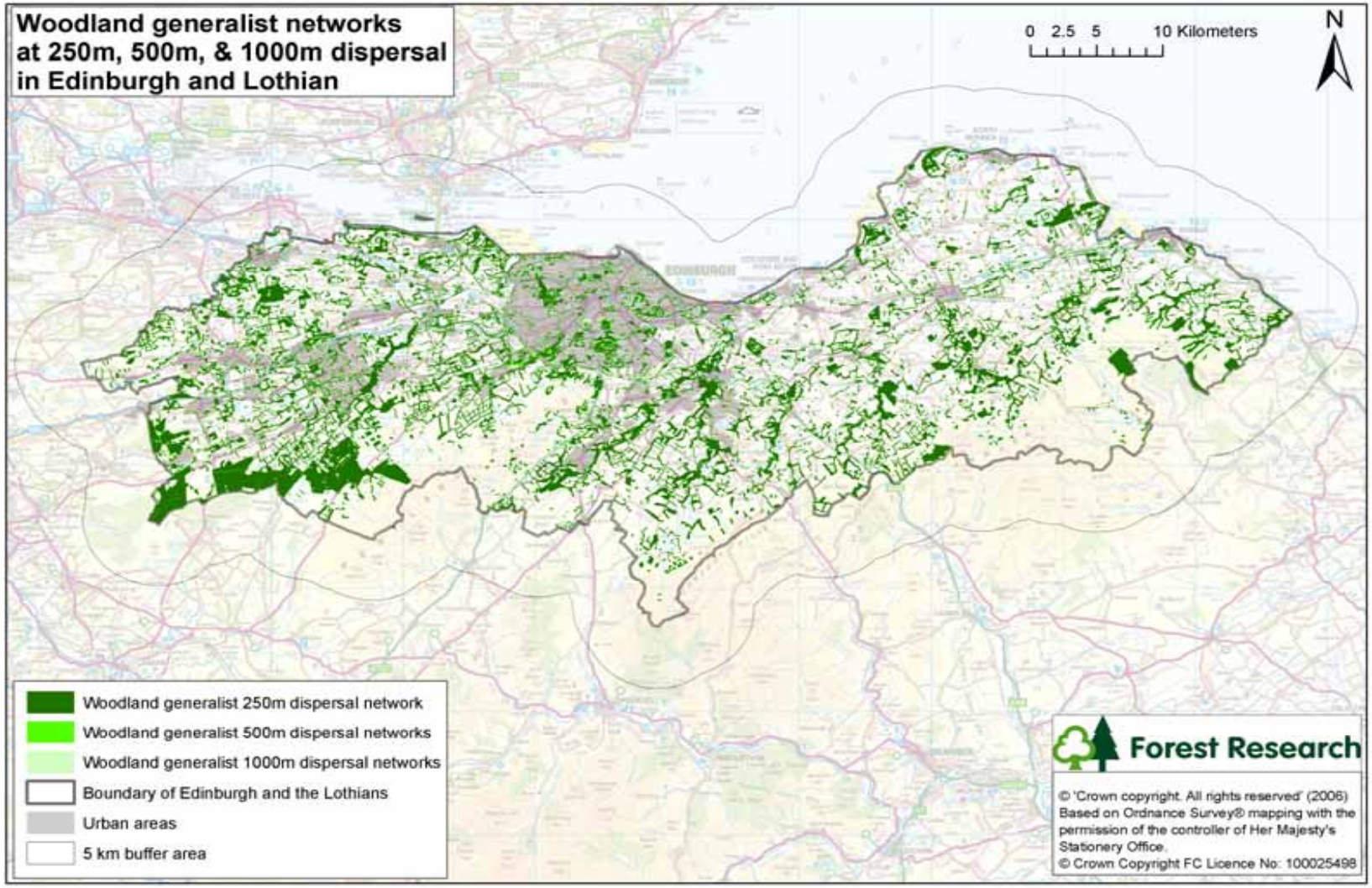

Figure 5. Comparison of habitat networks for woodland generalists capable of dispersing 250m, 500m and 1000m. The networks have been overlaid with the greatest dispersal underneath and the least dispersal network on top.

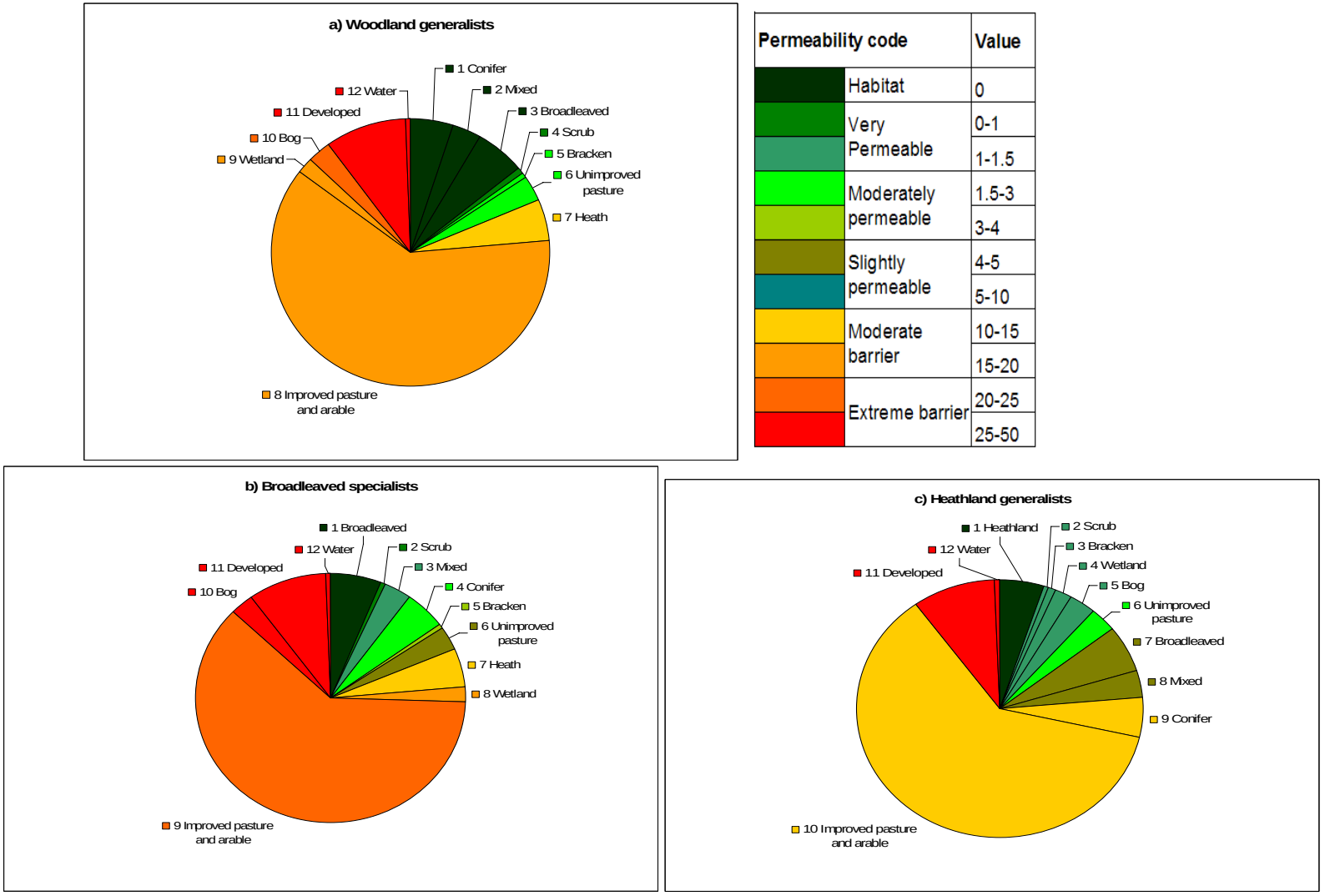

Figure 6. A comparison of the permeability of the matrix of the landscape of Edinburgh and the Lothians to a) Woodland generalists b) Broadleaved specialists and c) Heathland generalists.

Table 5. Very high quality (8 ancient woodland indicator plants or more) and high quality (4-7 ancient woodland indicator plants) core woodland areas in Edinburgh and the Lothians region. The identifying number represents the location of the woodland shown in Figure 4.

Unitary Authority	Woodland name	Grid reference	Quality (VH or H)	Woodland ID	Core Area ID
West Lothian	Philipstoun	NT070763	VH	1	2
	Avon gorge	NS969751	VH	2	1
	Oakbank - Almond	NT076665	VH	3	3
	Mid Calder	NT089690	VH	4	3
	Murieston Water	NT058646	VH	5	3
	Bellsquarry	NT058646	VH	6	3
	Murieston castle	NT051638	H	7	3
	Newpark	NT045643	H	8	3
	Auchenhard	NS995631	H	9	N/A
	Polkemmet Country Park	NS924648	H	10	N/A
	Hillhouse	NT003752	H	11	1
	Woodcockdale	NS982760	H	12	1
	Cathlaw Hill wood	NS979720	H	13	1
	Duddingston (near South Queensferry)	NT102771	H	14	2
	The Binns	NT067793	H	15	2
	Linnhouse Water	NT075665	H	16	3
Edinburgh	Newbridge	NT129732	H	17	3
	Clifton Hall	NT104702	H	18	3
	Dreghorn	NT223683	VH	19	4
	Craigmillar Castle	NT284710	VH	20	16
	Nether Liberton	NT273713	H	21	16
	Gilmerton (Drum)	NT299697	H	22	16
	Merchiston	NT233722	H	23	N/A
	Riccarton	NT174692	H	24	4
	Balerno	NT166664	H	25	4
	Currie	NT188673	H	26	4
	Hermitage of Braid	NT250703	VH	27	17
	Colinton Dell	NT213694	VH	60	4
Midlothian	North Esk (Penicuik-Polton)	NT274627	VH	28	5
	South Esk (Temple-Bonnyrigg)	NT330610	VH	29	16
	Eskbank	NT310670	VH	30	16
	Rosewell	NT298623	H	31	5
	Redside Burn	NT312592	VH	32	16
	Edgelaw Reservoir	NT300582	VH	33	16
	Gowkeshill - Gorebridge	NT351630	VH	34	6
	Dalkeith Park	NT326666	H	35	16
	Vogrie	NT383632	H	36	6
	Borthwick Castle	NT373595	H	37	6
	Loquhariot woods	NT382608	H	38	6
	Preston Hall	NT393659	H	39	6
	Oxenfoord Castle woods	NT386655	H	40	6
	Railway walk Ormiston	NT388692	H	41	N/A
	Newhall	NT179566	VH	42	N/A

Unitary Authority	Woodland name	Grid reference	Quality (VH or H)	Woodland ID	Core Area ID
	Amazondean	NT164565	H	43	N/A
	Linn Dean Water	NT467595	H	44	N/A
East Lothian	Whitecraig	NT347703	VH	45	16
	Saltoun	NT468665	VH	46	7
	Nunraw	NT599704	VH	47	9
	Woodhall	NT677727	VH	48	10
	Hailes Castle	NT576759	VH	49	14
	Lammermuir Deans wood	NT709714	H	50	11
	Bolton Muir wood	NT506680	H	51	8
	Petersmuir wood	NT484662	H	52	7
	Spittal wood	NT466764	H	53	13
	Bara wood	NT560691	H	54	N/A
	Papana Water woods	NT586685	H	55	9
	Dunglass Church	NT762718	H	56	12
	Laverocklaw	NT473753	H	57	13
	Stenton	NT625742	H	58	N/A
	Monynut Edge	NT706667	H	59	N/A

3.1.6. Woodland generalists

The extent and functional connectivity of individual woodland generalist networks is illustrated in Figure 7. The metrics for woodland generalists (Table 6) 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 500m to 1000m. This has the effect of reducing the number of woodland generalist networks (Table 6a) by about 52% while increasing the network area 1.5 times. For this study we have settled on the 1000m dispersal distance, reflecting moderately mobile woodland generalists: woodland birds, fox, badger, and wind-dispersed woodland edge plants.

3.1.7. Woodland specialists

Figure 8 shows 4 distributions of networks for specialists of high quality broadleaved woodland, high quality mixed/broadleaved woodland, other broadleaved woodland and all other woodland. The map provides a spatially referenced index of a range of woodland networks of varying biodiversity value in Edinburgh and the Lothians. In particular, it provides an estimate of the degree of linkage of high quality woodland (core woodland areas) with adjacent woodland of lower quality. It can be used to determine and locate core woodland areas which should be protected and expanded. The maps also show how woodland expansion might seek to link existing structures, to form stepping stones between two or more networks. This will be explored in detail with the plans for the core development areas. Because the matrix is not permeable to woodland specialist species dispersal, Figure 8 tends to re-emphasise the distribution of quality woodlands shown in Figure 2.

