FINAL REPORT

Forest Habitat Networks Scotland
Highland Conservancy Report September 2005

Ecology Division Forest Research

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

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

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Executive Summary

This report continues the work undertaken in the Scotland Forest Habitat Network (FHN) project, applying a Generic Focal Species (GFS) approach to assess forest and open habitat networks at the regional scale. The work has been organised and researched in a way that provides a practical plan for developing FHNs in the Highlands. A major component of the work has been the collection of data to take account of the variability in habitat quality and the determination of complex associations.

The analyses undertaken for Highland Conservancy focused on three GFS associated with specific woodland types: Atlantic oakwood specialists; ancient pinewood specialists; and pinewood specialists, at maximum dispersal distances of 250 m, 500 m, and 1000 m. Woodland officers and foresters were interviewed to determine habitat quality, based on three components: structure, deadwood, and ground flora. Information regarding management plans allowed us to pose an assumption that current plans will lead to a significant improvement in biodiversity quality, allowing a separate analysis to be conducted to predict the contribution of woodlands as habitat sources in 50 years time. A methodology was employed to suggest Atlantic oakwood habitat in the Highlands as a spatial inventory of the Atlantic oakwoods is lacking. This identified the sessile oakwood extent from its potential distribution predicted by the Scottish Natural Heritage (SNH) / Macaulay Institute Native Woodland Model (NWM) combined with the Scottish Semi-natural Woodland Inventory (SSNWI) dataset, limited to below 200 m elevation.

The outputs were analysed to determine potential areas of interaction between woodland and open ground networks. These analyses showed that the overlap by heathland generalist networks on wooded networks was greater than that by the woodland specialist networks on heathland networks. This is clearly a function of the size of the larger heathland networks, but also highlights the ability of the heathland generalist to utilise woodland habitat.

A brief sensitivity analysis indicated that the assumptions used in the modelling process appear to be robust, although we will be undertaking further, more complex, sensitivity testing as the regional analyses progress.

A case study undertaken for the Atlantic oakwoods surrounding Loch Sunart demonstrated how the restoration and management of relatively small areas of oakwood can be targeted to reduce habitat fragmentation of the existing Atlantic oakwood habitat, allowing dispersal across a much larger geographic area. In addition, the analysis identified oakwood patches that may be too small to support characteristic sedentary species that require substantial habitat to maintain viability, enabling directed management to be undertaken.

The FHN analyses from this work will be used in 2006 to direct new Scottish Forestry Grant Schemes in Highland conservancy by offering an additional premium for targeted planting which will functionally connect habitat fragments. A methodology has been developed to assess network connectivity, score each application, and determine how much locational premium will be paid. This will be a valuable use of the FHN approach, as previous schemes have been spatially unconstrained and have consequently not addressed the problem of habitat fragmentation.

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Introduction

Scotland FHN project

The national analysis gave a broad explanation of how the Biological and Environmental Evaluation Tools for Landscape Ecology (BEETLE) model tests the landscape pattern against 'focal' species profiles [VanRooij *et al.* 2001]. In this Scotland FHN project we have used the Generic Focal Species (GFS) approach. The outputs of the model are assessed in terms of: how the spatial arrangement of patches in the landscape, facilitate utilisation by the GFS; and where the habitat size and the dispersal distance between patches is constrained. In addition, the model allows an examination of how plans might affect species that utilise open habitats. It is just as important to avoid fragmenting open habitats of high ecological value, as to improve the functional connectivity for woodland species.

The BEETLE method was used to assess forest and open habitat networks at the national scale (Ray *et al.* 2005). This report deals with the next stage of analysis at the regional scale, for the FC Highland conservancy region. The work has been organised and researched in a way that provides a practical plan for developing FHNs at the Highland 'regional' scale. A major component of the work has been the collection of data to take account of the variability in habitat quality and the determination of complex associations. The maps for woodland specialist networks include a rudimentary biodiversity appraisal that has allowed us to judge where high biodiversity value source habitat exists, and how it influences specialist networks. Moreover, it shows a practical, objective planning approach in the use of landscape models to investigate the impact of landcover on species viability and dispersal at the landscape scale. Subsequently, the manipulation and analyses of the data sets has been time-consuming.

Methods

Generic Focal Species GFS

The analyses undertaken for Highland Conservancy focused on three GFS associated with specific woodland types: Atlantic oakwood specialists; ancient pinewood specialists; and pinewood specialists.

<u>Atlantic oakwoods</u>

The location and extent of woodlands that may be classified as Atlantic oakwoods is poorly understood, making identification of relevant stands for analysis difficult. In Highland Conservancy, Atlantic oakwoods are mainly composed of upland oak woodland, which is characterised by a predominance of oak (most frequently sessile, but pedunculate can be locally common) and birch in the canopy, with varying amounts of holly, rowan and hazel as the main understory species (Hall & Kirby 1998). The proportion of birch increases towards the north-west, where upland oak woodland is usually replaced by Northern Birchwoods.

This study focused upon upland oak woodlands which are designated as NVC W11 and W17 and are dominated by sessile oak, as these are most closely associated with Atlantic oakwoods. However in the past many of the oakwoods have been neglected and heavily grazed by sheep and deer (*e.g.* UK Biodiversity Action Group 1995; Humphrey *et al.* 2004), and some oakwoods were underplanted.

<u>Ancient Scots pinewoods and plantation Scots pinewoods</u>

Scots pinewoods are widely distributed across Highland Conservancy, comprising of ancient semi-natural and semi-natural pinewoods, planted woods of native species, new native woodlands, and plantations of Scots pine. The native, or Caledonian, pinewood comprises relict, indigenous pine forests of Scots pine (*Pinus sylvestris* var. *scotica*), and associated birch (*Betula* spp.) and juniper (*Juniperus communis*) woodlands of northern character. The majority

of this habitat corresponds to NVC type W18 (*Pinus sylvestris – Hylocomium splendens*) woodland, but it also includes some birch-dominated stands of W17 (*Quercus petraea – Betula pubescens – Dicranum majus*) woodland and W4 (*Betula pubescens – Molinia caerulea*) woodland. The analyses undertaken in this work are concerned mainly with the NVC type W18. Pinewoods naturally occur on strongly leached podzolic soils, and are commonly associated with downy birch in the west and silver birch towards the east. Rowan may be common locally, with sporadic Juniper and clumps of other broadleaved trees and shrubs, including alder, aspen, bird cherry, hazel, and rowan. Temporal variation in stand structure can occur, with mature pine stands naturally giving way to mixed young stands of birch, rowan and other broadleaves, before reverting to pine as the stand matures.
The field layer is characterised by acid tolerant plants such as wavy hairgrass (*Deschampsia flexuosa*), heather (*Calluna vulgaris*), blaeberry (*Vaccinium myrtillus*), cowberry (*Vaccinium vitis-idaea*), and occasionally crowberry (*Empetrum nigrum*). In western pinewoods, these shrubs are less abundant, with sedges and purple moorgrass (*Molinia caerulea*) becoming more prevalent and mosses, particularly *Sphagnum* species, and liverworts occurring on wetter ground. Rare plant species such as *Pyrola* wintergreens and twinflower are often found in the pinewoods.

Datasets

The following datasets were used in addition to those used for the national analyses:

- National Inventory of Woods and Trees (NIWT)
- Scottish Semi Natural Woodland Inventory (SSNWI)
- Scottish Ancient Woodland (derived from two Scottish inventories: the Inventory of Ancient and Long-established woodland sites, and the Inventory of Semi-natural woodlands.
- Caledonian Pinewood Inventory (CPI)
- Forest Enterprise (FE) sub-compartment database
- Native Woodland Model
- New planting datasets – Woodland Grant Scheme 3 (WGS3), Scottish Forestry Grant Scheme (SFGS), Forest Plan (Fplan)

Data preparation

Regional landcover matrix

The base landcover matrix constructed for the national analysis was used in these analyses, as was the application of an elevation factor of 2 to the cost matrix to reflect the higher cost of species dispersal at elevations over 500 m.

Focal species profiles and dispersal costs

Focal species profiles for regional scale analyses

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

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

In addition to the treatment of dispersal ability in the model we have considered three GFS types:

- Atlantic oakwood specialists
- ancient pinewood specialists
- pinewood specialists

Two time periods have been chosen to reflect the effects of remedial work currently being undertaken to improve the quality of many of the pine, and oak, woodlands:

- Current (2005) using original habitat quality designations and original costs
- Projected (2055) using a revised habitat dataset in which those areas that experts had identified as being poor or average quality now, but were expected to increase in quality in the next 50 years, were given a higher quality score and therefore a lower cost. If the new quality designation was 'good', those stands were added to the habitat. Costs for non-habitat were also revised to reflect maturing stands, *i.e.* recently planted or young stands would provide better habitat in 50 years time and therefore would have lower costs.

For the Atlantic oakwood specialist, two predictive datasets were used:

- Restricted (using woodland corresponding with NVC identifiers 70, 71, 72, 73, 75, 83)
- Inclusive (using woodland corresponding with NVC identifiers 70 to 75, 80 to 84, 122, 125, 126)

Each GFS can take each of the three dispersal characteristics, and both of the time periods, giving 18 permutations for analysis. The use of two predictive datasets for the Atlantic oakwood specialist provides 6 additional analyses, increasing the total number of permutations to 24. At two meetings of members of the FHN Scotland Steering Group, the focal species profiles for ancient pinewood specialists and pinewood specialists were discussed and provisionally agreed. Costs for Atlantic oakwood specialists were derived from the broadleaved woodland specialist costs previously agreed by the FHN Scotland Steering Group.

We will wait until a number of regional analyses have been undertaken to determine how the geographic variation in landcover influences costs.

The farm and parkland category has been split between uplands and lowlands, for the reasons described in Forest Habitat Networks Scotland – Progress Report March 2005: farm and parkland often described wood pasture in the uplands and thus had a high biodiversity value as it is extensively managed, whereas in the lowlands farm and parkland was often degraded shelter belt woodland of less biodiversity value, consisting largely of highly modified and managed land. Upland and lowland areas (shown in Figure 1) have been defined using climate, geology and landuse (Humphrey *et.al*. 2005).

Differentiation of the cost of dispersal through coniferous plantation to reflect the relatively more open canopy of pine plantation compared to spruce plantation has not been included in the Highland Conservancy analyses. The drawback to this approach is that it would lead to a large area of non-pine coniferous woodland being designated as pine habitat for the pine woodland specialist, resulting in an artificially high number of habitat networks. Subsequently, we could have little confidence in the predicted networks and the analyses would invite criticism.

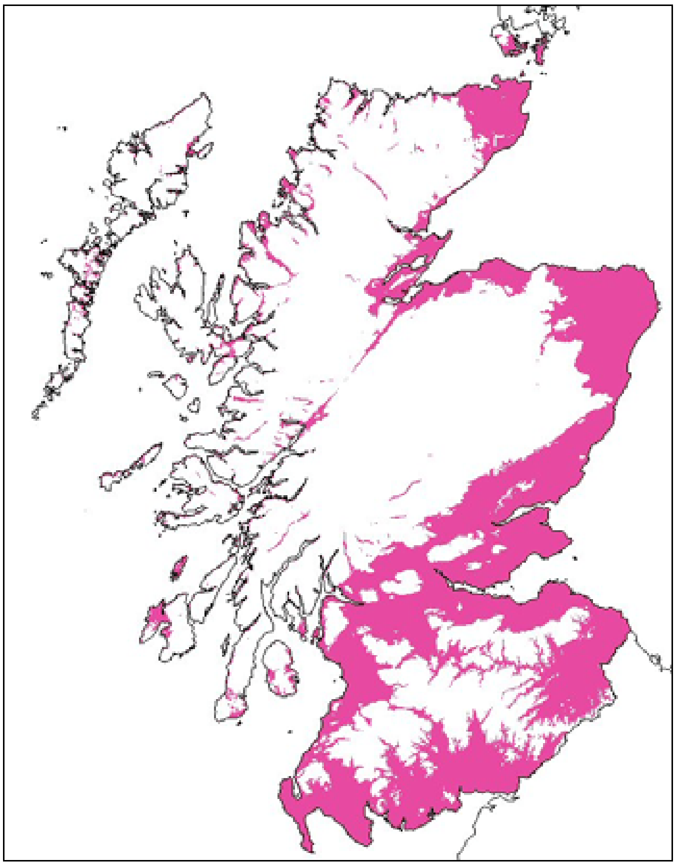


Figure 1 Location of lowland zone (Humphrey *et al.* 2005)

Atlantic oakwood specialists

The definition of habitat for Atlantic oakwood specialists has been derived from considered discussion between Duncan Stone, Duncan Ray, and Darren Moseley during June to August 2005. Habitat is defined as: SSNWI = 80 to 90% broadleaved or broadleaved, 80 to 90% semi-natural or semi-natural, with a minimum canopy cover of 10% and spatially corresponding to NWM sessile oak sites under 200 m elevation. It was assumed that Atlantic oakwood specialists would require oakwood habitat and would also be sensitive to the woodland edge. This was represented within the GIS by the internal buffering of a distance of 2 tree heights (50 m), which is considered to be the normal extent of any edge effects (Murica 1995). A 50 metre internal buffer was removed from the habitat layer. Although the 50 metre edge was not considered as source habitat, it was assigned a cost of 1 in the land cover matrix. Other SSNWI data excluded from the defined habitat has been added to the cost matrix in the following manner:

- SSNWI < 10% canopy cover — cost = 2
- upland areas of farm/parkland — cost = 5
- lowland areas of farm or parkland — cost = 15
- other SSNWI & NIWT data — cost = 2

Ancient pine woodland specialists

The definition of habitat for ancient pine woodland specialists has been derived from discussions between Duncan Stone, Duncan Ray, Louise Sing, and Darren Moseley in May 2005 and further considered discussion between Duncan Ray and Darren Moseley during June and July 2005. Habitat is defined as: SSNWI = 80 to 90% coniferous or coniferous, 80 to 90%

semi-natural or semi-natural, with a minimum canopy cover of 50%; NIWT = indicative forest type is semi-natural, coniferous; CPI = Caledonian pinewood. A 50 m buffer, representing the edge effect, was applied as described for Atlantic oakwood specialists, with the area removed being assigned a cost of 1 in the land cover matrix. Other SSNWI data excluded from the defined habitat has been added to the cost matrix as per Atlantic oakwood specialists.

Pinewood specialists

The definition of habitat for pinewood specialists has been derived from discussions between Duncan Stone, Duncan Ray, Louise Sing, and Darren Moseley in May 2005 and further considered discussion between Duncan Ray and Darren Moseley during June and July 2005. Habitat is defined as: SSNWI = 80 to 90% coniferous or coniferous, 80 to 90% semi-natural or semi-natural; NIWT = indicative forest type is semi-natural, coniferous; CPI = Caledonian pinewood, or cal planted area; FE/Estate sub-compartment database = Scots pine. A 50 m buffer, representing the edge effect, applied as described for Atlantic oakwood specialists, with the area removed being assigned a cost of 1 in the land cover matrix. Other SSNWI data excluded from the defined habitat has been added to the cost matrix as per Atlantic oakwood specialists.

A list of some of the dispersal costs used in the analyses are shown in Appendix 1.

Habitat

In identifying the specific woodland types for which we wish to develop FHNs *e.g.* Atlantic oakwoods, ancient pinewoods, and pinewoods, it was apparent that the data sources, the spatial inventories of woodland, did not allow identification of some woodland. Since it was important to identify woodland and their quality wherever possible, an interview with local woodland officers and foresters was organised to confirm woodland type and identify quality information. The interview was designed to 'broadly' categorise the main species and quality of major woodland blocks. The scope, scale and resources of the FHN project do not permit a very detailed description of woodlands at the sub-compartment level, therefore the interview and interpretation focused on an overall score for woodland blocks. For the purposes of woodland assessment, areas under 2 ha were not considered as most would be eliminated in the GIS analysis during the removal of the 50 m internal buffer.

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

1. Structure
1.a. 'Good' structural composition will include: tree species mix suited to the site, multi-layer canopy, gaps in the canopy. The majority of the trees would be at least 100 years old.
1.b. 'Moderate' composition will include two of the factors described in 1.a.
1.c. 'Poor' composition will include one or none of the factors described in 1.a.

2. Deadwood
2.a. 'Good' deadwood component will include the following elements in varying stages of decay: some standing deadwood – snags (and hung broken branches), sap runs, fallen deadwood.
2.b. 'Moderate' deadwood will include two of the factors described in 2.a.
2.c. 'Poor' deadwood will include one or none of the factors described in 2.a.

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

3.c. 'Poor' field layer will include one or none of the factors described in 3.a.
The assessment is based upon a union of the SSNWI, the NIWT, and FE and estates sub-compartment databases. In addition the CPI and ASNWI are used for identifying ancient pinewoods and pinewoods.
A single overall quality score is agreed by the woodland officer or forester based upon structure, deadwood, and field layer quality, set out in combinations shown in Table 1.

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

	Component Quality		
Overall quality	Good	Moderate	Poor
Good	3	-	-
Good	2	1	-
Moderate	2	-	1
Moderate	1	2	-
Moderate	1	1	1
Moderate	-	3	-
Moderate	-	2	1
Poor	1	-	2
Poor	-	1	2
Poor	-	-	3

Woodland officers or foresters regularly commented on woodland blocks for which management plans are in place. This allowed us to pose an assumption that current plans will lead to a significant improvement in biodiversity quality, and allow the construction of a woodland model which includes new source habitat and more extensive woodland conducive to movement and dispersal. The specially managed woodlands were flagged within the spatial database so that a separate analysis could be conducted to predict the contribution of woodlands as habitat sources in 50 years time.

Atlantic oakwood specialists

Habitat for Atlantic oakwood specialists was identified from a number of sources (see Appendix 2b for details of all sources and the rules used to derive the data). FE and estate sub-compartment databases were qualified by forest managers and other experts in each of the districts within Highland Conservancy with regard to the quality of the Atlantic oakwood.

As the amount of time required to collect private woodland data was too great, an alternative approach was taken, based on a methodology developed by Bryce (2002) (Figure 2). This identified Sessile oakwood extent based on potential woodland type as predicted by the SNH MLURI Native Woodland Model (Towers 2002) combined with the SSNWI (Sessile oak forms the major component of Atlantic oakwoods in the Highlands (Hall & Kirby 1998)). The criteria were:

- SSNWI woodland that was semi-natural or 80 to 90% semi-natural broadleaved, with a minimum of 10% canopy cover (the categories 'fragmented and open' (1 to 9%) and 'open' (<1%) were excluded as it is unlikely that such areas would constitute Atlantic oakwoods)
- Native woodland model NVC identifiers most likely to form sessile oakwoods were chosen (70 to 75, 80 to 84, 122, 125, 126, *i.e.* the main types (Table 2))

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

NVC Identifier	NVC type
70	W11 (Upland oakwood)
71	W11/W4 (Upland oakwood or downy birch wet woodland)
72	W11/W17 (Upland oakwood or Northern birchwood)
73	W11 & W7 mosaic (Upland oakwood and alder-ash wet woodland mosaic)
74	W11/W9 (Upland oakwood or ashwood)
75	W11/W7 (Upland oakwood or alder-ash wet woodland)
80	W17 (Northern birchwood)
81	W17 & W4 mosaic (Northern birchwood & downy birch wet woodland mosaic)
82	W17/W18 (Northern birchwood or native pinewood)
83	W17/W11 (Northern birchwood or Upland oakwood)
84	W17/W18 & W4 (Northern birchwood or native pinewood & downy birch wet woodland with open ground)
122	W4 & W17 mosaic (Downy birch wet woodland & Upland oakwood mosaic)
125	W4/Sc5/W17/W18 (Downy birch wet woodland with open ground & peatland with scattered trees/scrub & Northern birchwood or native pinewood mosaic)
126	W4/W17/W18 (Downy birch wet woodland with open ground & northern birchwood or native pinewood mosaic)

Site altitude was used to distinguish areas likely to conform to the CORINE (Commission of the European Communities 1991) oakwood definitions (41.532 British sessile oakwood) rather than the associated birchwood types (41.B12 Medio-European dry acidophilous birch woods and 41.B2 Sub-boreal birch woods), as sites at higher elevation are more likely to tend towards birchwood types. Examination of the existing selection of oakwood candidate Special Areas of Conservation (cSACs) (European Commission 1992) provided a guide to the maximum likely altitude of these oakwood types, with a 200 m filter being adopted.

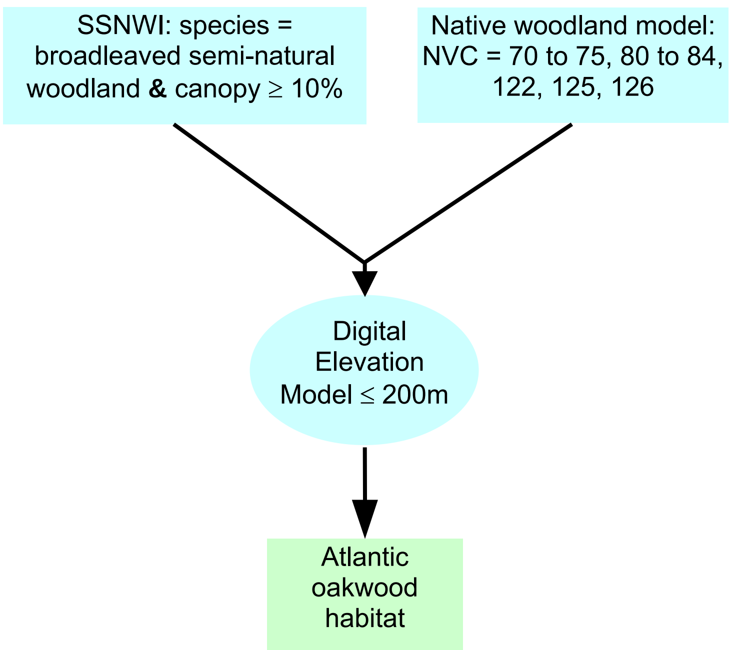


Figure 2. The methodology used to predict the inclusive dataset of Atlantic oakwood habitat using the Native Woodland Model (NWM) and Scottish Semi-natural Woodland Inventory (SSNWI) data. The restricted dataset was derived in the same way, but only used NVC identifiers 70, 71, 72, 73, 75, 83).

A second, restricted, dataset was derived, using only identifiers with W11 present either as a single type or in mosaics (NVC identifiers 70, 71, 72, 73, 75, 83). These were thought to be the categories most likely to correspond to old sessile oakwoods with oak present rather than woods that may be purely birch.

The restricted dataset and the original, inclusive, dataset were designated as good quality oak and added to a restricted Atlantic oakwood analysis or an inclusive Atlantic oakwood analysis respectively.

The original predictions produced by Bryce (2002) had been ground-truthed based on a sample size of 86 woodland blocks. The proportion of the sample sites found to be of qualifying habitat was extrapolated to indicate the range within which the true extent of old sessile oakwoods in Scotland is likely to lie. Those areas of oak woodland from Bryce's (2002) original data that had been ground-truthed as having a proportion of area qualifying as oak woodland > 0.3 were designated as good quality sessile oak woodland and incorporated into the current analyses as habitat. Areas in which the proportion of area qualifying as oak woodland was < 0.3 or had not been qualified, was designated as poor quality oak woodland.