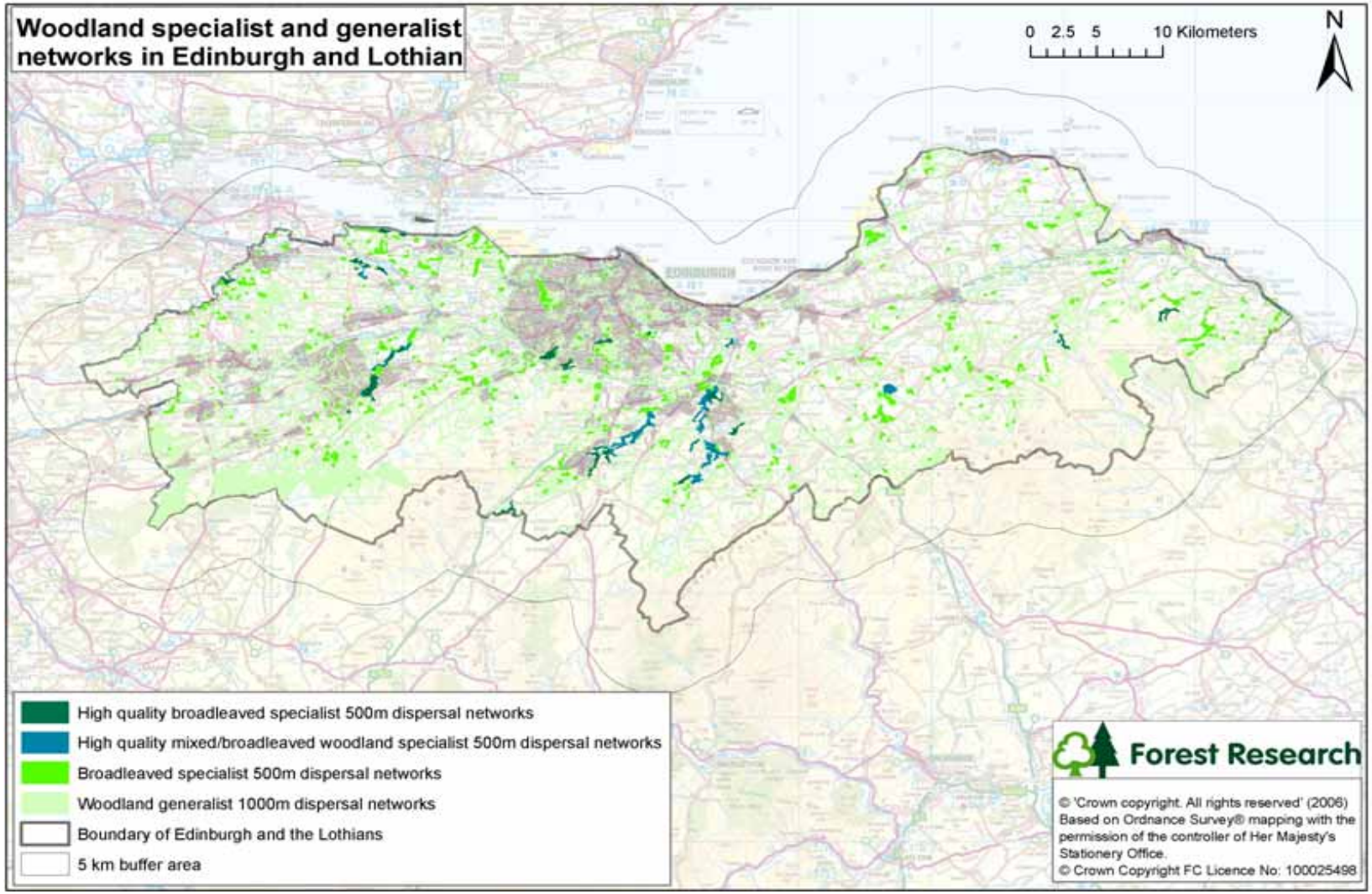

Figure 7. Individual networks for woodland generalists, each network is separately colour coded to show the extent and functional connectivity of large woodland networks.

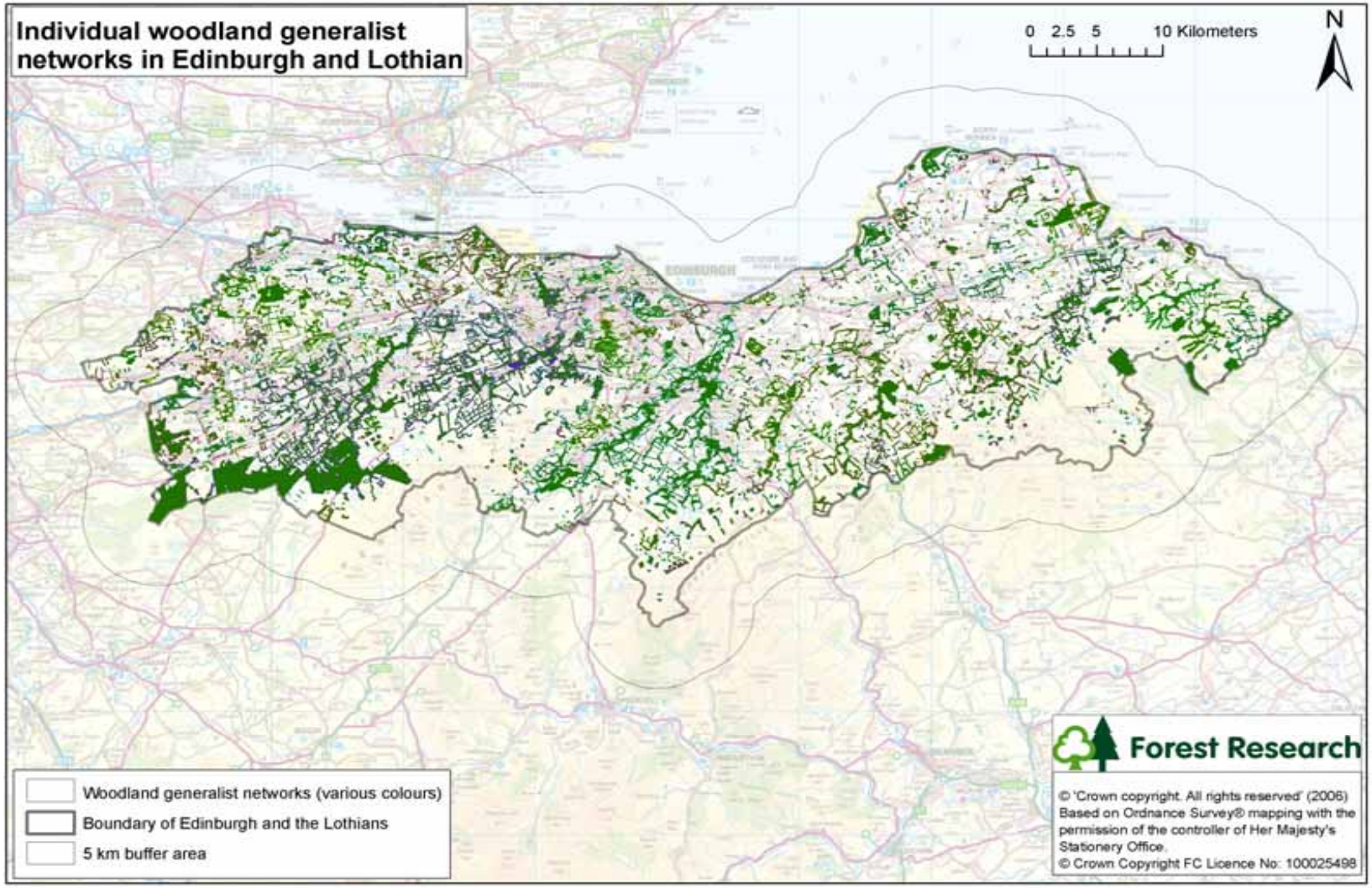

Figure 8. Networks for specialists of high quality broadleaved and mixed woodland combined with other broadleaved specialists and woodland generalists in the region of Edinburgh and the Lothians.

For the purposes of this study we have settled on a dispersal distance of 500m for specialist networks, reflecting less mobile species. The metrics (Table 6b-d) show 417 broadleaved networks covering 5935 ha. Of these, there are 28 high quality mixed/broadleaved woodland networks covering 1591 ha, and 25 high quality broadleaved networks covering 790 ha. The figures show that broadleaved woodland blocks tend to be smaller than mixed woodland blocks. The 250m to 1000m dispersal sensitivity analysis shows that the number of high quality mixed/broadleaved woodland specialist networks is reduced by 60% with a 1.7 times increase in network size (Table 6c). Networks of this type constitute small sections of the woodland generalist network, they are slightly less fragmented than, for example, high quality broadleaved specialist networks (reduction in networks - 44%, size increase 2 times), and can be more easily connected through existing woodland corridors. The woodland specialist sensitivity analysis does not show the disproportionate reduction in network numbers between 500m and 1000m dispersal, coupled with an increase in mean network size, that was apparent for woodland generalists. The matrix is much less permeable to specialists than generalists.

3.1.8. Heathland generalists

To show that networks can be calculated for open ground habitats, we include an assessment of the Lothians landscape for heathland generalists (Figure 9). Figure 9 shows clearly the heathland habitat occurring in the Pentland Hills, the edge of the Moorfoot Hills, and particularly the Lammermuir Hills. It also shows the impact of increased permeability of the matrix to heathland specialists compared to woodland species, developed in the BEETLE model, as the network is clearly a more extensive area surrounding the habitat described by the land cover data.

This matrix permeability is also apparent in the metrics and sensitivity analysis (Table 6d). The number of heathland GFS networks is reduced by 56% when the dispersal distance is increased from 250m to 1000m, while the network area increases by 1.4 times. This is slightly better response to the sensitivity analysis than for woodland generalists (Table 6a).

3.1.9. Priority open habitat

In producing habitat networks, we have analysed land cover permeability (see Section 2.3), with the functional forest habitat networks comprising woodland components in an intimate mixture with elements of open habitat. Whilst the open habitat components are still physically separate from the woodland, it is important to emphasise their location so that they can be fully considered when forest habitat network development is being planned (figure 10).

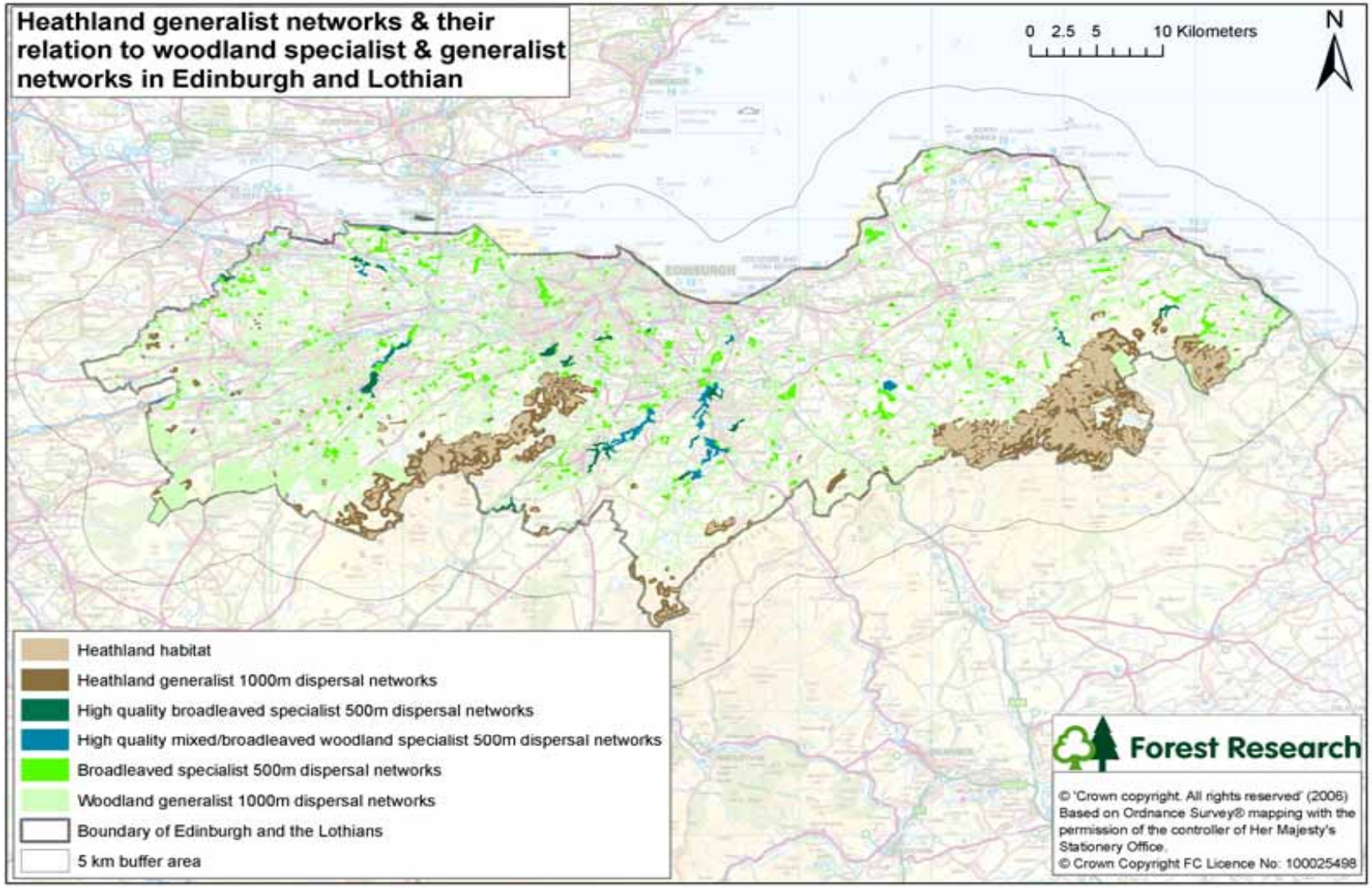

Figure 9. The distribution of networks for heathland generalists and their relationship with woodland networks in the region of Edinburgh and the Lothians.