Ancient pine woodland specialists

Habitat for ancient pine woodland specialists was identified from NIWT (where indicative forest type is semi-natural coniferous) and from SSNWI, using the conifer categories with a naturalness category of either semi-natural, 80 to 90% semi-natural, or mixed semi-natural/planted where canopy cover was greater than 50%.

Each of these datasets was qualified by forest managers and other experts in each of the districts within Highland Conservancy with regard to the quality of the ancient pine woodland. Unknown areas were designated as unqualified pinewood and given a higher dispersal cost of 1.75 for areas with a canopy cover greater than 50% and a cost of 1.5 for those areas with a canopy cover less than 50% (Appendix 1).

The SSNWI woodland excluded as habitat was added to the landcover matrix.

Appendix 2c describes the data sources and rules used to designate costs for each ancient pinewood type

Pine woodland specialists

Habitat for pine woodland specialists was identified from NIWT (where indicative forest type is semi-natural coniferous) and from SSNWI, using the conifer categories with a naturalness category of semi-natural, 80 to 90% semi-natural, or mixed semi-natural/planted. The SSNWI woodland excluded as habitat was added to the landcover matrix. The WGS3, Fplan, and SFGS datasets and the ancient woodland inventory was used to identify new planting, or restocking, of pine stands not captured by the SSNWI or NIWT datasets.

Appendix 2d describes the data sources and rules used to designate costs for each pinewood type

Sensitivity analyses
A series of sensitivity analyses were undertaken to test the robustness of the dispersal costs applied to each of the generic focal species by increasing and decreasing costs by 20%.

Atlantic oakwood specialists
An analysis was undertaken on a 50 km square centred on Moidart, an area associated with a large extent of high quality Atlantic oakwood, incorporating Loch Sunart.

Extent of analysis: Left 145000.8283, Right 201000.8283, Bottom 748000, Top 800500

Ancient pinewood specialists
An analysis was undertaken on a 50 km square centred on Strathspey, an area which incorporates a large proportion of the Ancient pine woodland in Scotland.

Extent of analysis: Left 268762.8283, Right 318762.8283, Bottom 785311, Top 835311

Potential interactions between woodland specialists and heathland generalists

Consideration has been given to how the woodland in general, and the Atlantic oakwood, ancient pinewood, and pinewood specialist networks in particular, might overlap with open habitat species networks. It is important to consider the impact on the biodiversity of open habitats of high ecological value, that could be fragmented by woodland expansion, and mitigate the effects by careful planning. The heathland generalist represented the GFS open ground users in this analysis.

Use of the BEETLE FHN approach as a management tool – case study

A case study was undertaken to demonstrate how the BEETLE FHN approach can be used as a decision-support tool by forest managers or planning agencies to direct forest habitat expansion. The study area was centred upon Loch Sunart, where Atlantic oakwood habitat has high importance. A relatively small dispersal distance (250 m) was considered appropriate, as the specialist species that define Atlantic oakwoods tend to belong to the bryophyte group. Two BEETLE analyses were undertaken, the first using existing habitat, and the second demonstrating how strategic additions of oak woodland may be used to consolidate the networks.

Use of the BEETLE FHN approach for determining eligibility of new planting plans for the Highland Locational Premium Scheme (HLPS).

Following the announcement of a locational premium scheme in Highland, a methodology was developed to assess whether a proposal would achieve network connectivity and, if so, how much locational premium would be paid.

Results & Discussion

Generic focal species networks

Atlantic oakwood specialists

The approach using the restricted dataset (Tables 3 & 4) produced fewer networks and a smaller total area of networks than the analysis of the inclusive dataset (Tables 5 & 6). However, the mean area of the restricted networks, at all dispersal distances, was more than twice as large as those produced by the inclusive dataset, indicating that the restricted networks, although less extensive in Highland Conservancy, are less fragmented than the inclusive networks. It was considered that using the restricted dataset would provide a more robust approach than using the inclusive dataset as the woodland types captured by the restricted methodology should exclude areas where oak gives way to birch.

The difference between the current (2005) and projected (2055) analyses was less pronounced than those between datasets, with the 2055 analyses producing a reduced number of slightly larger networks than the current dataset. However, this difference does reflect the effect of maturing woodland, which has been represented by the current (2005) high dispersal costs through young woodland being reduced in the 2055 analysis.

Restricted dataset

Table 3. Summary statistics of the 2005 restricted dataset networks for Atlantic oakwood specialists within Highland Conservancy.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	1 945	31 288	16.1	514
500	1 607	38 740	24.1	623
1000	1 289	51 396	39.9	755

Table 4. Summary statistics of the 2055 restricted dataset networks for Atlantic oakwood specialists within Highland Conservancy.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	1 916	31 809	16.6	515
500	1 575	39 829	25.3	634
1000	1 250	53 628	42.9	768

Inclusive dataset

Table 5. Summary statistics of the 2005 inclusive dataset networks for Atlantic oakwood specialists within Highland Conservancy.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	5 317	41 330	7.8	568
500	4 649	50 913	11.0	766
1000	3 900	67 254	17.2	1 093

Table 6. Summary statistics of the 2055 inclusive dataset networks for Atlantic oakwood specialists within Highland Conservancy.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	5 263	41 982	8.0	570
500	4 577	52 265	11.4	780
1000	3 810	70 035	18.4	1 080

Ancient pinewood specialists

The projected (2055) analysis using the revised habitat dataset (Table 8) indicated that work currently being undertaken to improve woodland quality in a number of stands through FCS management grants, together with young stands becoming more utilisable by ancient pinewood specialists, will consolidate a number of ancient pinewoods.

Table 7. Summary statistics of the 2005 dataset networks for ancient pinewood specialists within Highland Conservancy.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	340	32 395	95.3	6 257
500	262	37 048	141.4	7 099
1000	202	43 463	215.2	8 159

Table 8. Summary statistics of the 2055 dataset networks for ancient pinewood specialists within Highland Conservancy.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	319	34 201	107.2	6 375
500	242	39 995	165.3	7 236
1000	185	47 024	254.2	8 345

Pinewood specialists

The pinewood specialist analyses indicate that the networks for this GFS are both extensive and individually large (Table 9). The differences between the networks produced by the current (2005) and projected (2055) analyses whilst small, indicate future consolidation of the pinewood specialist networks.

Table 9. Summary statistics of the 2005 dataset networks for pinewood specialists within Highland Conservancy.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	2 300	136 880	59.5	10 181
500	1 694	156 085	92.1	12 623
1000	1 247	181 872	145.8	13 264

Table 10. Summary statistics of the 2055 dataset networks for pinewood specialists within Highland Conservancy.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	2 087	140 353	67.3	12 079
500	1 523	161 767	106.2	12 727
1000	1 100	191 138	173.7	13 450

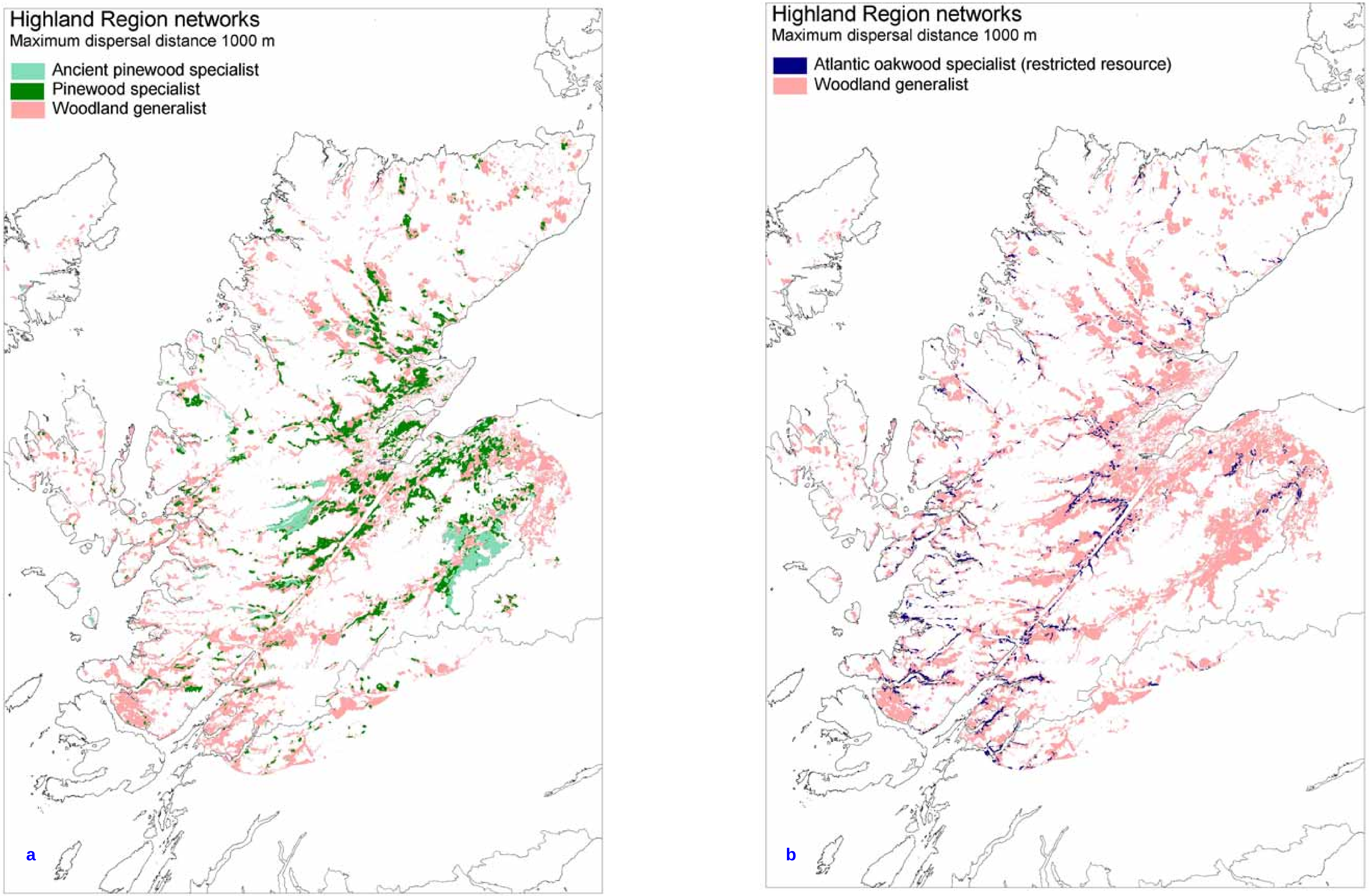


Figure 3. The distribution of forest habitat networks in Highland Conservancy at a maximum 1000 m dispersal distance showing (a) Ancient pinewood specialists nested on top of pinewood specialists, which are in turn nested on top of the woodland generalist network; (b) Atlantic oakwood specialists nested on top of the woodland generalist network.

Potential interactions between woodland specialists and heathland generalists

The areas where potential interactions may occur between the woodland specialists used in these analyses and heathland generalists are shown in Figure 4. The overlap between heathland and the woodland specialist networks accounted for between 11% and 28% of the woodland specialist habitat, but less than 2% of the heathland habitat (Table 11). This is clearly a function of the size of the networks, but also highlights the ability of the heathland generalist to utilise woodland habitat.

Table 11. The overlap of the heathland generalist network with Atlantic oakwood, ancient pinewood, and pinewood specialist networks at a maximum 1000 m dispersal distance.

Generic focal species	Area of GFS (ha)	Area of overlap (ha) between woodland specialists and heathland generalist	Percentage of woodland specialist network in heathland network	Percentage of heathland network in woodland specialist network
Atlantic oakwood specialist	51 396	14 088	0.6%	27.4%
Ancient pinewood specialist	43 463	4 780	0.2%	11.0%
Pinewood specialist	206 037	33 701	1.4%	16.4%
Heathland generalist	2 471 549			

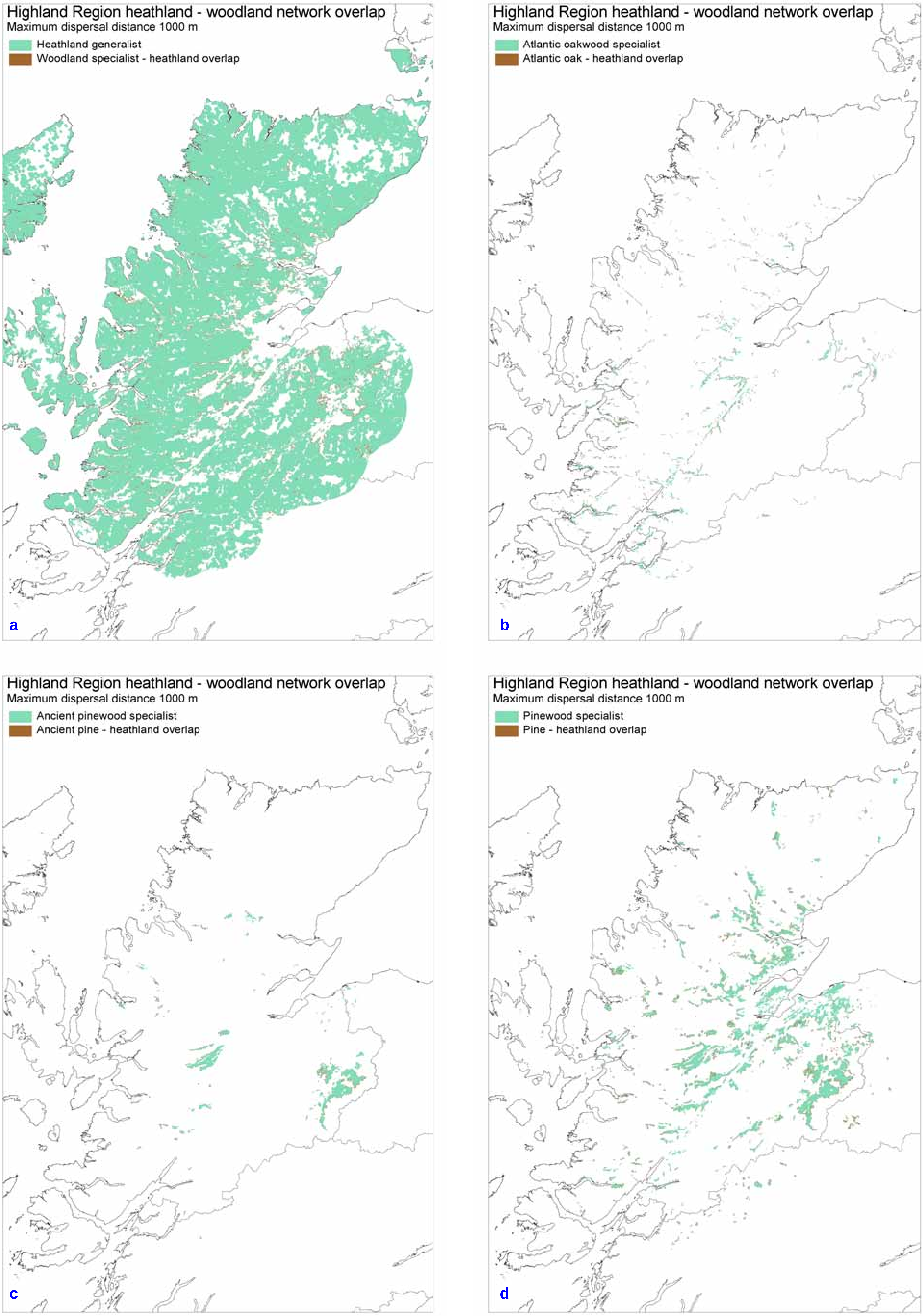


Figure 4 Potential interactions in Highland Conservancy at a maximum 1000 m dispersal distance between: (a) heathland generalists and woodland specialists; (b) Atlantic oakwood specialists and heathland generalists; (c) Ancient pinewood specialists and heathland generalists; (d) Pinewood specialists and heathland generalists. The distribution of specialist forest habitat networks and the area of overlap between the heathland generalist are shown.

Sensitivity analyses

Whilst increasing and decreasing the dispersal costs for Atlantic oakwood specialists and Ancient pinewood specialists by 20% affected the number and size of networks produced, the differences did not produce spurious results (Tables 12 to 17). This indicates that the assumptions used in the modelling process are appear to be robust, although we will be undertaking further sensitivity testing as the regional analyses progress.

Atlantic oakwood specialists

Table 12. Summary statistics of the 2005 dataset networks for Atlantic oakwood specialists within Highland Conservancy using original costs.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	284	5 679	20.0	278
500	238	6 850	28.8	332
1000	197	8 694	44.1	469

Table 13. Summary statistics of the 2005 dataset networks for Atlantic oakwood specialists within Highland Conservancy with costs increased by 20%.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	297	5 445	18.3	269
500	247	6 506	26.3	320
1000	204	8 125	39.8	447

Table 14. Summary statistics of the 2005 dataset networks for Atlantic oakwood specialists within Highland Conservancy with costs decreased by 20%.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	268	5 985	22.3	286
500	230	7 339	31.9	347
1000	185	9 485	51.3	532

Ancient pinewood specialists

Table 15. Summary statistics of the 2005 dataset networks for ancient pinewood specialists within Highland Conservancy using original costs.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	113	18795	166.3	6237
500	91	20639	226.8	7087
1000	72	23299	323.6	8161

Table 16. Summary statistics of the 2005 dataset networks for ancient pinewood specialists within Highland Conservancy with costs decreased by 20%.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	120	18395	153.3	6110
500	96	20042	208.8	6864
1000	78	22514	288.6	7909

Table 17. Summary statistics of the 2005 dataset networks for ancient pinewood specialists within Highland Conservancy with costs increased by 20%.

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	104	19315	185.7	6379
500	87	21433	246.4	7335
1000	66	24349	368.9	8446

Suggested application of the FHN analyses

The FHN analyses can be used to inform decision making at both national and regional scales. Whilst the former is most useful for strategic decisions, the latter allows for geographic variation in forest type. The Forest Research Landscape Ecology group suggests the priority for addressing woodland fragmentation should be:

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

<u>National scale</u>

- Identification of fragmented woodland that can be **consolidated** by **woodland improvement**. These areas can be identified locally as small clusters of networks.
- Identification of existing habitat patches or ‘nodes’, from which buffered **expansion** and/or **restoration** can be undertaken to increase patch size.
- **Broadleaved specialist networks** can be placed on top of woodland generalist networks to indicate where broadleaved specialist networks can be **expanded** through **restructuring** of other woodland, *i.e.* conversion to broadleaved, removal of conifers from mixed woodland (Figure 1).
- **Woodland generalist networks**: where appropriate, some managed open habitat may be converted into a more semi-natural open habitat, which will allow greater dispersal of woodland generalists and allow greater network size and **connectivity** (Figure 1).
- Identification of opportunities for **connecting** existing **broadleaved specialist networks** to increase patch size, allowing species with high area requirements to be supported (Figure 1). Tree species planted should be suited to the habitat type, *e.g.* native broadleaves to be selected for high quality broadleaved networks.
- Examination at the different dispersal distances (500 m, 1000 m, and 5000 m) allowing the analyses to be applied to a range of species, smaller dispersal distances indicating how the networks become increasingly fragmented for more sedentary species.
- Identification of **open ground** areas where forest expansion is not appropriate.
- Determine how forest plans can be developed to **minimise disruption** to existing FHNs.
- Examination of the broadleaved woodland specialist networks to **identify potential threats** posed by grey squirrel movement into red squirrel enclaves.

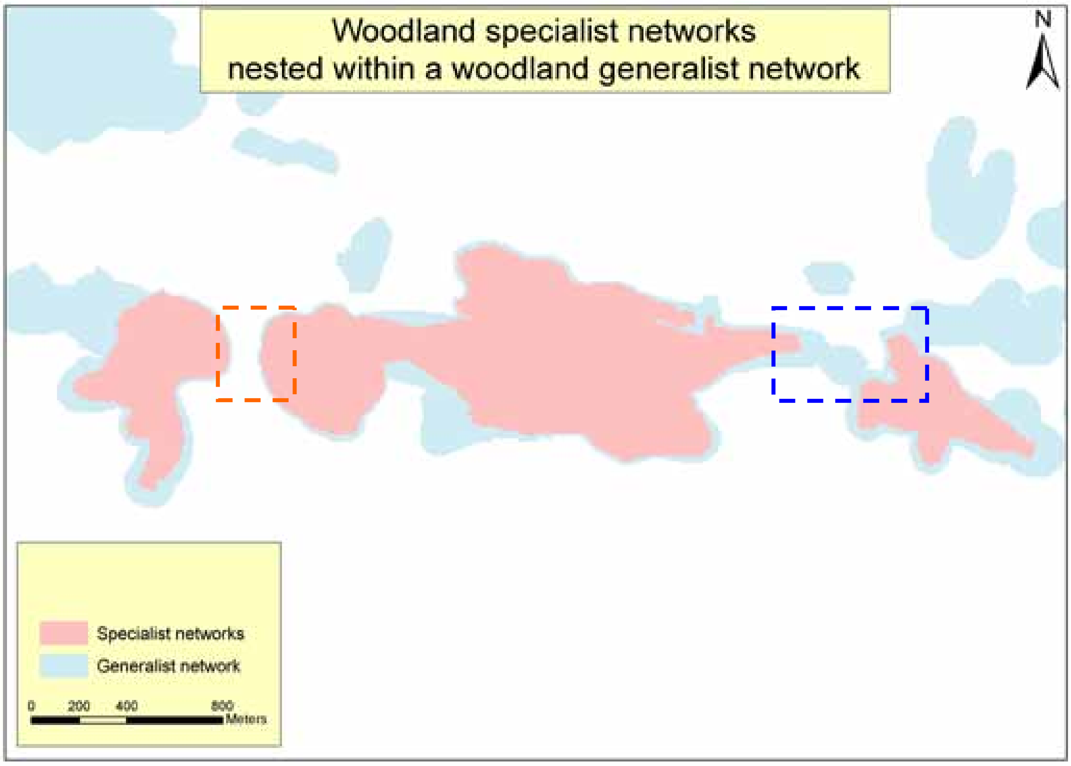


Figure 1. Example of where a specialist network can be expanded through restructuring existing woodland (area highlighted by the blue dashed box) and where open habitat may be converted into a more semi-natural open habitat to functionally connect existing networks (area highlighted by the orange dashed box).

Regional scale

- All **high quality woodland** should be **expanded** by planting contiguous patches or buffered expansion.
- Those woodlands containing **high quality patches of either ancient pinewood or Atlantic oakwood** should be designated for **consolidation** and **buffered expansion**. It is important to designate these areas as nodes, which should be protected, from where expansion of the network biodiversity can begin.
- Those woodlands containing **medium quality patches of either ancient pinewood or Atlantic oakwood** should be designated for **structural management**, to improve the condition of the woodland to encourage a greater number of ancient woodland indicator species (Figure 2). This would bring these areas into the **higher quality woodland categories**. Management should concentrate on approaches that maintain and enhance the existing ground flora, encourage deadwood, and produce a multi-layer tree and shrub structure.