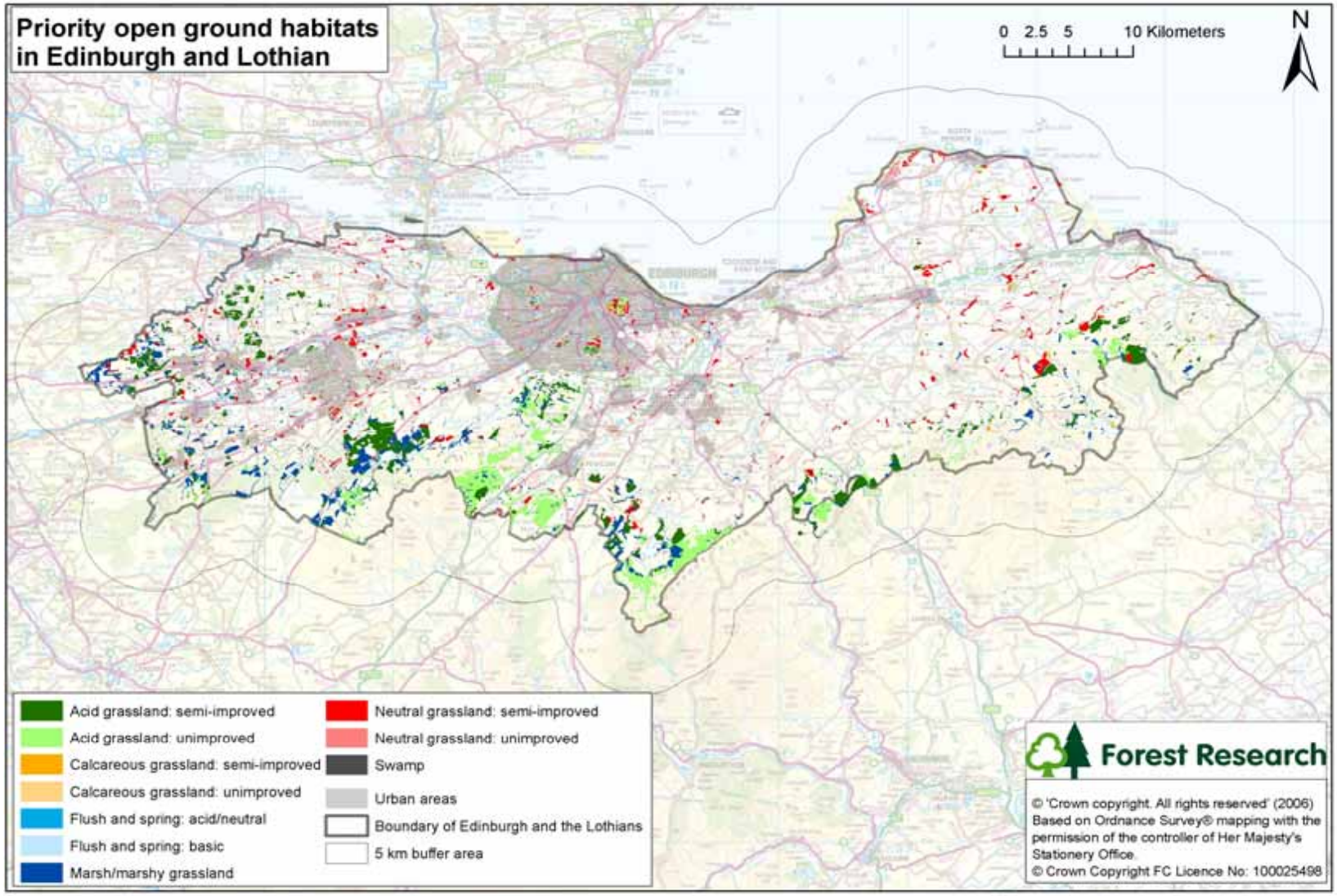

Figure 10. Priority open ground habitats in the region of Edinburgh and the Lothians.

Table 6. Landscape metrics for the five generic focal species analyses covering the region of Edinburgh and the Lothians.

a) Woodland generalist

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	4195	30991	7.4	2871
500	3439	34966	10.2	4159
1000	1980	46146	23.3	10031

b) Broadleaved specialist

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	500	4018	8.0	128
500	417	5935	14.2	328
1000	315	9190	29.2	433

c) High quality mixed/broadleaved woodland specialist

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	50	1236	24.7	156
500	28	1591	56.8	324
1000	20	2110	105.5	398

d) High quality broadleaved specialist

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	36	585	16.3	92
500	25	790	31.6	116
1000	20	1146	57.3	145

e) Heathland generalist

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	210	11179	53.2	6219
500	145	12981	89.5	6973
1000	91	15725	172.8	7732

3.2. Woodlands In and Around Towns

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 to woodland from their homes:

- 2 ha of woodland within 500m
  AND
- 20 ha within 4 km

3.2.1. 2ha woodlands within 500m

Figure 11 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' through the area to the west of Lothian Road as far as Bruntsfield.

To the east of Edinburgh, 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.

3.2.2. 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 12 shows there is a gap in the distribution in north western waterfront of Edinburgh from Meadowbank north to the Port of Leith.

3.3. Woodland habitat creation, networks and development opportunities

The Edinburgh and the Lothians Structure Plan (Anon 2004a) describes 15 core development areas within which local plans are providing land for housing and business as an integral part of the planning strategy for the Lothians.

3.3.1. Edinburgh City Centre (see Figure 13)

Edinburgh city centre does have extensive areas of green space, however there are a few small zones which fail the Space for People woodland standard. Realistically there is very little scope for creating large woodlands within the city.

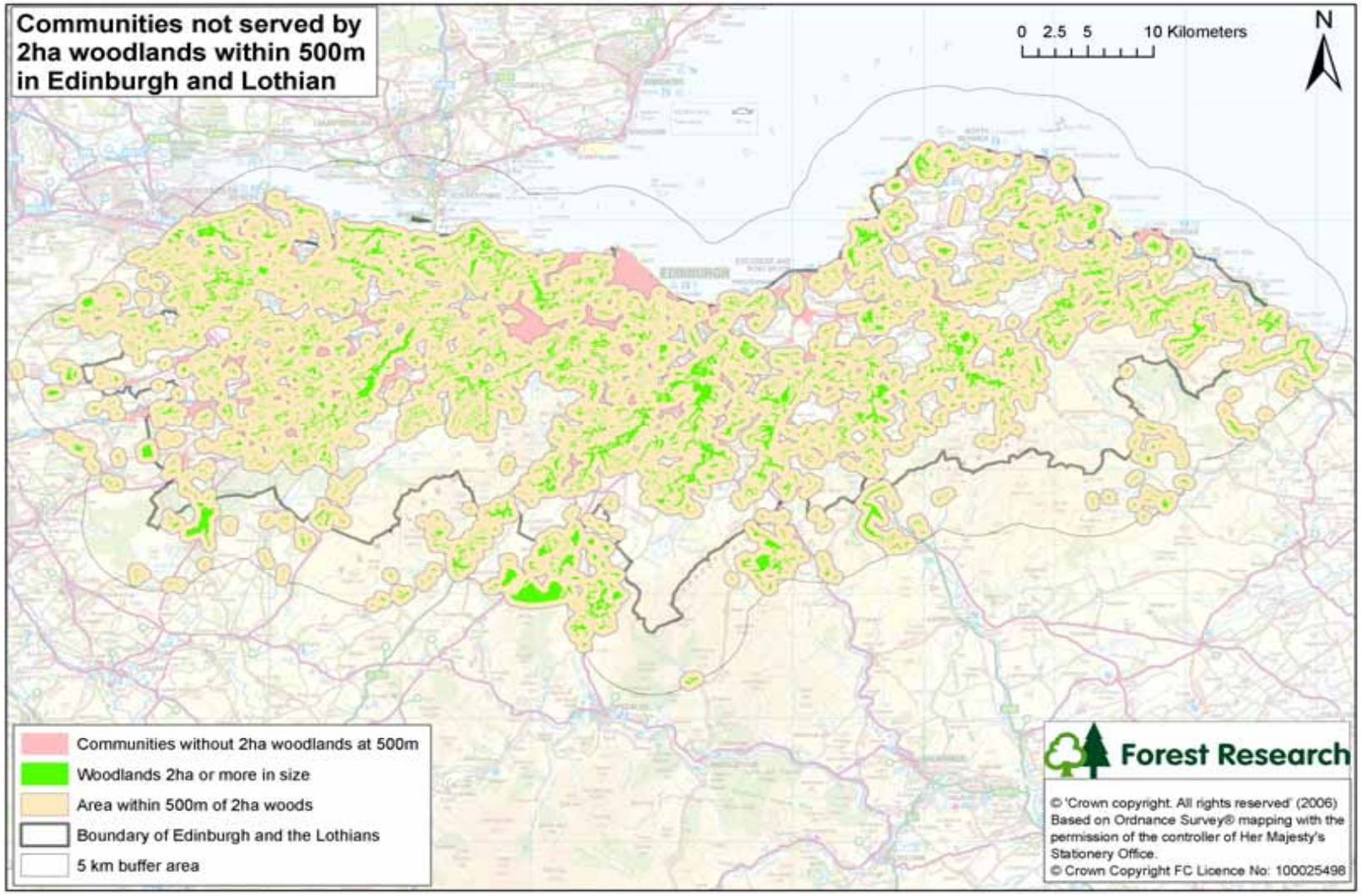

Figure 11. Communities not served by 2ha woodlands within a distance of 500m in the region of Edinburgh and the Lothians.

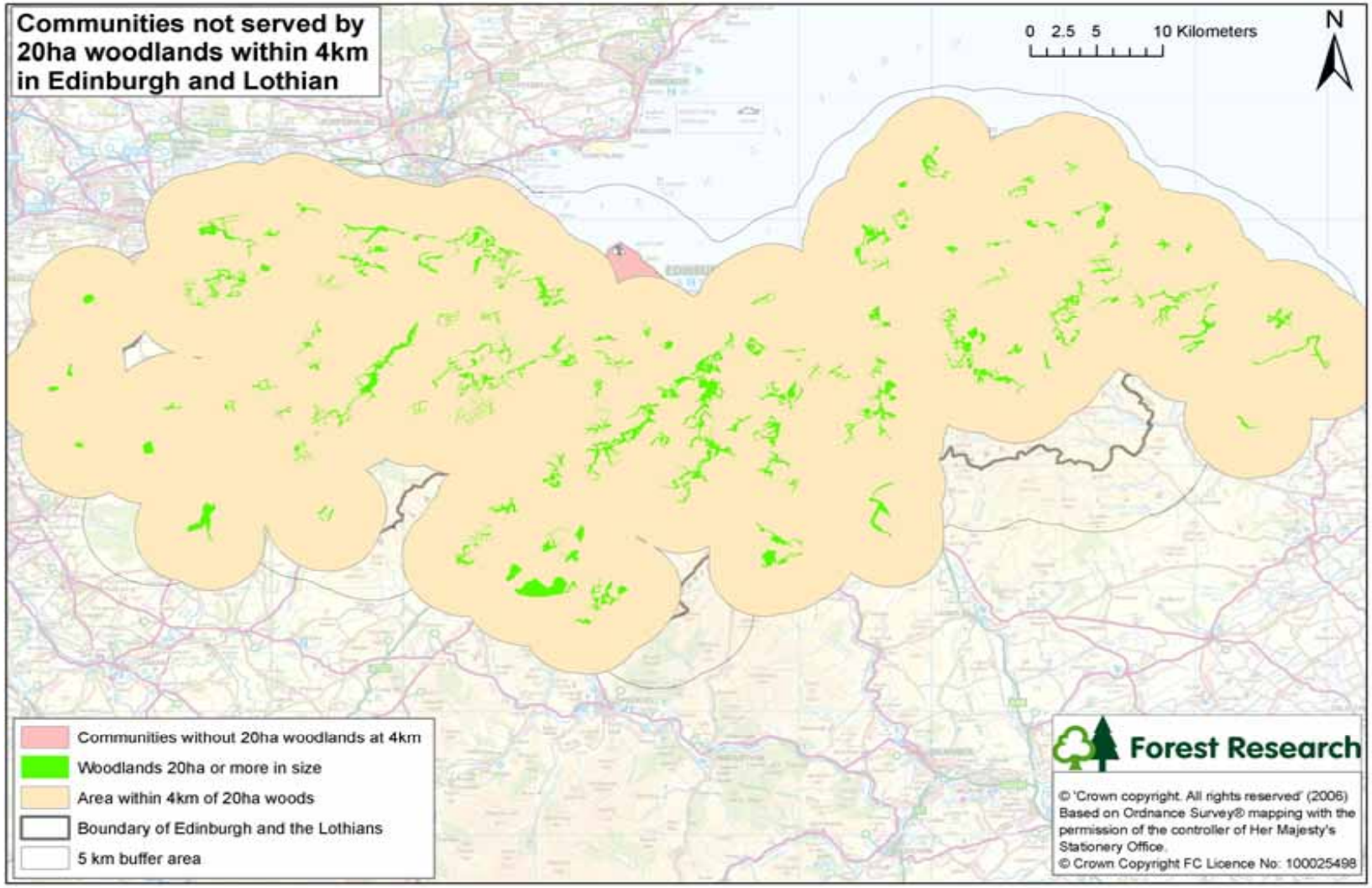

Figure 12. Communities not served by woodlands of 20 ha or more within a distance of 4km.

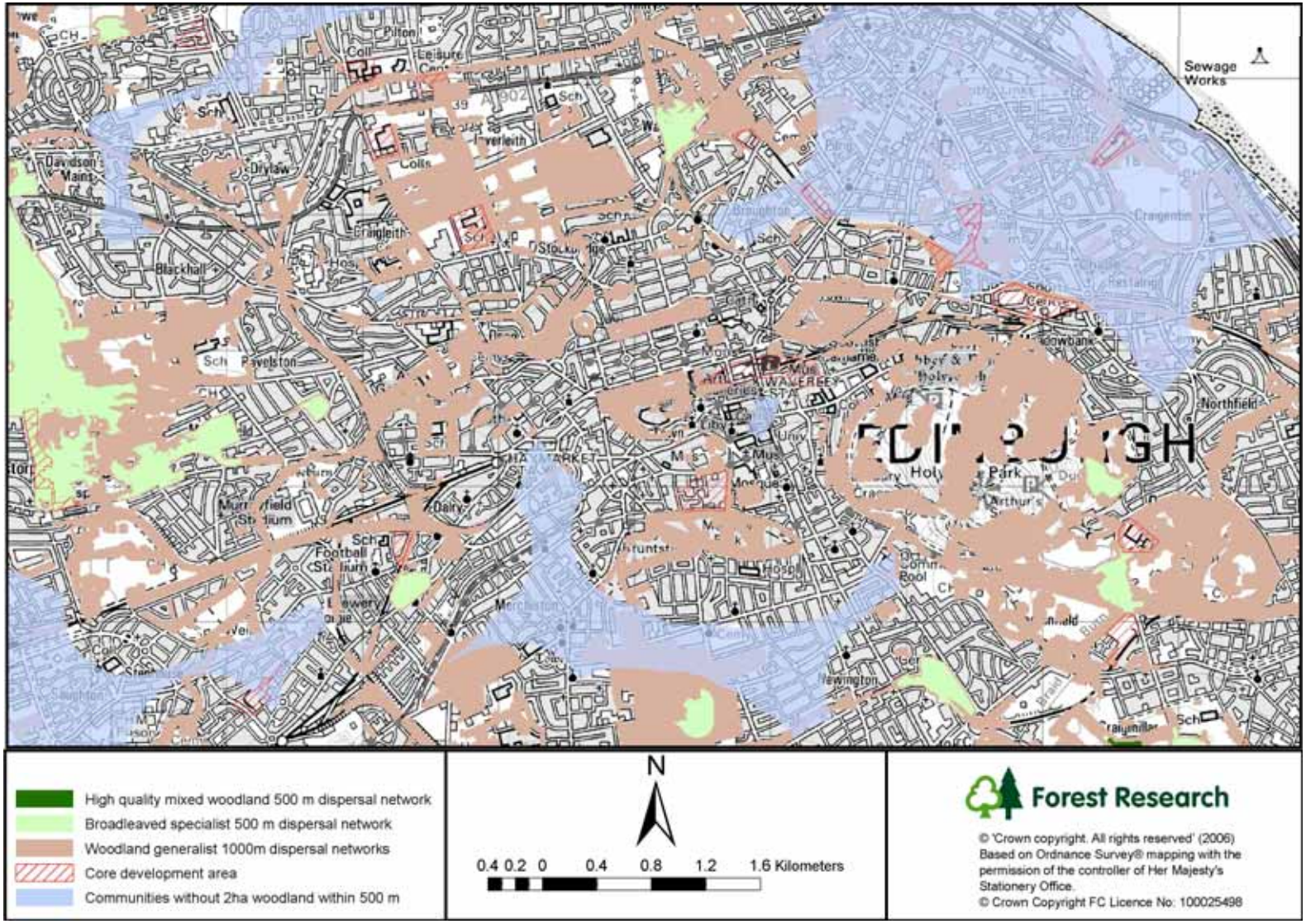

Figure 13. Development and woodland network opportunities in Edinburgh city centre.

However there should be many opportunities to plant more trees within the city, in parks (Holyrood and the Meadows), in other open areas and in streets. Larger existing woodland areas include Corstorphine Hill and the Royal Botanic Gardens. Ideally these woodlands should be linked within a network by more street trees and small groups of trees in existing green space, to provide a greater resilience for woodland species against change, and a more satisfying urban character for people.

3.3.2. Waterfront Edinburgh (see Figure 14)

The woodland potential of the Edinburgh waterfront is likely to be quite limited, as development areas are small with a high requirement for housing. However there will be opportunities to link urban streets with street trees capable of extending the wooded character of the Botanic Gardens in Inverleith Row through the waterfront area to Muirhouse and Silverknowes. Scrub and woodland along the Shore Road and within the proposed development area would help provide the links for the network.

3.3.3. Edinburgh Park/South Gyle/Sighthill (see Figure 15)

Although the area to the south and west of Saughtonhall to the city by-pass at Hermiston Gate has a few green spaces in the form of public parks and golf courses, the area fails to provide 2ha of woodland for the sizeable community. Woodland patches should form stepping stones across the western edge of the city, towards the broadleaved woodland habitat of the Gogar Burn, the line of the Union Canal and the high quality woodlands of Riccarton.

3.3.4. Newbridge/Kirkliston/Ratho (see Figure 16)

There is an important opportunity to create a woodland habitat network through the edge of this core development area to link the high quality woodlands of the River Almond to the very high quality woods from Philpstoun along the line of the Union Canal through the Winchburgh core development area. Due to the high biodiversity value of the woodland at each end of the proposed corridor, new woodland would have to vary in size, to provide significant new core woodland habitat in the future as the woodland matures. There is some existing woodland and scrub along the line of the canal, and at Ratho along the edge of the bing. The woodland should also be expanded on both sides of the motorway south of Kirkliston. (see also Winchburgh)

3.3.5. Musselburgh and Wallyford (see Figure 17)

The provision of small woodlands within the core development areas of these two towns provides an opportunity to provide existing communities, as well as future residents up to the ‘Space for People’ standard. Currently sizeable areas of the towns have no access to small (2ha minimum) woodlands within 500m. If woodlands were placed on the outer edge of new developments, then there would be a good chance that the biodiversity value of those future such woods will be high. The reason is that the high quality network at Whitecraig is nearby, and efforts should be made to functionally link this woodland with new woodland expansion. Ideally the Whitecraig woods should be expanded with contiguous new woodland areas, to protect and consolidate its high biodiversity quality.

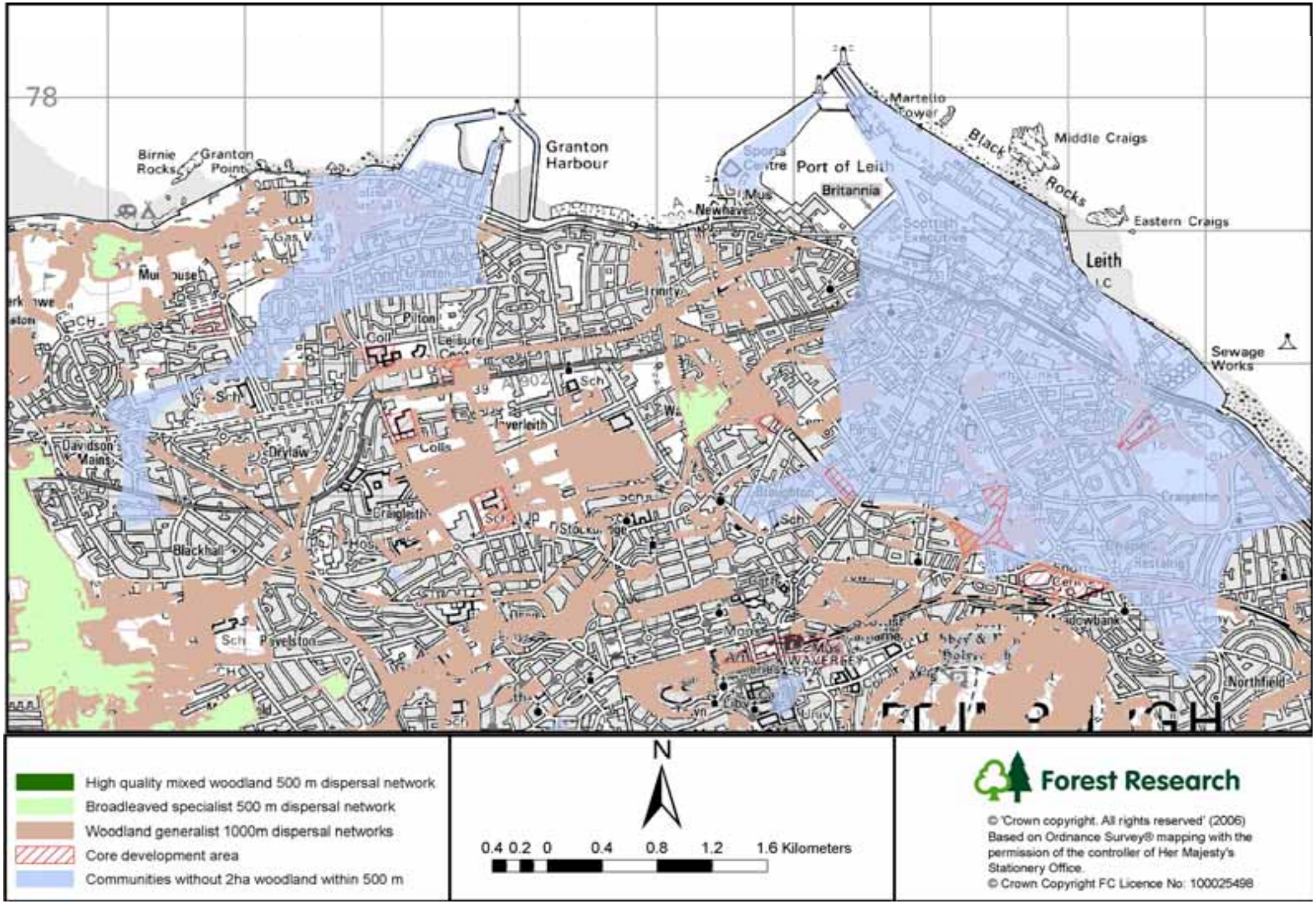

Figure 14. The core development area of Edinburgh waterfront, is lacking the minimum woodland standards of 2 ha woodlands for the Granton, Pilrig and Leith communities.

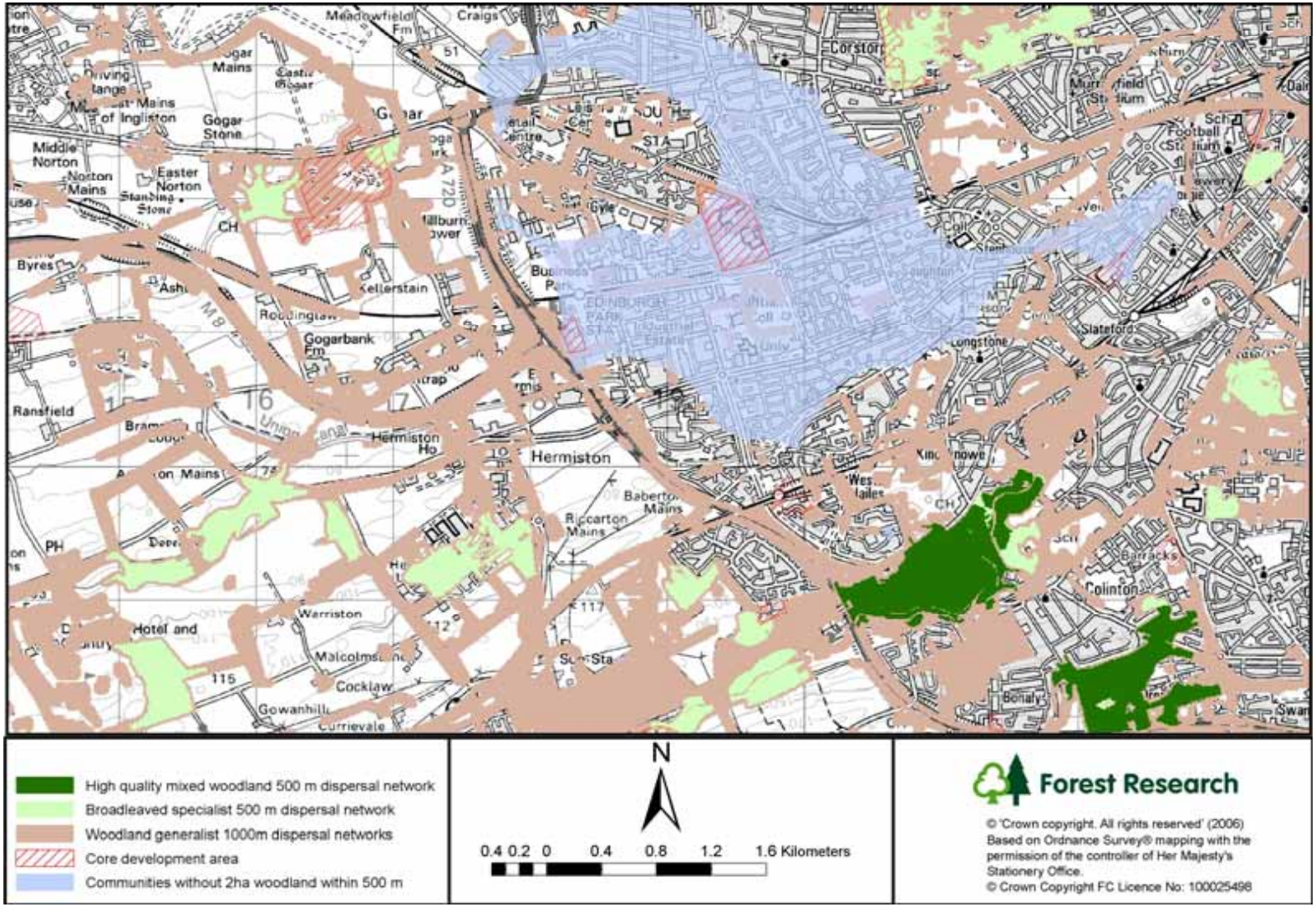

Figure 15. Core development areas of Sighthill, Edinburgh Park and South Gyle showing communities without access to 2ha of woodland within 500m.

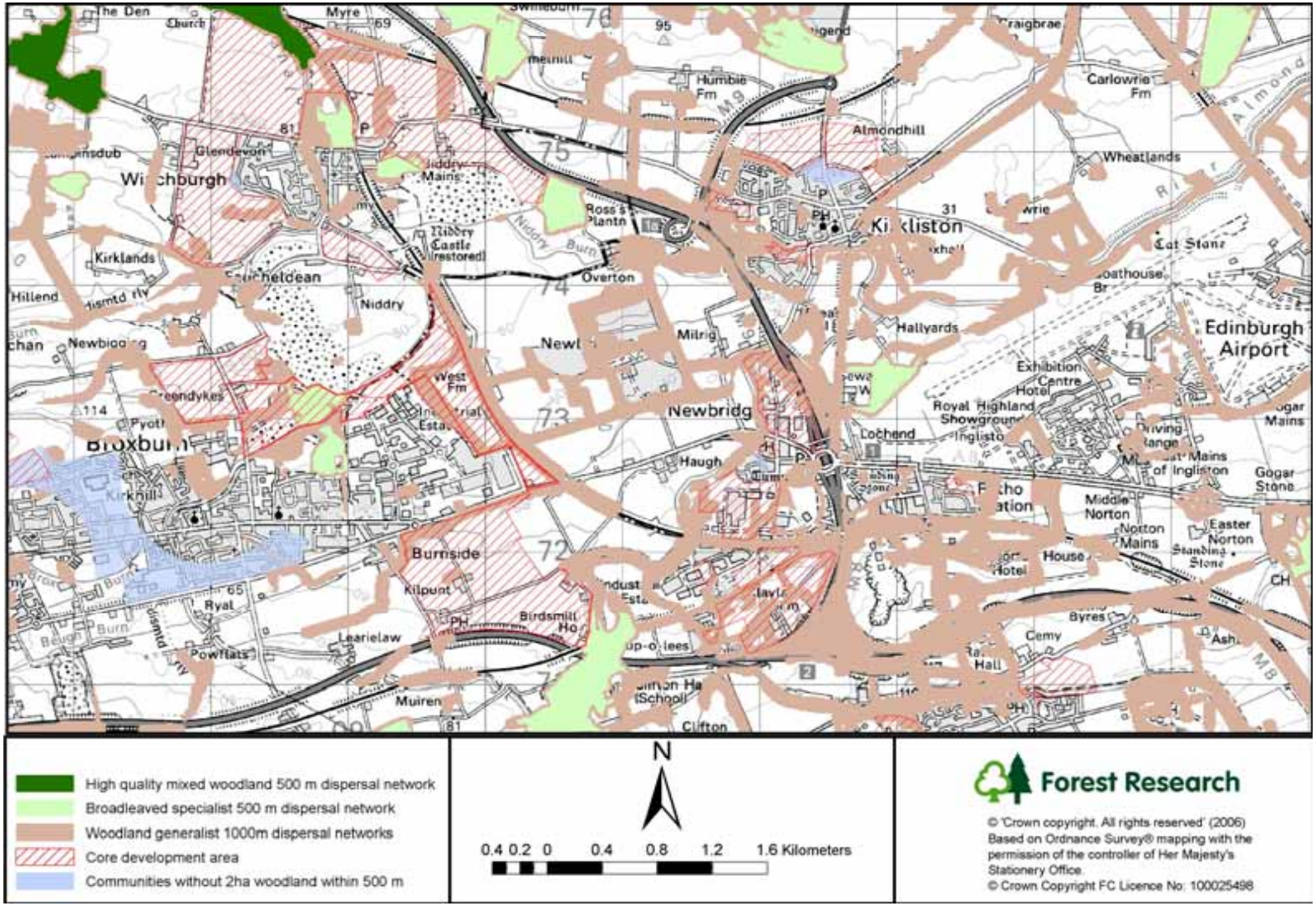

Figure 16. Opportunities to link very high quality woodlands of the Almond valley with the Union Canal and north through Winchburgh to the high value woods of Mounthooly and Philpstoun.