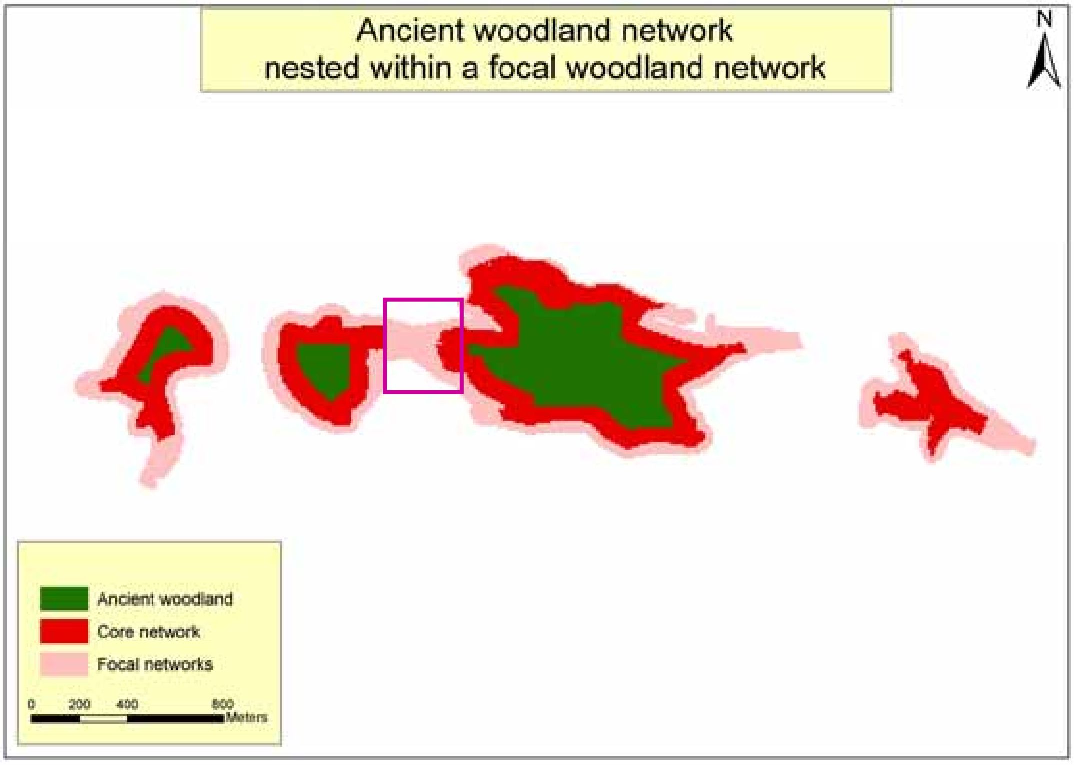


Figure 2. Example of where an ancient or high quality woodland patch (green) within it's 'core' network (bright red), which is nested within a lower quality 'focal' specialist networks (pale red). The purple dashed box highlights where restoration of woodland can be undertaken to increase woodland quality, linking the two areas of ancient or high quality woodland in the core network.

- Where appropriate, woodland **stepping stones** should be introduced to link existing networks (Figure 3).
- Woodlands occurring on ancient woodland sites, but not indicated as high/good quality should be rehabilitated to increase the quality of the woodland. Steps taken may include **livestock exclusion** or **removal of exotic species**.
- **Habitat condition monitoring** can be used to identify those areas that may be quickly be brought up to a good quality, thus increasing 'core forest areas' and consequently networks for **high quality specialists** (ancient pinewood, Atlantic oakwood).

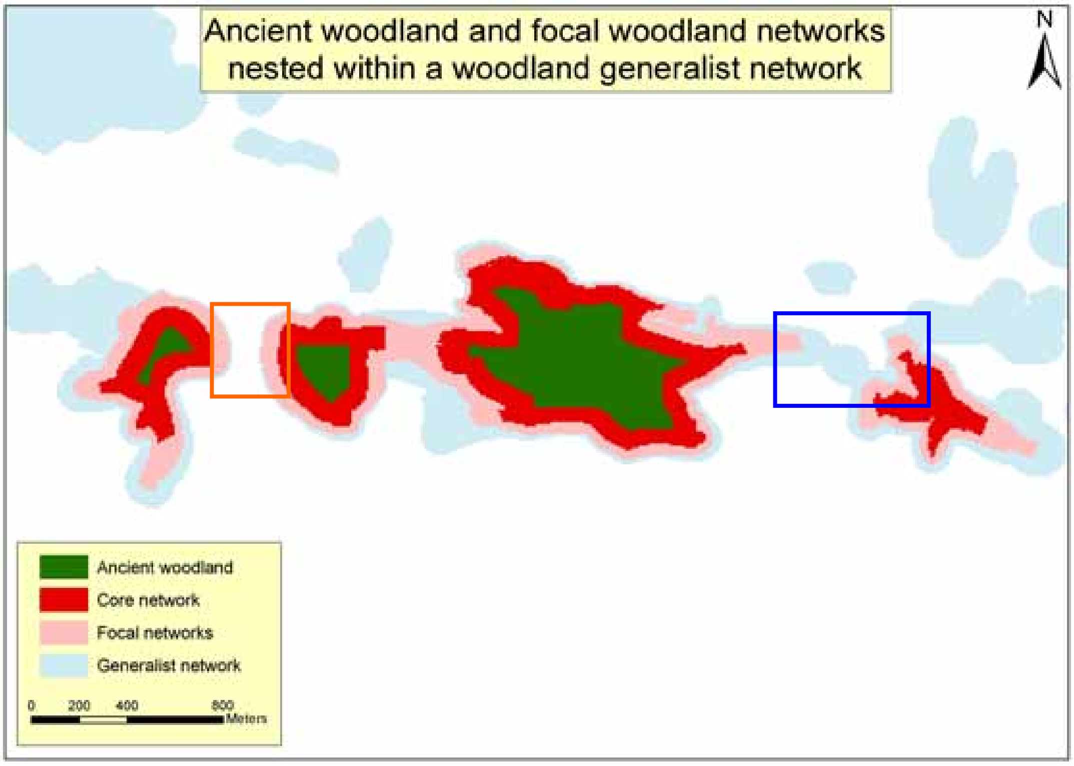


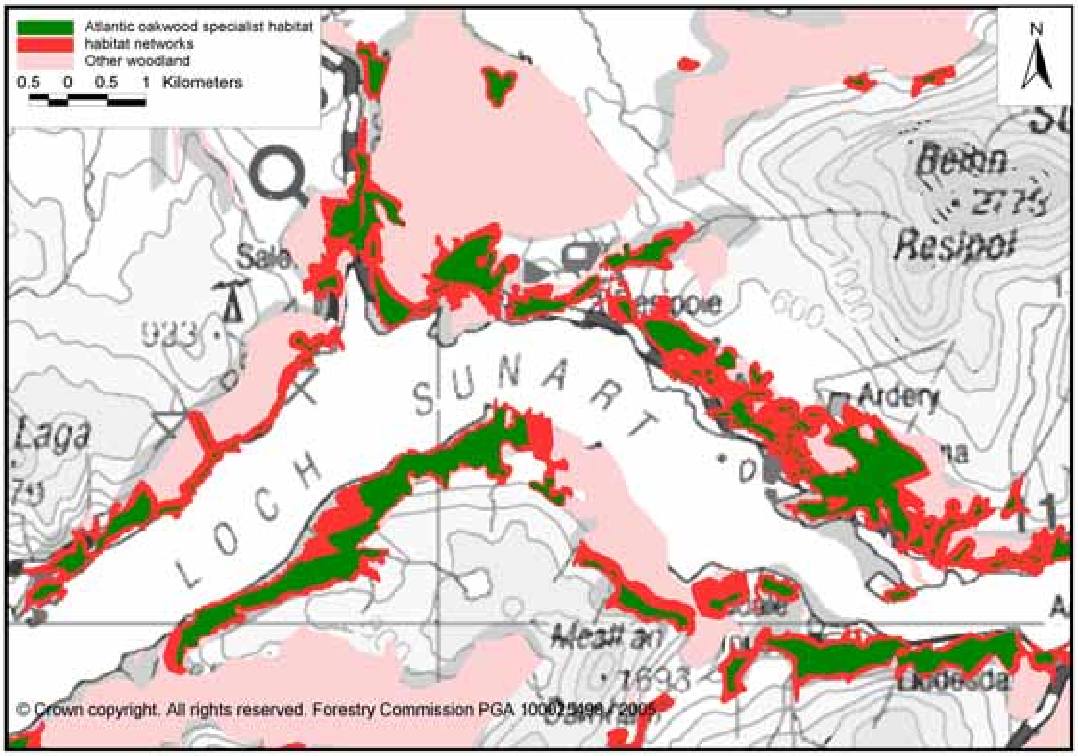
Figure 3. Example of where an ancient or high quality woodland patch (green) within it's 'core' network (bright red), which is nested within a lower quality 'focal' specialist networks (pale red), which in turn is situated within the woodland generalist network (pale blue). The blue dashed box indicates where the woodland may be transformed from it's current type to become part of the focal network, allowing dispersal to occur between the central and right hand side network. The orange dashed box indicates where a woodland 'stepping stone' may be planted to functionally connect the existing networks.

Use of the BEETLE FHN approach as a management tool – case study

The consolidation of networks can be clearly seen at a local scale around the shores of Loch Sunart area (Table 18 & Figure 5) when comparing the maximum dispersal distances of (Figure 5a) 1000 m and (Figure 5b) 250 m. The obvious difference between the two networks is greater connectivity of woodland for the 1000 m dispersal distance, indicating that, in this location, those species with high dispersal ability should be able to move freely through the woodland which separates the fragmented patches of Atlantic oakwood. For those species with low dispersal ability (Figure 5b) movement between habitat patches may be restricted, with some of the functional networks unlikely to be large enough to support species with a high area requirement. Figure 5c demonstrates how the restoration and management of relatively small areas of oakwood can be targeted to reduce habitat fragmentation of the existing Atlantic oakwood habitat, allowing dispersal across a much larger geographic area. In addition, the analysis identifies oakwood patches that may be too small to support characteristic sedentary species that require substantial habitat to maintain viability, enabling directed management to be undertaken.