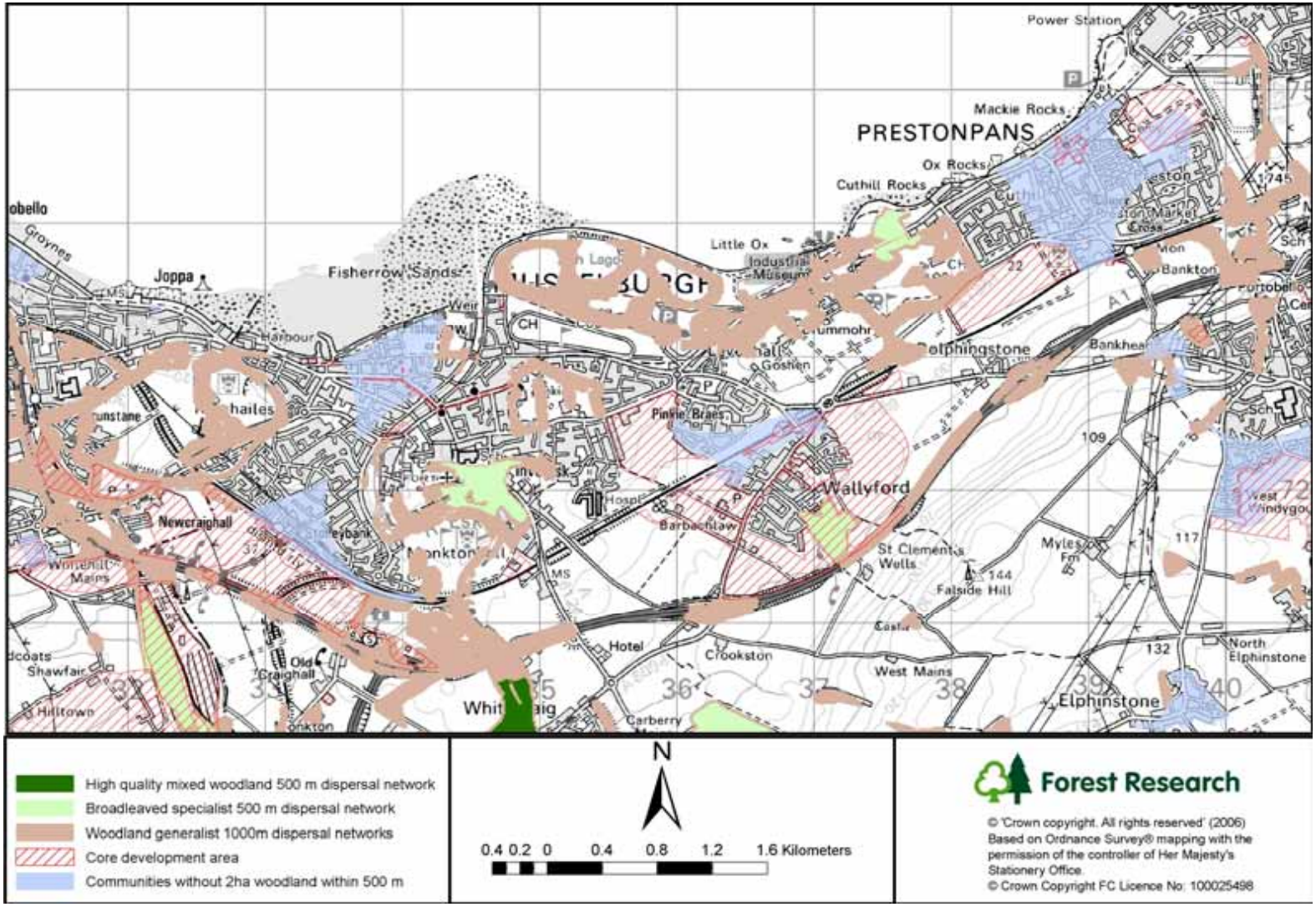

Figure 17. The core development areas of Musselburgh and Wallyford, and communities not meeting the Space for People criteria.

3.3.6. Blindwells (see Figure 18)

The new village planned for Blindwells is on old open cast coal workings. The area does not support high quality woodland networks, but there is a woodland generalist network with broadleaved components to the south and east of Gladsmuir. The communities of Tranent, Macmerry, Elphinstone, and Prestonpans do not have access to existing small woodlands within 500m. There is an excellent opportunity in this area to begin to develop a new woodland network along the line of both sides of the main line railway. The new woodland would provide access for local communities, and for the future residents of Blindwells village, and help reduce the noise and impact of the mainline railway on the new community. A linear woodland varying in width to provide future core woodland habitat would also link in with existing woods south and east of Gladsmuir, extending and improving the limited woodland in this part of East Lothian.

3.3.7. Haddington (see Figure 19)

Haddington has a good woodland generalist network consisting largely of existing field boundarys linked to broadleaved woodlands to the east, south and west of the town. The core development area to the west of Haddington could break this network, and efforts should be made to plant new woodland along the eastern edge of the core development area. This would also serve the purpose of providing the existing community of the eastern part of the town with the Space for People standard for access to small woods within walking distance.

3.3.8. North Berwick (see Figure 20)

The local plan suggests the large area to the west of North Berwick is not for housing or business development, but for a leisure and tourist facility (golf course). The area contains two existing broadleaved woodland networks which should be connected if possible. More important is the opportunity to link a woodland network on the north edge of the development area planned on the south side of North Berwick to existing broadleaved networks currently ending at Wamphray to the south.

3.3.9. Dunbar (see Figure 21)

Existing woodland generalist networks almost link around the south side of Dunbar. There is an excellent opportunity for the planned development at Halihall to include new woodland to the south, to begin the linkage of the network between the south side of Dunbar and the A1 dual carriageway with networks to the south (near Spott) and west (near North Belton), and on to the woodlands surrounding John Muir Country Park. Woodland linkage would be useful along the north and southern edge of the A1, and would provide a screen and noise reducing barrier to the new community of Halihall. The north side of Dunbar does not meet the Space for People standard for woodland access. It is perhaps not important or appropriate to expect urban woodland along the coastal fringe of Dunbar.

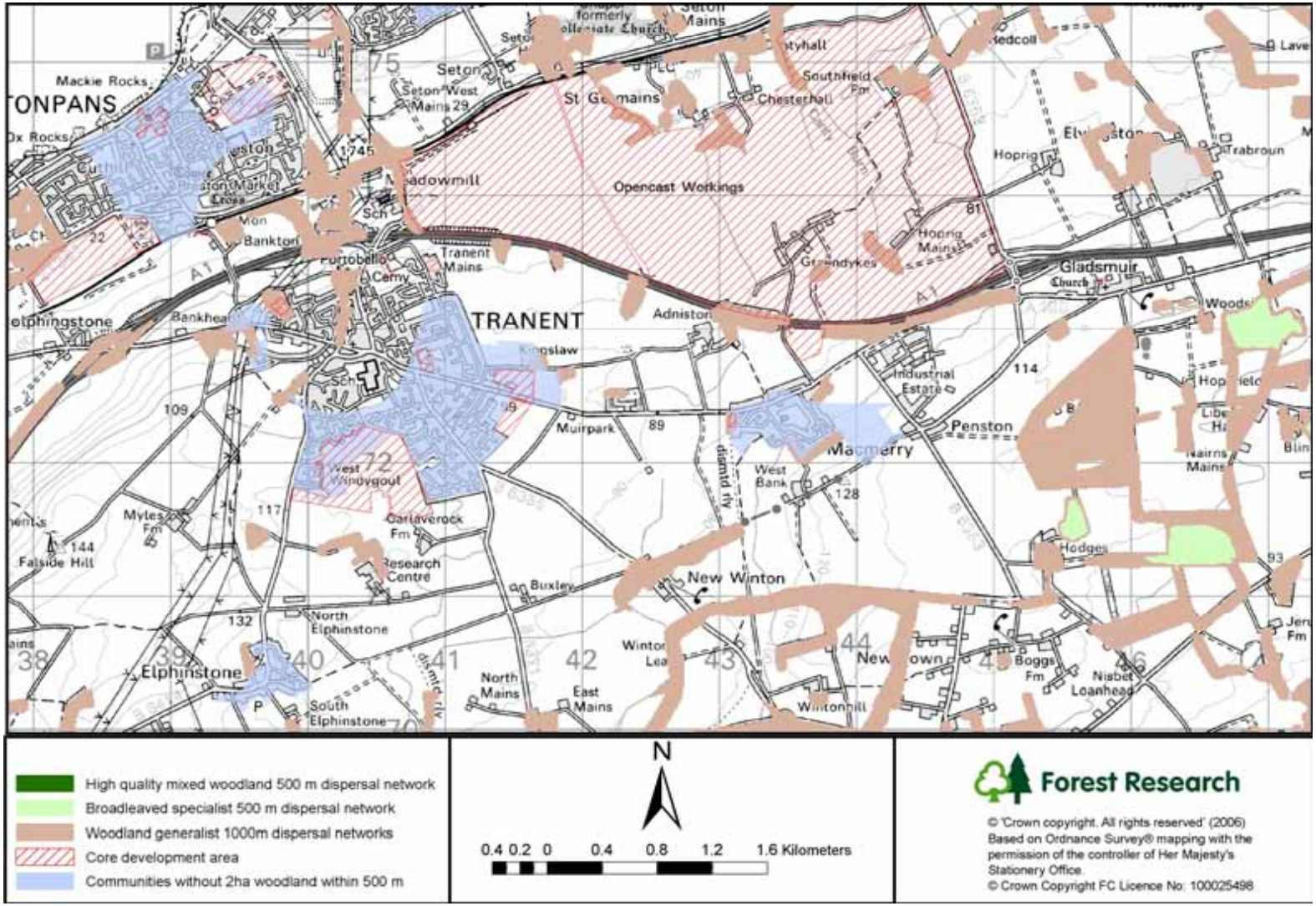

Figure 18. The core development area at Blindwells and the requirement for 'Space for People' standards for the communities of Tranent, Elphinstone, Macmerry, and Prestonpans.

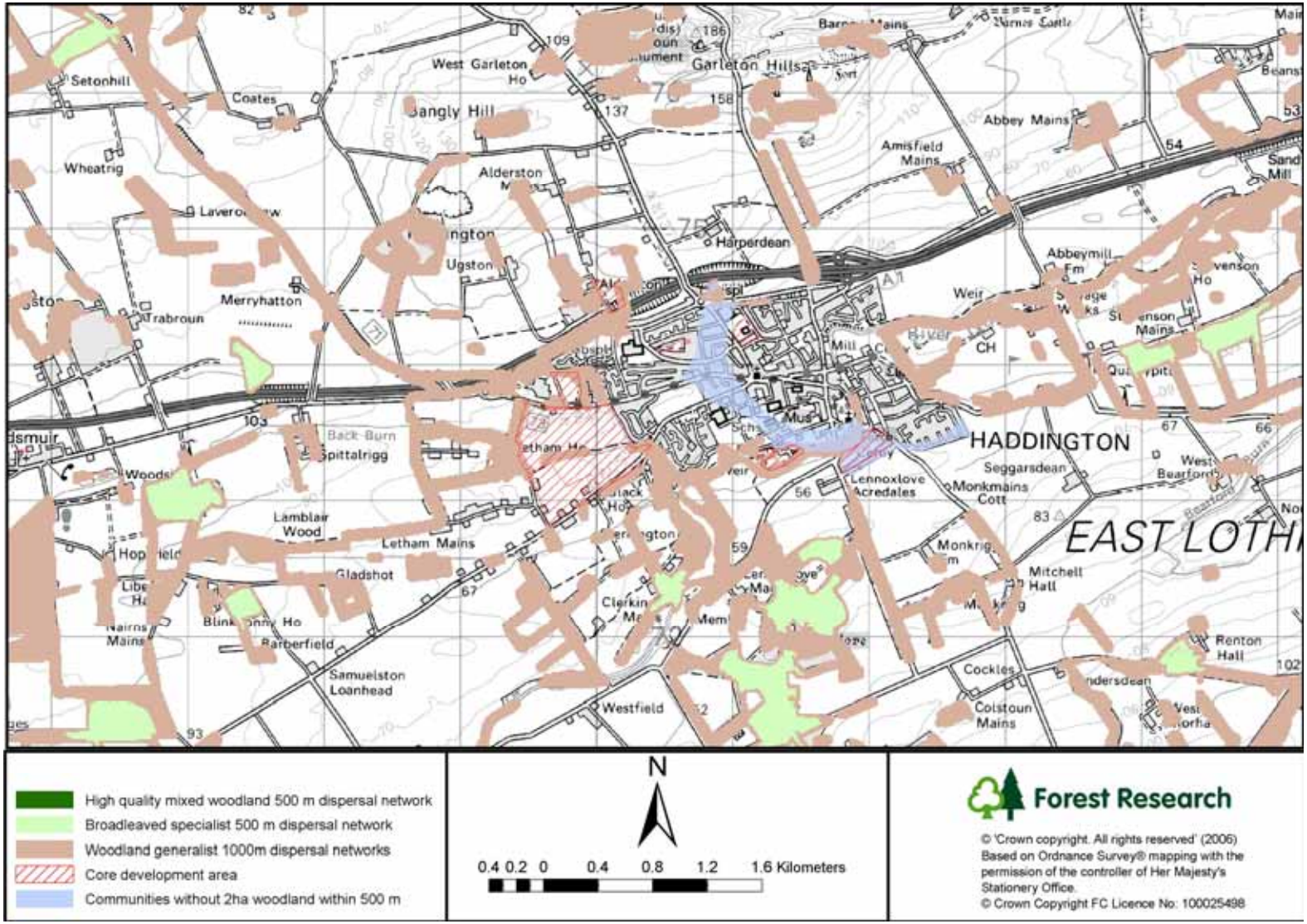

Figure 19. Woodland and field boundary networks around Haddington and the core development area.

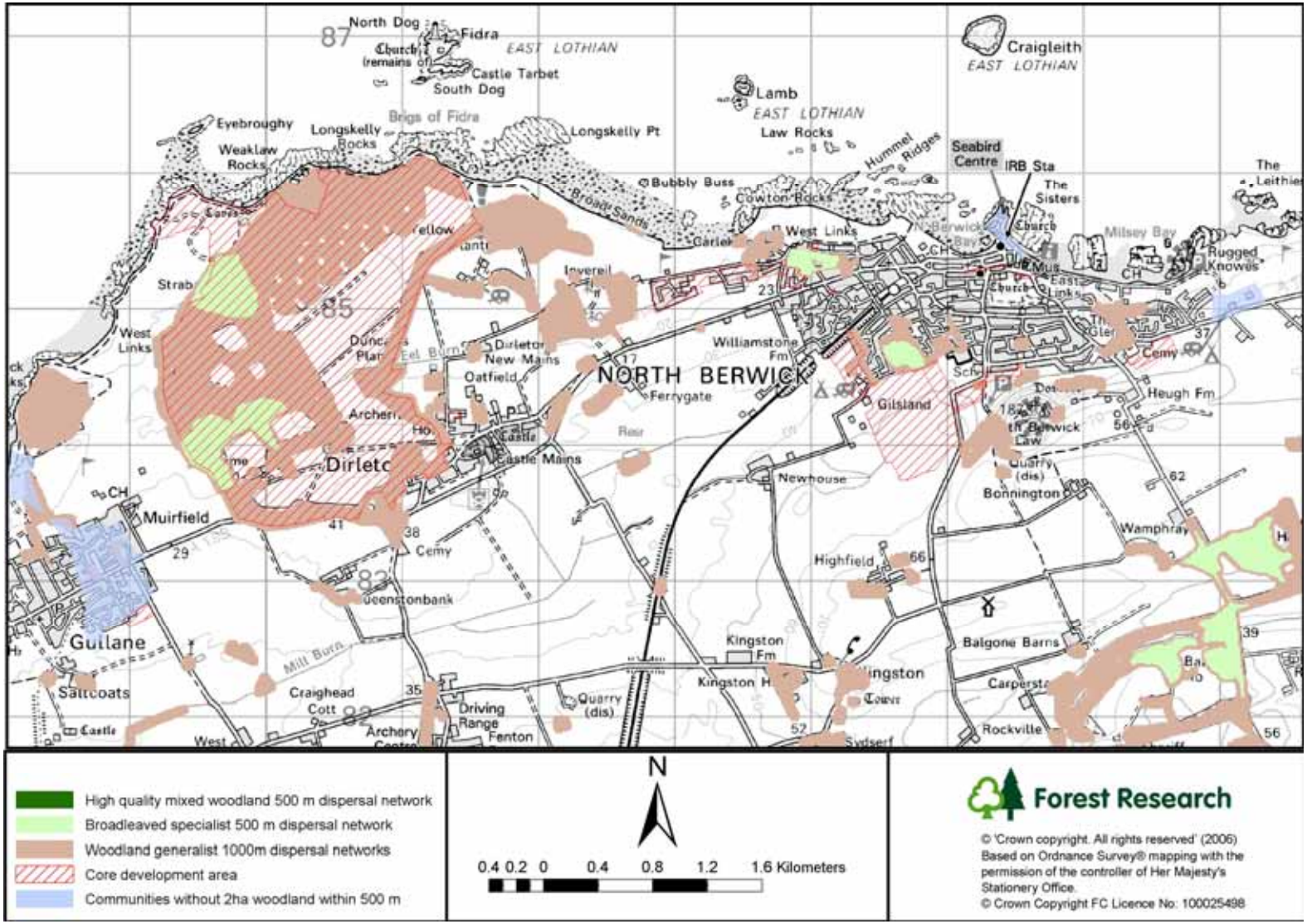

Figure 20. Woodland networks and core development around North Berwick.

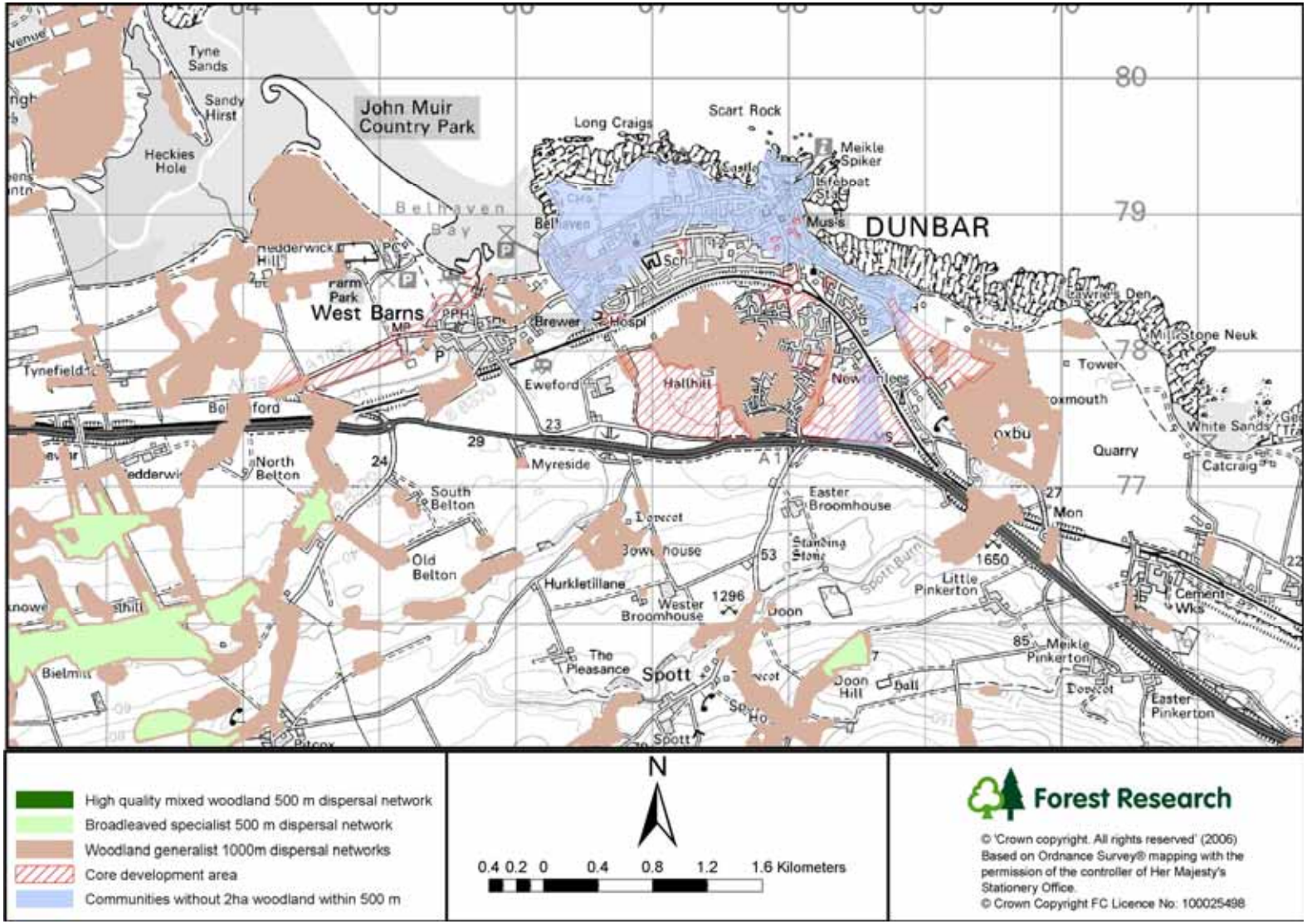

Figure 21. Woodland networks surrounding Dunbar.

3.3.10. Waverley Line Corridor (see Figure 22)

The planned Waverley line will run south from Edinburgh through Dalkeith and Newtongrange. The area straddles the confluence of the two prime woodland networks of Midlothian: the North River Esk network, and the South River Esk Network. The actual confluence of the river systems lies to the north of Dalkeith in Dalkeith Park. The town of Dalkeith however, acts as a barrier preventing the functional ecological linkage of the high quality woodlands to the south. The restoration of this linkage should be the highest priority of the development of the woodland network in Midlothian. It is important to maintain a capacity for woodland species to disperse more freely, and to widen the genetic resource within species of the two high quality woodland systems. Since the town of Dalkeith represents the main barrier, the functional linkage should be made to the south of the town, in one or two places.

The first opportunity lies between the riparian woods of Hawthornden, out of the gorge, through Midfield, and across the southern edge of Polton and Bonnyrigg. The southern edge of the development area of Hopefield, and Poltonhall could place a section of the required link through to the high quality woods of Dalhousie grange, and Cockpen on the South Esk system. More woodland would be required along field edges and following the lines of streams or flushes where possible.

3.3.11. A701 Corridor (see Figure 23)

A second link could be made between the North and South Esk systems between Aikendean Glen on the South Esk system, along field edges through to St Joseph's Hospital woods and across the North Esk, north of Rosewell. Links could be made through the core development area planned for housing on the west side of Rosewell, across the edge of farmland close to the railway track and into Roslin Glen Woods. Such a plan would build on the changing character, to a more wooded area, surrounding Rosewell and the south side of Bonnyrigg, and would help maintain the separate identities of these villages.

To the west of the North Esk lie the valleys of the Kill Burn and the Bilston Burn which contain impressive areas of woodland currently fragmented from the main Esk Valley. Efforts should be made to re-establish the links that were broken by the coal mine at Bilston into the very high quality woods of Polton Glen. The newly developing Bio-technology Park at the edge of Bush Estate has already restored a section of the Kill Burn across Gowkley Moss. Further efforts to restore the woodland to the east and west across the A701 are still needed. The advantage would be a reconnection of the old estate woods of Bush into the Esk Valley woodland, and to the west the link between Bush Estate and the woods of Woodhouselee in the Pentlands, through woodland expansion along field edges of the Easter Howgate farmland.

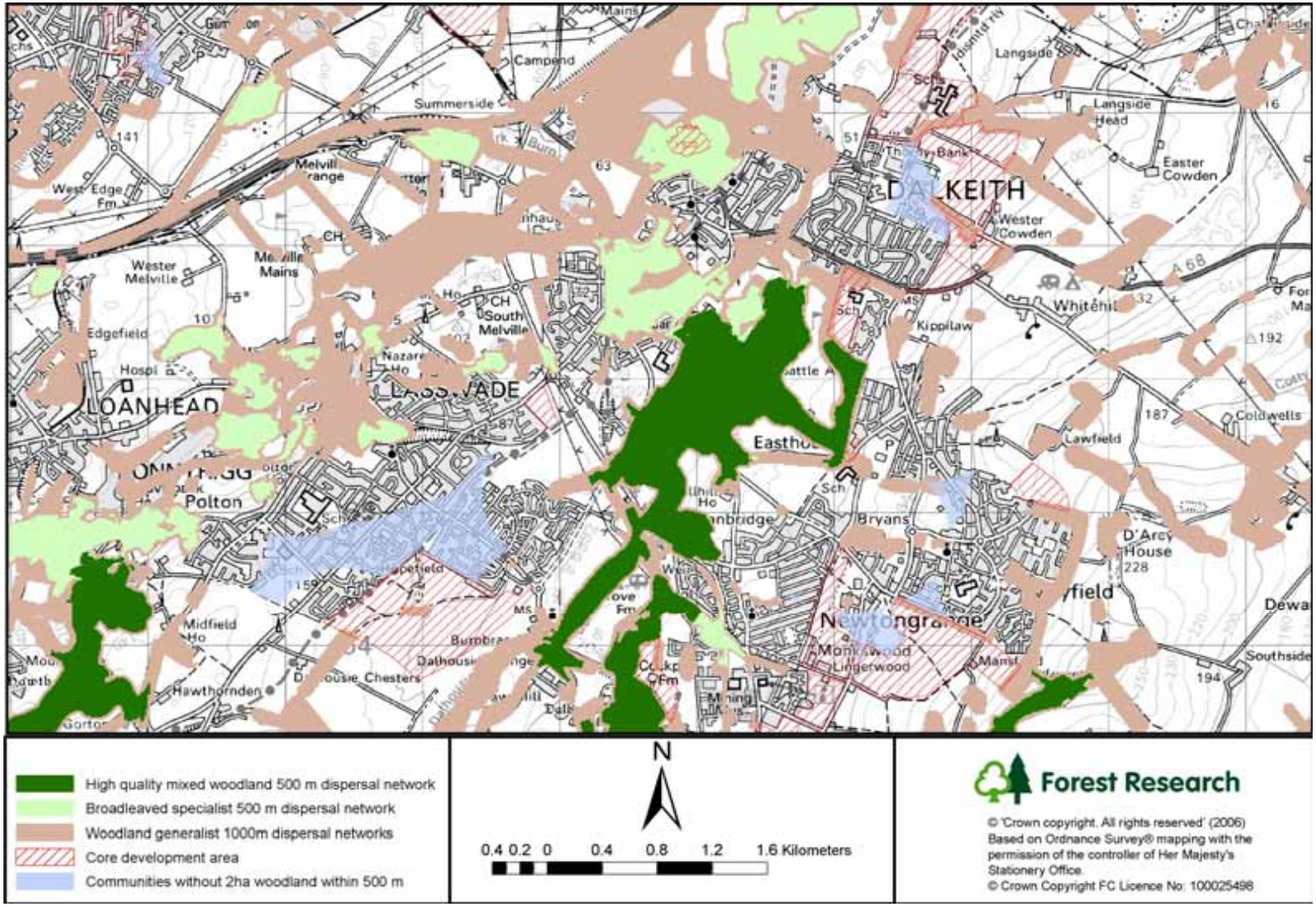

Figure 22. The high quality woodland network of the Esk Valley and the development requirements of the Waverley Corridor.