Table 18. Summary statistics of networks surrounding Loch Sunart for Atlantic oakwood specialists

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	42	1 088	25.9	231
500	28	1 298	46.4	259
1000	17	1 607	94.5	469


Atlantic oakwood specialist habitat
habitat networks
Other woodland
0.5 0 0.5 1 Kilometers
N
Sale
Laga
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Ardery
Resipole
Beinn Resipol
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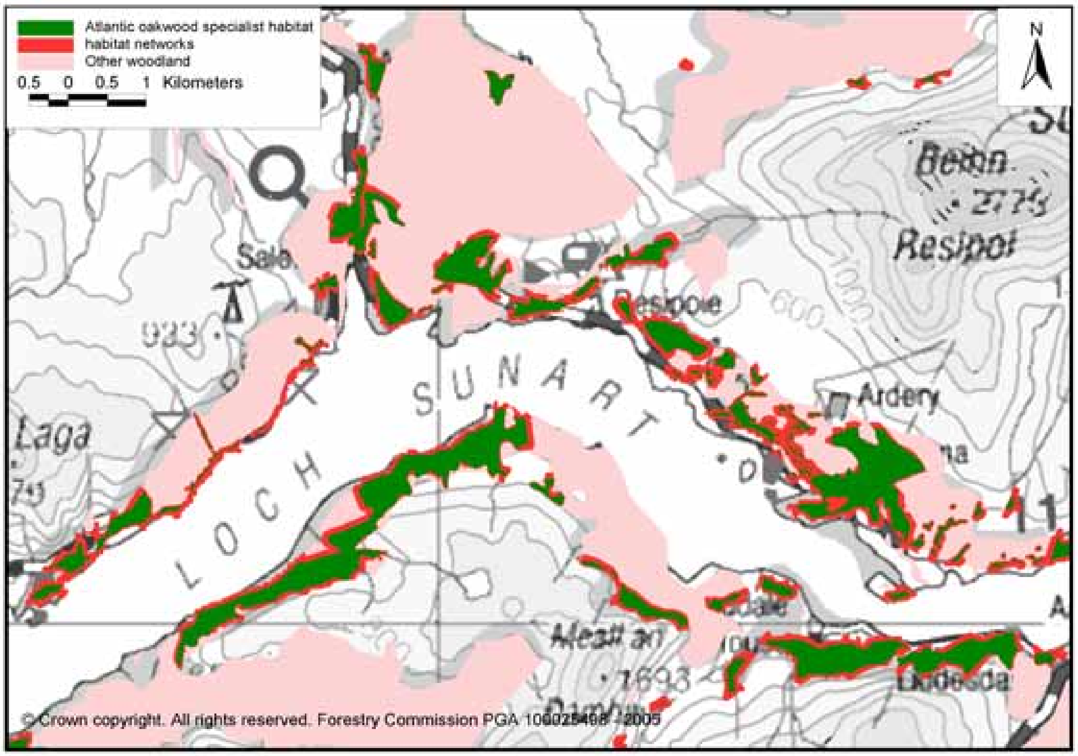
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habitat networks
Other woodland
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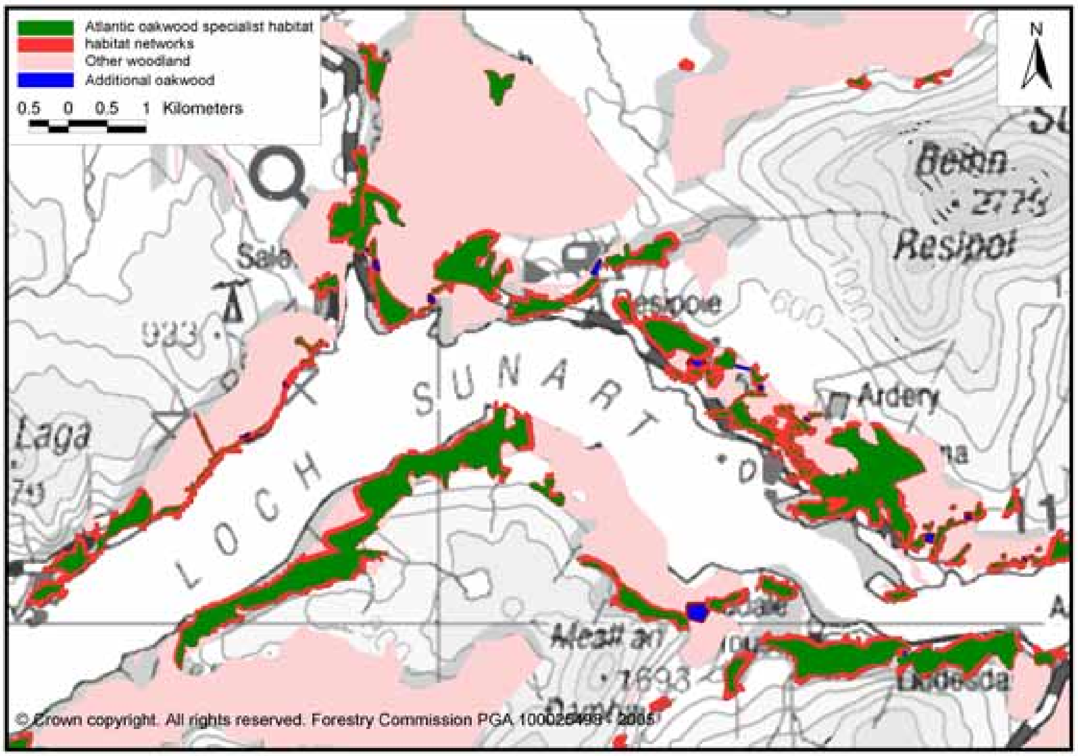


Figure 5. Habitat networks for Atlantic oakwood specialists with a maximum dispersal distance of (a) 1000 m and (b) 250 m, located around Loch Sunart. The area in green represents Atlantic oakwood habitat, as defined in the methodology, with a 50 m woodland edge, whilst the area in red represents the functional habitat network. Figure 5 (c) demonstrates how networks for specialists with a small dispersal ability, in this case 250 m, can be joined by the strategic planting of additional habitat, represented by the blue colour.

The analyses identify the functional networks connecting physically fragmented Atlantic oakwood in Highland Conservancy, and allow examination of the resource at the local scale. The value of the BEETLE forest habitat networks analysis is twofold: firstly it objectively identifies habitat networks, indicating the potential for dispersal across non-specialist habitat, and secondly it can be used to plan the consolidation and expansion of the specialist habitat to reduce fragmentation and support viable meta-populations at the landscape scale. This approach is suitable for adaptive management, enabling practitioners to test scenarios or the outcomes of woodland management. The generic focal species approach provides a useful tool for identifying Atlantic oakwood management and expansion priorities to reduce woodland fragmentation. The outputs from such analyses can be used in a number of ways:

1. Restoration of PAWS within networks. This should be a priority, as PAWS within networks will theoretically have a better chance of colonisation by species associated with the network type.
2. Expansion and conversion within and on or across the boundaries of networks to maintain functional connectivity with the network.
3. Consolidation of ancient woodland fragments by buffered expansion.
4. Management grants to support structural, species and deadwood diversity in woodlands within or close to the boundaries of specialist networks.
5. Identification of open ground specialist networks, which will prevent damaging the biodiversity of open habitats.

Use of these datasets to build FHNs on a local scale should be undertaken in conjunction with an Ecological Site Classification to confirm that woodland expansion is undertaken on suitable sites.

The analyses in this report cover illustrate how the BEETLE decision-support system can be used to guide management at a range of scales: at habitat and forest scale (Loch Sunart) to guide management at an operational level; at a regional scale (Highland Conservancy) to inform strategic planning and policy making. The former may be used to assess the biodiversity impacts of a number of management scenarios both spatially and temporally.

Use of the BEETLE FHN approach for determining eligibility of new planting plans for the Highland Locational Premium Scheme (HLPS).

The Scottish Forestry Minister, Rhona Brankin, announced the launch of a locational premium scheme 26 January 2006 that aims "to achieve a targeted expansion of Forest Habitat Networks in Highland to improve forest diversity and biodiversity and to increase the ability of forest species and habitats to adapt to climatic changes." In addition to the existing Scottish Forestry Grant Scheme (SFGS) payments, applicants will receive a premium of up to £2 000 per qualifying hectare for new planting proposals that increase FHN connectivity.

A methodology was developed to assess whether a proposal would achieve network connectivity and, if so, how much locational premium would be paid. The approach, detailed below, assumes a maximum dispersal distance of 1 000 m, representing relatively mobile species.

The first step was to identify areas where new planting proposals could potentially link together networks by creating an additional 1 000 m cost distance buffer around the networks. New plantings outside this area would be excluded, as it is unlikely that they would close enough for dispersal events between the new and existing habitat to occur. This 'potential zone' can be accessed via the Forestry Commissions Land Information Search, a web-based application that will allow the user to zoom to an area of interest (Figure 6). Paper versions of the maps will be made available for viewing at the Highland conservancy office. This step quickly allows applicants to determine whether their proposal intersects the potential zone and, if so, they can begin the consultation process with Highland conservancy. Providing this first criterion has been satisfied, applicants go through the usual SFGS procedure and their proposal is dealt with at one of a series of surgeries. The procedure has been largely automated for speed and simplicity, but allows full transparency if the applicant has any queries.

The landscape scale analysis approach involves the digitising of new planting areas from which a 50 m internal buffer is removed and added to the landcover matrix, with the remaining core area being added to the habitat layer. As the analysis requires habitat to be present following the removal of the internal buffer, the procedure checks that the woodland is 110 m wide. If this is not the case, the scheme is not eligible. The analysis is then undertaken for eligible schemes using both pinewood and broadleaf specialists to determine whether the scheme has connected networks functionally. An output table provides the necessary information regarding how the new planting has contributed to the existing networks and allows the analyst to calculate how much premium the new scheme is eligible for.

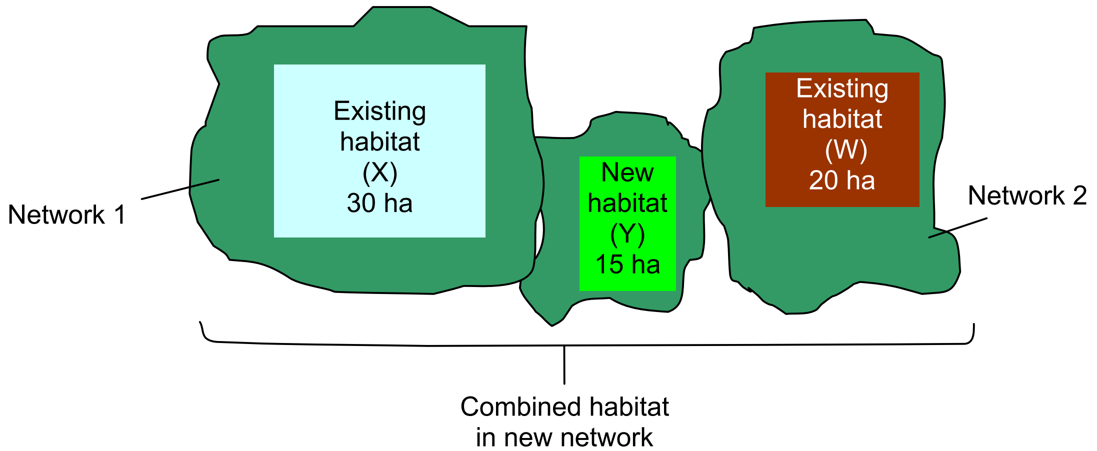
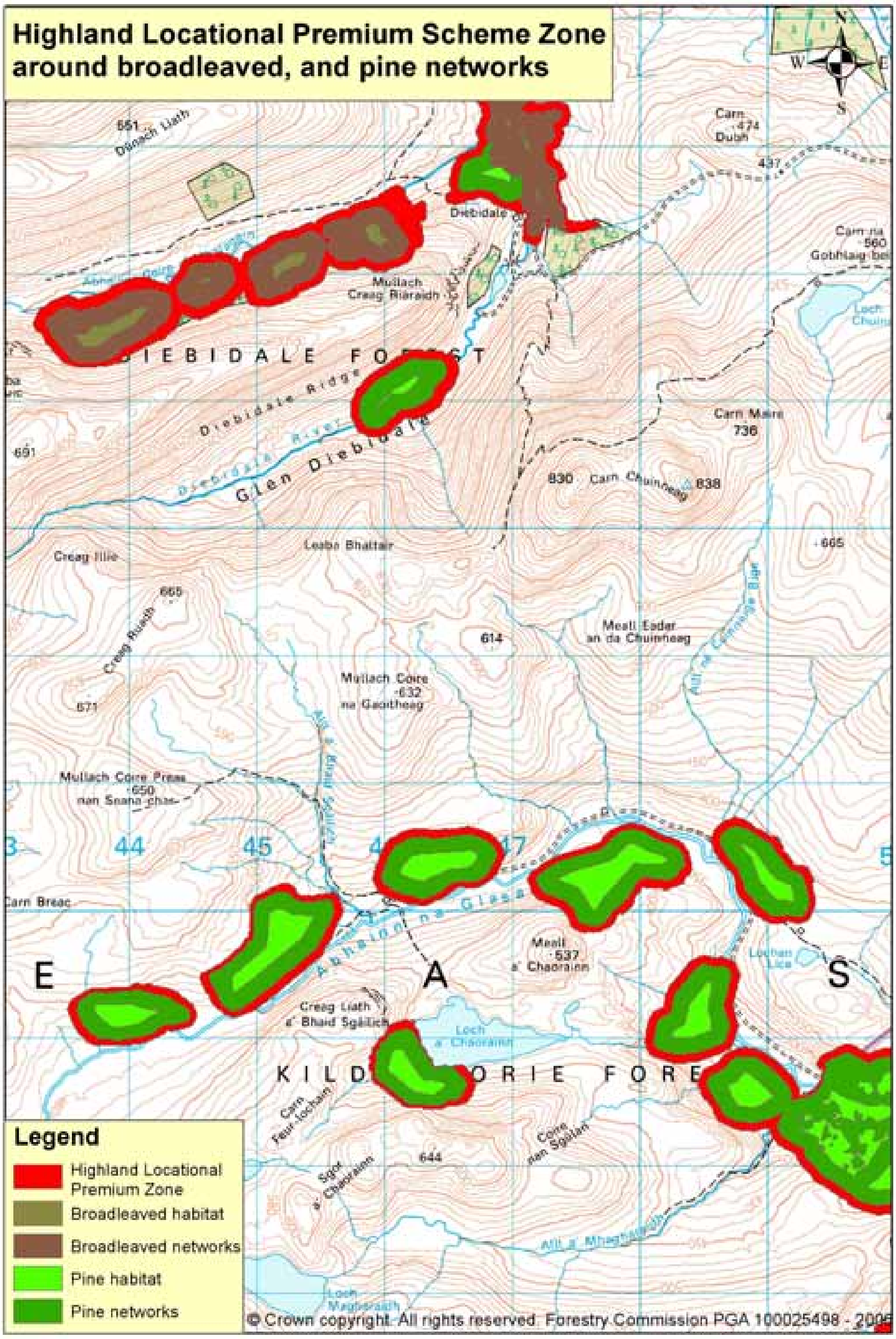


Figure 7. A representation of how a new planting scheme will be scored for eligibility to the Highland Locational Premium Scheme. New habitat (Y) is added into the landscape matrix, resulting in functional connectivity between existing habitat patches W and X. A score and figure for proportionality then are derived.

The scoring system examines the amount of habitat linked together, rather than the amount of network, to avoid bias towards schemes within semi-natural landscapes (with high landscape permeability) over schemes within more modified landscapes (with low landscape permeability) (Figure 7.).

Figure 6. Example of how the Highland Locational Premium Scheme Zone map can be queried at a large scale to determine whether a potential new planting scheme would be eligible. The new scheme would have to intersect the red zone surrounding networks of the same type, *i.e.* pine and pine (in green) or broadleaved and broadleaved (in brown).



The automated calculation consists of two steps.

Step 1
Assess how much new habitat has been linked together using the following formula:

Score = Total habitat area (W+X+Y) – Largest block of existing habitat (X)

= (20 + 30 + 15 = 65) – 30 = 35

This calculation is weighted towards linking habitat, rather than benefiting cases where a large block of new planting is connected to a large existing block.

Step 2
Assess 'proportionality' – *i.e.* how much new habitat has been linked in relation to new habitat created.

Proportionality = Score ÷ Area of new habitat (Z)

= 35 ÷ 15 = 2.33

The second calculation gives credit for linking a lot of habitat with a minimum of planting, without benefiting cases where there is a lot of planting for little additional habitat linkage. The score and proportionality figures are then cross-referenced to determine how much of the scheme is eligible for HLPS payment (Table 19).

Table 19. Scoring system for the Highland Locational Premium Scheme. The score and proportionality are based on habitat, payments for eligible planting areas is made for the whole planting area.

"New habitat score" i.e. total area of habitat in new network (ha) minus largest area of habitat in existing networks (ha)	**"Proportionality"** i.e. "new habitat score" divided by area of new woodland planted (ha)	**Size of new woodland eligible for premium (ha)**	**Comment**
5	1.5	None	If these minimum scores are not reached, then the scheme is not eligible
5-50	≥1.5	Up to 20	Premium payable on up to 20 ha of new woodland planted, but proportionality means that 'new habitat score' needs to be one and a half times as big as new area planted*
50-200	≥3	Up to 50	Premium payable on up to 50 ha of new woodland planted, but proportionality means that 'new habitat score' needs to be three times as big as new area planted*
200+	≥4	Up to 100	Premium payable on up to 100 ha of new woodland planted, but proportionality means that 'new habitat score' needs to be four times as big as new area planted*

*** The size of the new woodland eligible for premium will be based on an amount that contributes towards the Forest Habitat Networks. This will be agreed with the Woodland Officer during the consultation.**

The HLPS use of the FHN approach will provide a valuable tool for planned woodland expansion, as previous schemes have been spatially unconstrained and have consequently not addressed the problem of habitat fragmentation.

Highland Locational Premium Assessment Procedure

The followed steps describe how the consultation between the applicant, woodland officer, and Highland Birchwoods analyst is undertaken.

1. The scheme is digitised in consultation with the applicant. At this stage, a check is made to ensure the new planting scheme overlaps the HLPS preference zone shape as this represents a further 1 km maximum dispersal distance. If the scheme doesn't overlap then the 'resistance' of the landscape will prevent it joining a network.
2. The analyst zooms to the networks that will be affected by the analysis, i.e. those that are within the HLPS preference zone adjacent to the scheme. This may be done automatically using the 'Zooms to a fixed extent' function or manually, ensuring that the extent of any networks that are likely to be affected by the new planting are included on the screen. The extent of the analysis is determined by what is visible in the screen, so if the whole of a network is not visible, it will be clipped. The processing speed is dependent on the extent of the analysis, so the quickest analysis will be the one that just covers all the likely networks.
3. The applicant, woodland officer, and analyst discuss the land cover data and make any significant alterations to it. Alterations can be made by changing the landcover code if appropriate, or by creating a new shapefile and using the union function to merge into the landcover.
4. When the applicant, woodland officer, and analyst are satisfied with the land cover and new planting proposal shapefiles, the Premium Scheme Assessment Tool dialogue is opened (Figure 7).

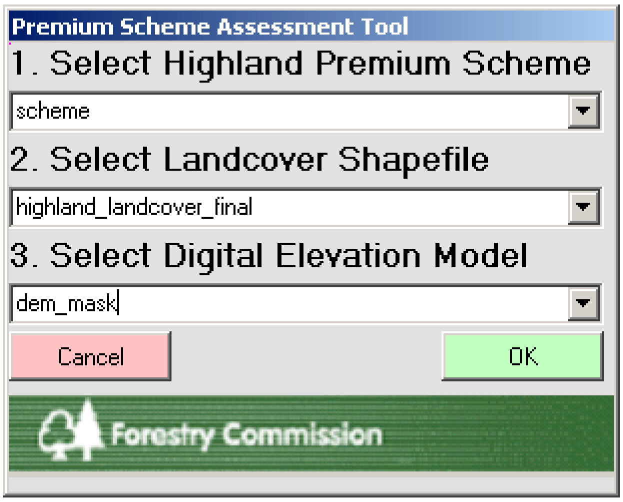


Figure 7. Premium Scheme Assessment tool dialogue box.

5. The 'Highland Scheme Assessment Tools' dialogue requires three files to be selected: 1. Highland Premium Scheme, *i.e.* the new planting proposal; 2. Landcover Shapefile; 3. Digital Elevation Model. Once these have been selected, the automated analysis is run.
6. If there is insufficient habitat, for example pinewood habitat, in the networks the new scheme adjoins, a warning message will appear, *e.g.* 'There is insufficient pine habitat in the aoi' and no networks will be created for that particular specialist – in this case for the pinewood specialist.
7. The outputs of the analysis are 1. A table (Table 20) appended to the planting scheme shapefile, 2. Two grids showing the current and potential networks for pinewood specialists and/or broadleaved specialists when the planting scheme links together existing networks (Figure 3). If no linkage is made, no grids are produced.

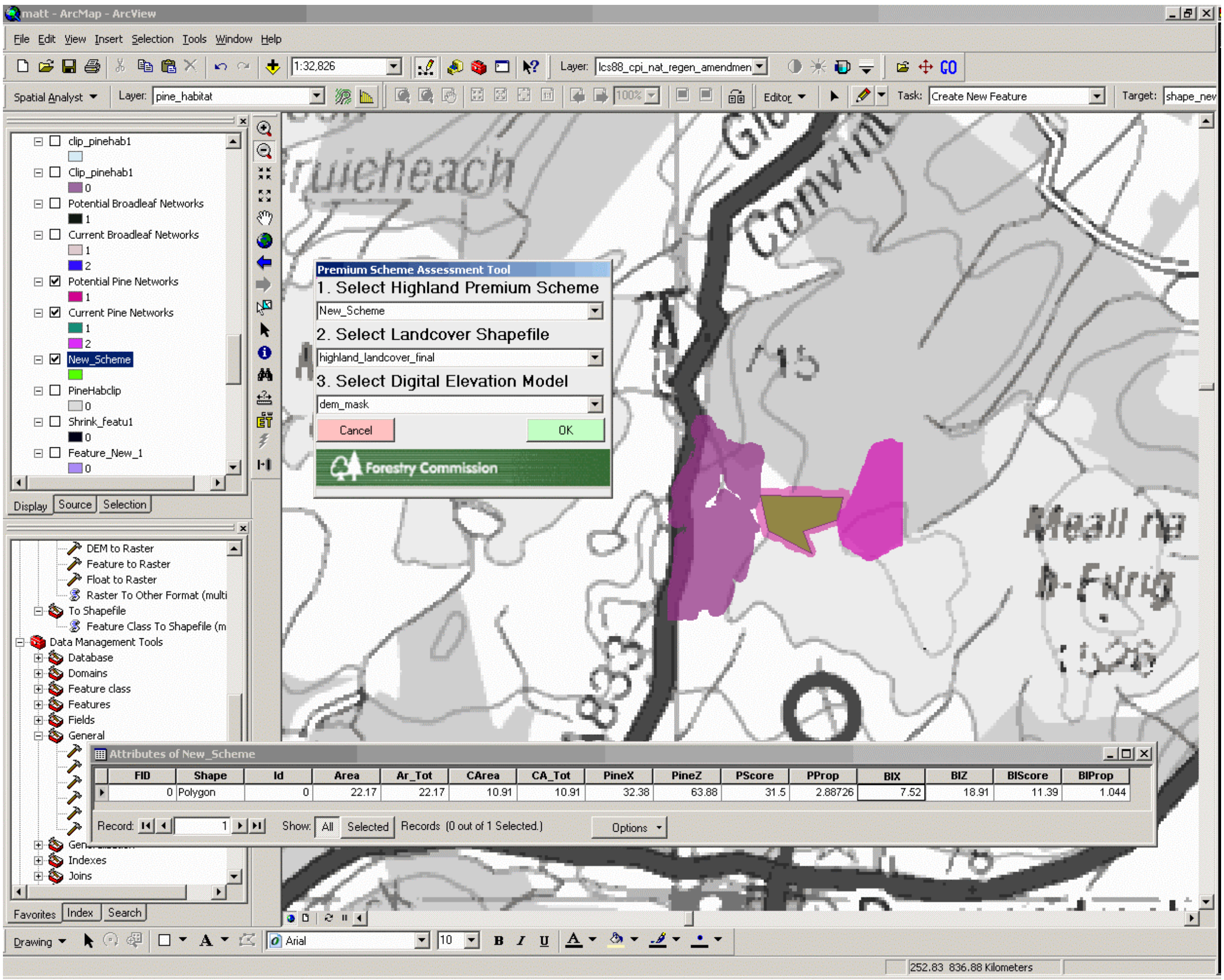
Table 20. Outputs appended to the planting scheme shapefile. Area = area of planting proposal, Ar_Tot = Total area of planting proposals, CArea = Core area (habitat) of scheme, CA_Tot = Total core area of planting proposals, PineX = the largest quantity of pine habitat in a network, PineZ = total area of pine habitat including the scheme in the network of interest, PScore = PineZ – PineX, PProp (pine proportional score) which is PScore divided by the core area of the scheme (CArea), BIX = the largest quantity of broadleaved habitat in a network, BIZ = total area of broadleaved habitat including the scheme in the network of interest, BIScore = BIZ – BLX, BIProp (broadleaved proportional score) which is the BIScore divided by the core area of the scheme (CArea).