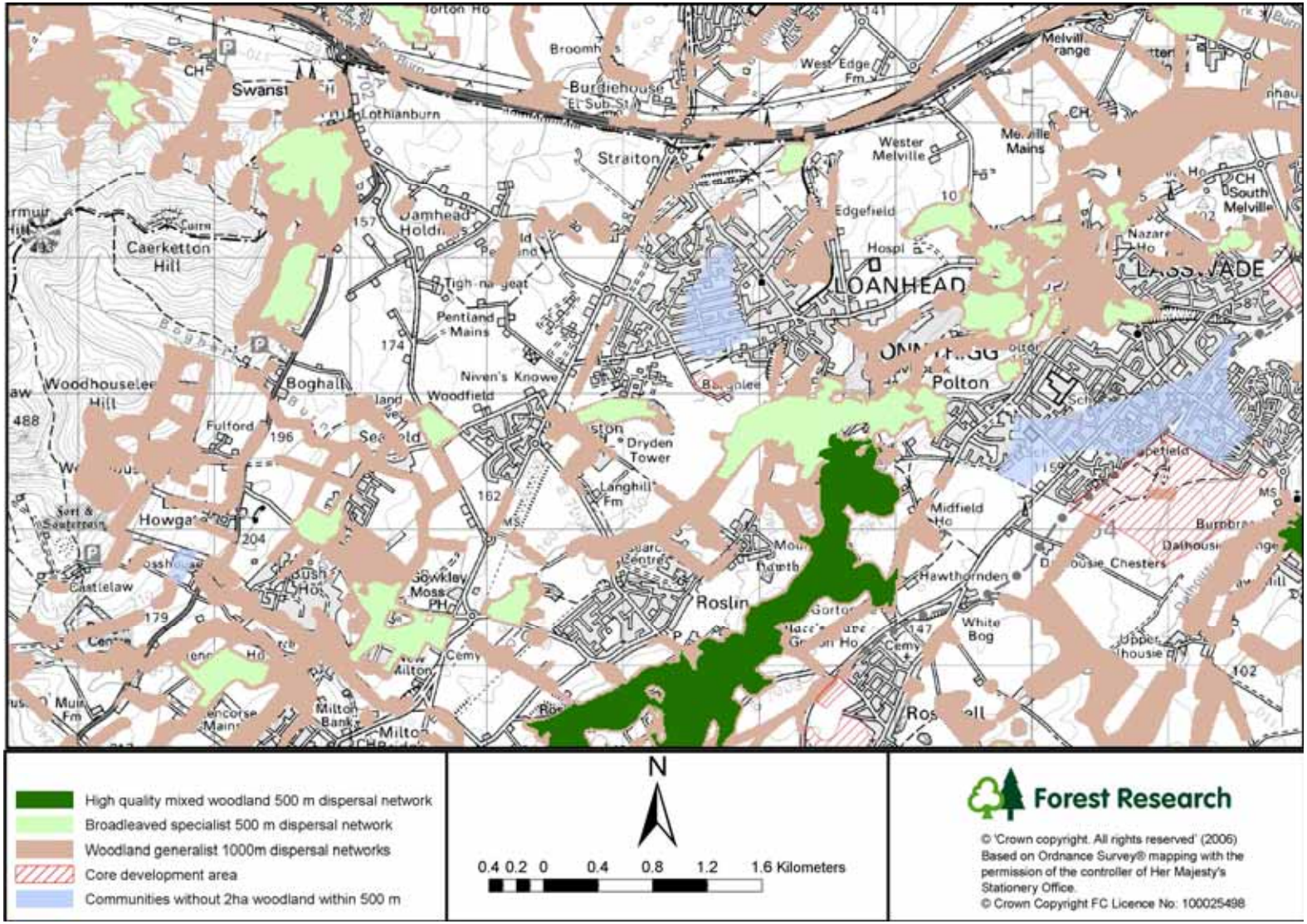

Figure 23. Tributary networks of the high quality North Esk woodland habitat network.

3.3.12. Livingston and the Almond Valley (see Figure 24)

A high quality woodland network runs through the edge of Livingston through Mid Calder and Murieston, and is supported by 10 or so woodlands within the valleys of the River Almond, Murieston Water and Linhouse Water, with the addition of a few woodlands scattered between these valleys. Despite its proximity to the urban fringe of Livingston and surrounding villages, the network contains high-biodiversity woodlands many of which are SSSIs. Calder Wood Country Park contains partly fragmented core-woodland habitat, and attempts should be made to expand these woods with native tree species, to consolidate core woodland-interior conditions. The long term resilience of the ancient semi-natural woodland SSSIs would be improved by buffered expansion to reduce edge effects.

New native woodland should be expanded west of Blackraw Farm to connect the network of Calder Wood with Murieston Wood along the Linhouse Water. Parts of the new woodland should be 150m or more wide to create core woodland conditions in the long term. This could help achieve a more robust network for dispersal limited species. A substantial buffer area of woodland is required to protect the small core woodland area of the Murieston Wood. The impact of development along the edge of the woodland could be very damaging for broadleaved woodland specialists. Core woodland conditions are rare in the Calder CWA networks and must be protected from edge effects, to maintain the high biodiversity required by woodland specialists.

Woodland expansion (both buffered and expansion) is also required south of Calder Wood SSSI along the Murieston Water to Nether Williamston, possibly across neutral unimproved grassland. The woodland of Nether Williamston should be carefully restored to expand the small area of core woodland conditions. Such an expansion and restoration would help maintain resilience of woodland biodiversity within the Murieston Water network.

The planned development on land south of Murieston across to the Lockerbie railway line could seriously damage the existing network close to the Linhouse Water. This piece of land could provide a key connection to link woodland habitats within a bigger network between the Almond Valley and Selm Muir Wood and, in time, perhaps connect to the Over Williamston Woods and Camilty Plantation to the south.

With some expansion the Bellsquarry, Newpark and Brotherton Woods (at Adambrae) could be linked into a network, and indeed linked to the Murieston Network with new native woodland stepping stones, and corridors, along the Glasgow railway line.

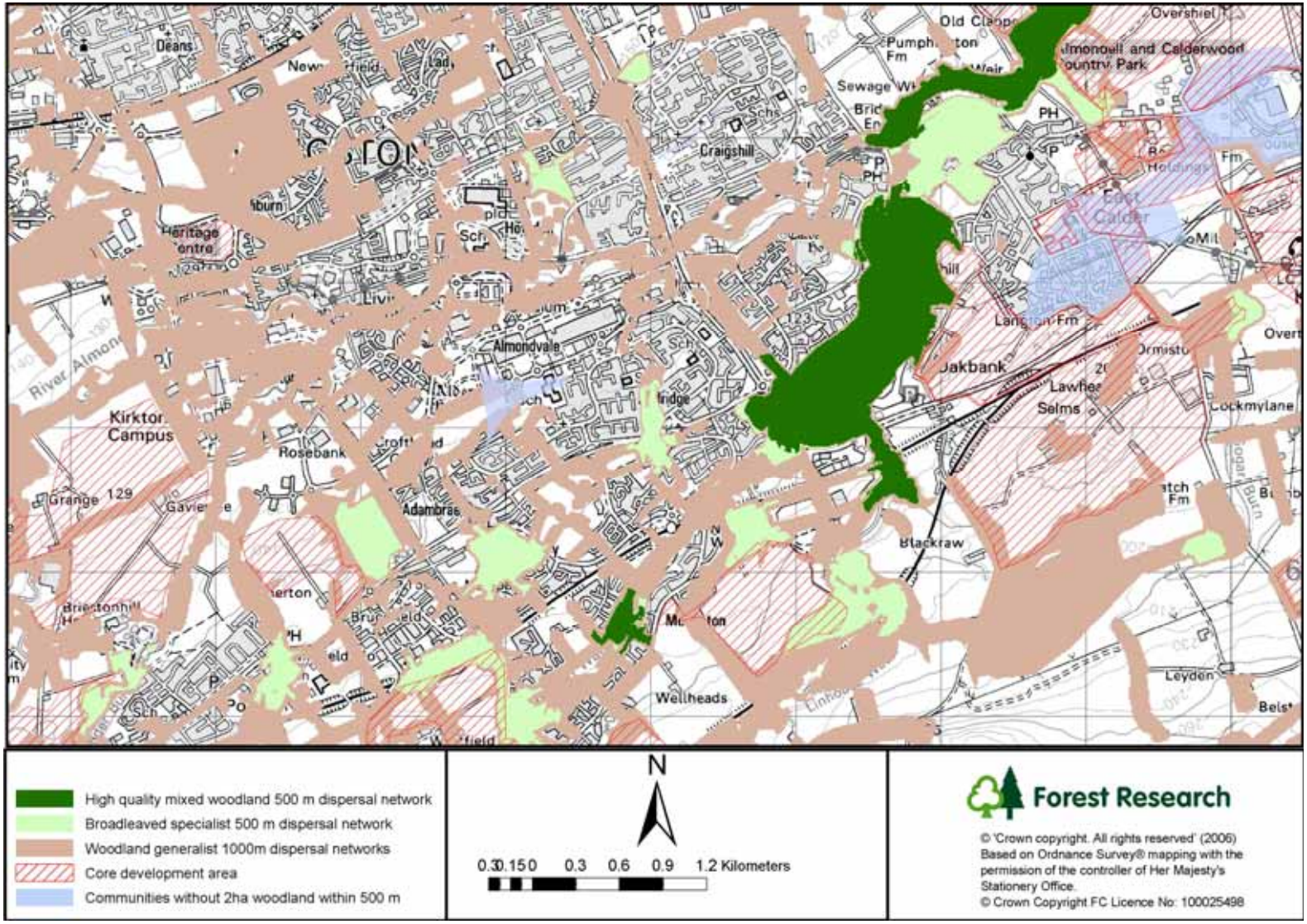

Figure 24. High quality woodland networks of Livingston and the Almond Valley.

To the north of Mid Calder and east of Livingston, woodlands from Clapperton, north along the Almond to Newbridge, form a network of small woodland habitats. The expansion and linkage of these woodlands should be a priority between the Visitor Centre and Clifton Hall, on both sides of the River Almond. The proposed development of Clapperton Hall should include substantial plantings of new native woodland to secure and maintain the habitat network between Drumshorelandmur and the Almond network.

3.3.13. Winchburgh/East Broxburn/Uphall (see Figure 25)

South of Hopetoun, and south of the M9, between the Edinburgh-Glasgow rail line and the Union Canal, lies the high quality woodland between Philpstoun and Winchburgh. The woodland is a key piece in the jigsaw to re-establish links between high quality woods of the old established estates of Philpstoun, Hopetoun and Dundas to the north and the Almond Valley to the south east. The Mounthooly link along the Union canal is linear and should be broadened to 150m wherever possible to provide more core-woodland habitat in the future. Linkages between the Hopetoun woods could be made at Philpstoun House, and to the Carmelhill woods by expanding new native woodland either side of the railway line and M9 motorway at Myre. The core development area north of Winchburgh provides an excellent and unique opportunity to include new native woodland (at least 150m wide to allow a 50m wide core-woodland habitat) on its northern boundary, to help secure the future FHN connection through West Lothian and into western Edinburgh through Dundas and Cramond, and to the south through Ratho.

3.3.14. Armadale (see Figure 26)

There is an opportunity for the core development area around Armadale to include more woodland to help stimulate and rejuvenate these post industrial communities. Woodland would improve the landscape and the environment, and could provide people with places to relax, restore and take more exercise. Currently large areas of the communities of Armadale and Blackridge do not meet the Space for People standard for woodland access. The new development areas offer the opportunity to provide new community woodland.

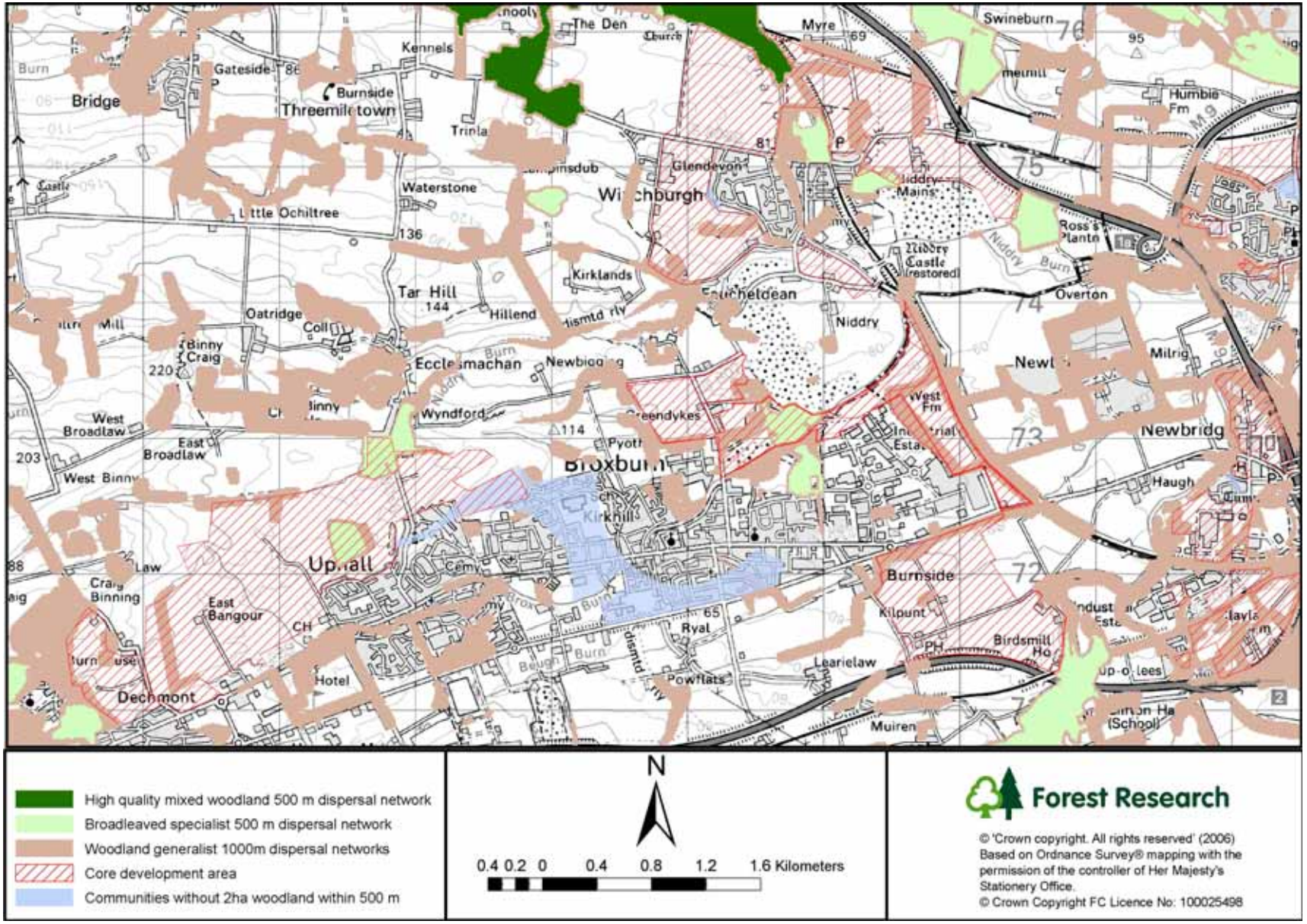

Figure 25. A high quality woodland habitat network between Mounthooly and the Almond Valley high quality network.

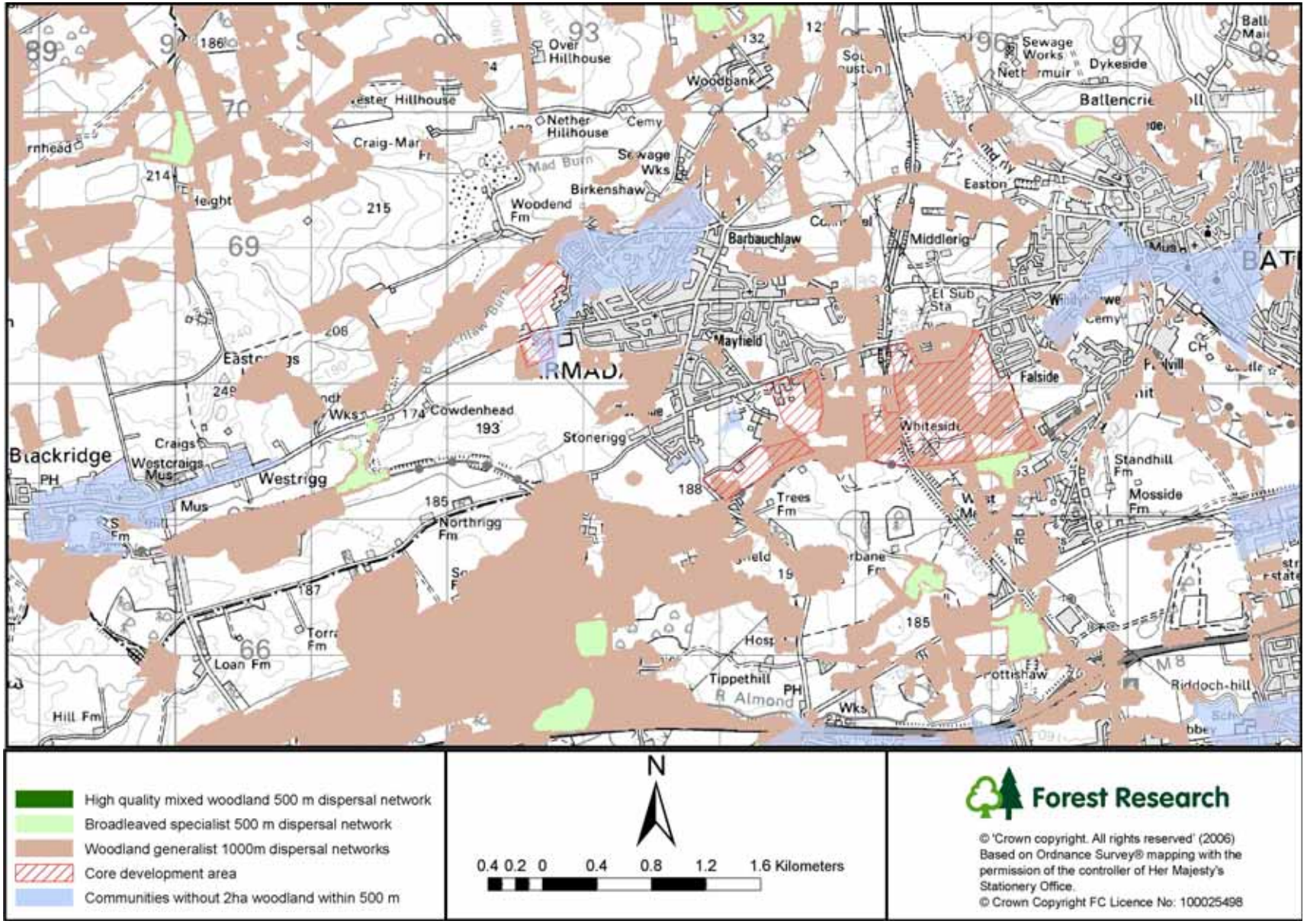

Figure 26. Woodland networks around Armadale.

4. Discussion

General

4.1. This was a desk-based study to identify extant Forest Habitat Networks of Edinburgh 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.

4.2. 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, providing 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). The ancient woodland inventory is not always a good predictor of quality as some woodlands in the inventory are very degraded and woodlands outside the inventory that may be of high quality are excluded. 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. Consequently there will be some woodlands that may require manual qualification and subsequent amendment in the land cover dataset following identification by local experts.

4.3. 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 1-3 plants. This would reduce the possibility of underestimating the number of quality woodlands. Indeed it would overestimate low quality woodlands, since many woods with little quality might 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: 0-3 indicator plants, 4-7 indicator plants, and 8 or more indicator plants, which required us to identify only the last 2 classes.

4.4. The ancient woodland indicator quality criteria method could be supplemented and confirmed by experience-based knowledge. Indeed, since this study was purely desk-based, we would recommend that local knowledge is used to confirm woodland quality. 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.

Habitat networks

4.5.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, as 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-habitats which should involve a diverse field layer, understory 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 and expand the landscape structural framework in a way that will provide a range of habitats to protect the biological diversity of Edinburgh and the Lothians. It is recommended (Scottish Executive 1999) that “planning authorities should seek to prevent further fragmentation or isolation and identify opportunities to restore links which have been broken”. Indeed, a strategic approach is encouraged, in which wildlife sites, landscape features and other areas of open space are linked together in an integrated habitat network, making an important contribution to the maintenance and enhancement of local biological diversity.

4.6.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 become apparent; plan woodland and open habitat in a way which maintains the functional connectivity between habitat patches; improve public perception and enjoyment of woodland to stimulate their appreciation of nature; select tree species that are suited to site now and during their lifespan. 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 planners is to assimilate this complex ecological issue with other social and infrastructural needs of society into strategies and plans that will deliver a solution which suits the different facets of sustainable development.

4.7. 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.

4.8. 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.

4.9. 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.

Woodlands In and Around Towns

4.10. People need space to live and this should include more natural space, 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 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.

4.11. 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).

4.12. The development during the 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 because little attempt was made to link the urban setting within 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. The UK Government has just signed the European Landscape Convention (ELC), which aims to ensure that the importance of landscapes is recognised. The ELC defines landscape as '...an area, as perceived by people, whose character is the result of the action of natural and/or human factors. The 'Woodlands in and around Towns' (WIAT) (Anon. 2005; Anon 2006) initiative has an important role to play in meeting the sentiment of these ELC objectives.

4.13. Finally, woodlands bring wildlife into urban settings. Woodland birds, spring blossom, autumn colours and woodland plants are welcome signs of the changing seasons, adding value to the quality of life for communities, and providing incentives and opportunities to explore and learn more about the natural world.

Core development area opportunities

4.14. Each of the core development areas provides opportunities to accommodate woodland in a way that will enhance sustainable development, either in maintaining the functional connectivity of high quality ancient woodland networks, or 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 woodland is the reservoir, the refuge for woodland biodiversity. The best way to safeguard these patches is to expand them in a way that extends the core area of woodland they contain. The core woodland area is the central part of woodland which is not influenced by the edge. Research has shown that an edge effect occurs within a distance of about twice the height of the canopy from the edge of a wood (about 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.

4.15. 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.

Consideration of open-habitat

4.16. The analyses detailed here provide an indication of the opportunities for directed woodland consolidation and expansion to increase biodiversity, they are not intended to be prescriptive. It is important to reiterate that the woodland

habitat networks are functional networks representing the dispersal of woodland species from source habitat patches through a diverse land cover matrix. As such, the networks show where woodland species can disperse through open ground habitats. Connecting nearby FHNs does not require contiguous woodland planting, it may be achieved by planting a relatively small woodland 'stepping stone' or by a reduction in the intensity of 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.

4.17. 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.

4.18. 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.

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.Woodlands In and Around Towns

- Within <u>all</u> of the urban fringe, and particularly within the Core Development Areas, 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. This should be over and above the duty of planning authorities "to ensure planning permissions make adequate provision for the preservation or planting of trees", as stated in section 159 of the Town and Country Planning (Scotland) Act 1997 (Scottish Executive 1999). An additional recommendation is that, where development involves the loss of trees, permission should normally be conditional on a replanting scheme with trees of appropriate species in appropriate numbers.
- Woodland planting on development sites should be substantial; 150m 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 little impact on improving the woodland biodiversity of the region. Under

these circumstances, development would only increase the fragmentation of neighbouring woodland habitat.

- 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.

5.3.Woodland biodiversity protection

- All high quality woodland should be expanded by planting contiguous patches.
- All high quality woodland should be protected from development by a buffer zone of at least 250m in width, allowing room for core woodland expansion and a surrounding scrubby and open ecotone. This will provide a more natural environment for communities (within a woodland setting), and will help reduce disturbance, and minimise the woodland edge effect on core woodland species.

5.4.Woodland management

- Woodlands containing 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 invasive species.
- Areas indicated by the ancient woodland inventory as having had ancient or long-established woodland but 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.

5.5.Woodland expansion

- Tree species planted should be suited to the habitat type, e.g. native broadleaves to be selected for high quality broadleaved networks. Use Ecological Site Classification (Pyatt et al. 2001; Ray 2001) to assess site types and inform species choice.
- Woodlands designated with low biodiversity quality compartments should be targeted for structural management, to improve the condition of the woodland to encourage a greater number and diversity of woodland species. This could, in time, bring these areas into the high quality broadleaved woodland category. Management should concentrate on approaches that maintain and enhance the appropriate woodland ground flora (see National Vegetation Classification (Rodwell 1991-2000) 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 these woods into existing networks.

5.6.Open-habitat management

- Woodland generalist networks: to improve the permeability of the landscape, surrounding open habitat should be managed in a less intensive way, or (where appropriate) restored to semi-natural habitat, which will allow greater dispersal of woodland generalists and allow greater network size and linkage.
- This approach does not suggest the conversion of open ground habitat to woodland habitat, as woodland expansion should only be considered after careful examination of the potential impact this may have on open ground habitat. Open ground can be managed in a way that benefits both open-habitat and woodland, e.g. management of improved grassland can be reduced to allow a more natural grassland develop, which will then increase the permeability of the land cover matrix for woodland species.

5.7.Specific recommendations

- The study has highlighted the high quality remnant woodland in Edinburgh and the Lothians, much of which exists in high quality, but fragmented, networks. High quality networks should be extended and linked to support the dispersal of woodland species in the landscape (refer to Figure 4 and Table 5 for Core Woodland Area descriptions). These include:
    - Avon Valley network of West Lothian (Core Woodland Area 1)
    - Almond Valley network of West Lothian (Core Woodland Area 3)
    - Hopetoun to Philpstoun network should be linked to the Almond network. (Core Woodland Area 2 to Core Woodland Area 3)
    - Almond network should be linked to the extensive plantation woodland to the south of West Lothian (Core Woodland Area 3 to Core Woodland Area 4)
    - The Philpstoun network should be linked to Dundas woodlands and to Ratho and the Union Canal (Core Woodland Area 3 to Core Woodland Area 4)
    - The Union Canal network should extend to Hermiston Gate and into Edinburgh city (Core Woodland Area 3 to Core Woodland Area 4)
    - The Edinburgh waterfront should provide woodland which links with Inverleith (RBG) (Figure 14)
    - North and South Esk should be linked across land to the south of Polton and Bonnyrigg (Core Woodland Area 5 to Core Woodland Area 15)
    - North and South Esk should be linked to the west of Rosewell, through St Joseph's woodland (Core Woodland Area 5 to Core Woodland Area 15)
    - North Esk network should be linked to the Bilston and Gill water woods (Core Woodland Area 5)
    - North Esk network should be linked through Bush Estate to Woodhouselee woods in the Pentlands (Core Woodland Area 5)
    - Gorebridge high quality woods should link to the south Esk at Dalhousie and Newtongrange (Core Woodland Area 15 to Core Woodland Area 6)
    - A new woodland network should be considered along the River Tyne, between Pathhead and Haddington (Core Woodland Area 6 to Core Woodland Area 14)
    - The small network centred on Whitecraig could be linked westwards to the Esk, and eastwards to the Tyne along the line of the existing railway walk

(Core Woodland Area 15 to Core Woodland Area 14 through Tranent (Figure 17))

- High quality woods at Saltoun should be linked to the Tyne network at Pencaitland (Core Woodland Areas 7, 8 to Core Woodland Area 14)
- The Garvald cleuch woods, Papple, and Luggate woodlands could be linked into the Tyne network at East Linton along the Biel Water and at Hailes Castle (Core Woodland Area 9 to Core Woodland Area 14)
- Cleuch woods to the west of Torness Power Station in the Dry Burn and onto Cocklaw Hill should be developed to form a small network linking semi- natural heath of the Lammermuir Hills through the improved farmland (Core Woodland Areas 10, 11, and 12)

6. Acknowledgements

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