Attributes of shape1.shp

FID	Shape*	Id	Area	Ar_Tot	CArea	CA_Tot	PineX	PineZ	PScore	PProp	BIX	BIZ	BIScore	BIProp
0	Polygon	0	1.88	1.88	0.04	0.04	4.76	4.8	0.04	1	3.72	4.26	0.54	13.5

Record: 1 Show: All Selected Records (0 out of 1 Selected.) Options

Figure 8. Example of a Highland Locational Premium Scheme analysis, indicating how a new planting scheme has linked together two existing networks.



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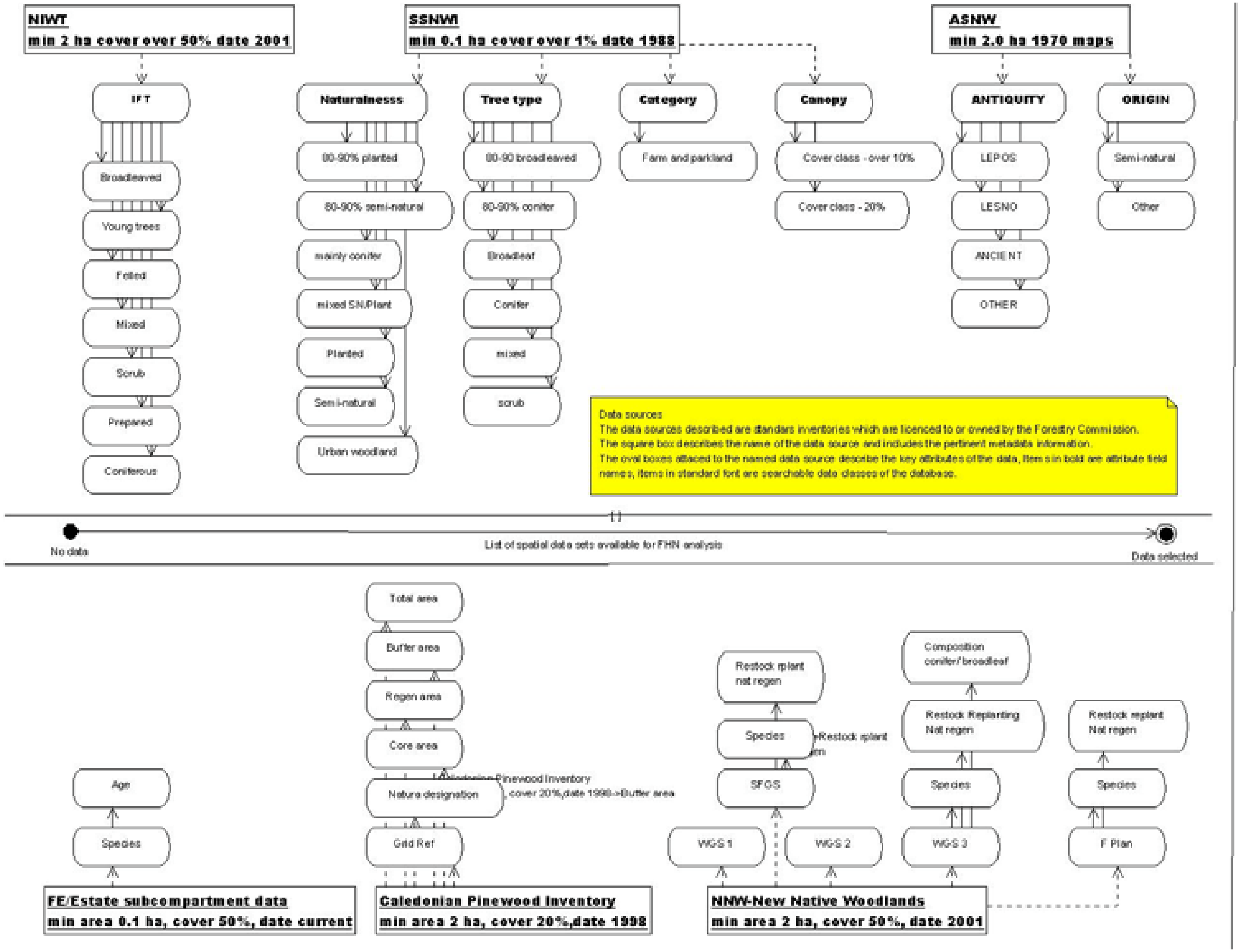
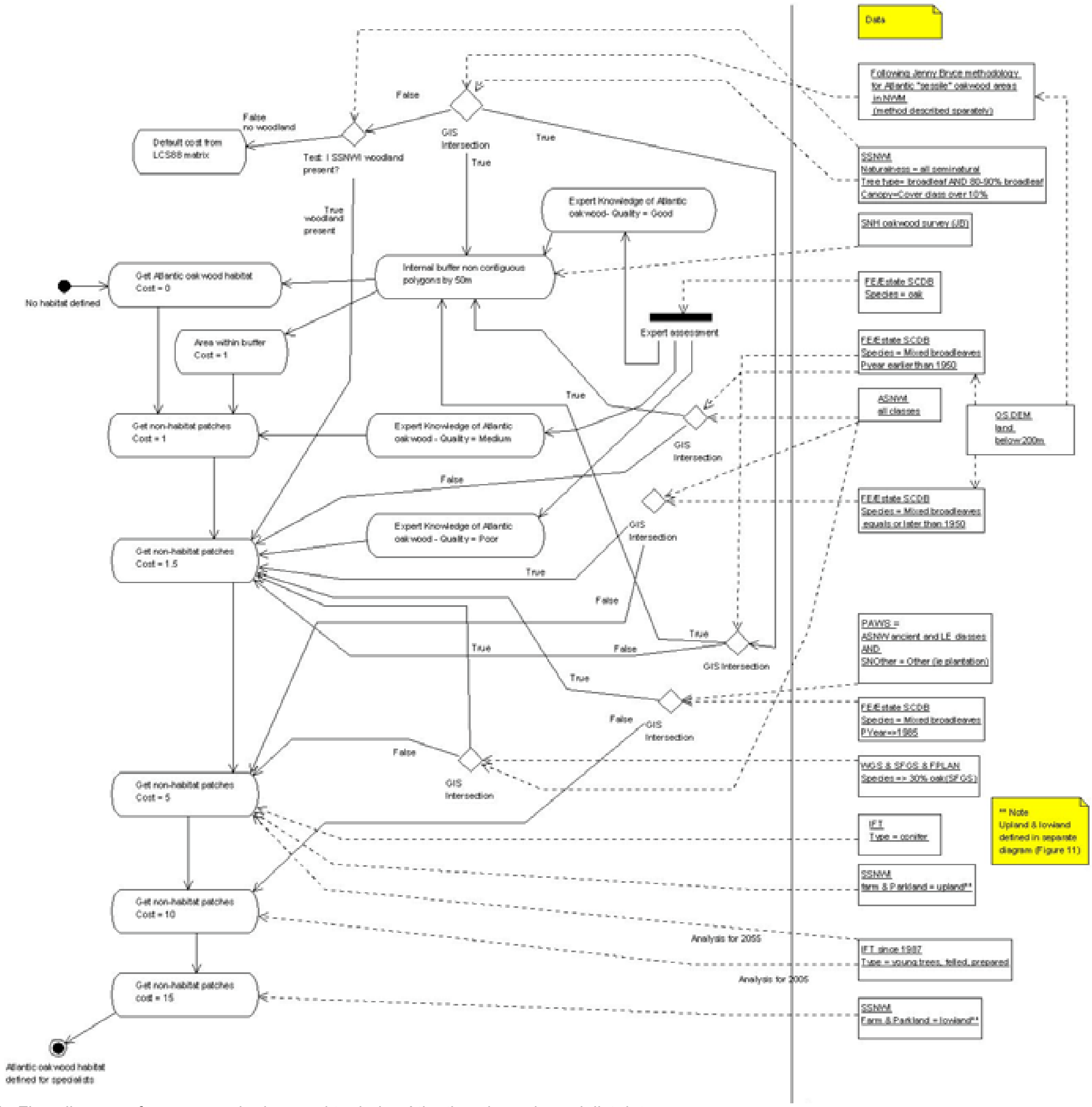
Appendix 1. Selected cost profiles for Atlantic oakwood specialist, ancient pinewood specialist, and pinewood specialist.

VALUE	Source	General landcover code	Detailed description	Pinewood Specialist	Ancient Pinewood Specialist	Atlantic Oakwood Specialist
1	LCS88	Broadleaf woodland	'Undiff. broadleaf (area)'	2.00	3.00	1.50
2	LCS88	Coniferous woodland	'Coniferous (plantation - area)'	2.00	2.00	5.00
3	LCS88	Coniferous woodland	'Coniferous (semi-natural - area)'	1.00	1.00	5.00
4	LCS88	Mixed woodland	'Undiff. mixed woodland (area)'	**2.00**	**5.00**	3.00
5	LCS88	Mixed woodland	'Forestry `ripping'	**5.00**	**5.00**	10.00
6	LCS88	Mixed woodland	'Open canopy (young plantation)'	**5.00**	**5.00**	10.00
7	LCS88	Mixed woodland	'Recent felling'	**5.00**	**2.00**	10.00
106	LCM2000	Broadleaved/mixed woodland	deciduous	**1.50**	**2.00**	1.50
109	LCM2000	Coniferous woodland	conifers	2.00	2.00	5.00
110	LCM2000	Coniferous woodland	felled	**2.00**	**2.00**	10.00
111	LCM2000	Coniferous woodland	new plantation	**2.00**	**2.00**	10.00
1001	NIWT	Broadleaved		1.50	1.50	1.50
1002	NIWT	Coniferous		**2.00**	**2.00**	5.00
1003	NIWT	Felled		**5.00**	**5.00**	10.00
1004	NIWT	Ground prepared for planting		**5.00**	**5.00**	10.00
1005	NIWT	Mixed		**5.00**	**5.00**	3.00
1006	NIWT	Scrub		5.00	5.00	5.00
1007	NIWT	Young trees		10.00	10.00	10.00
1008	NIWT	Plantation conifer	Upland planted conifer (pine)	2.00	2.00	5.00
1009	NIWT	Plantation conifer	Lowland planted conifer (spruce)	2.00	2.00	5.00
1104	SSNWI	Qualified pinewood	Semi-natural pinewood of good quality	habitat	habitat	4.00
1105	SSNWI	Qualified pinewood	Semi-natural pinewood of average quality	habitat	1.00	5.00
1106	SSNWI	Qualified pinewood	Semi-natural pinewood of poor quality	habitat	1.50	5.00
1107	VARIOUS	Unqualified pinewood	Pine of unknown quality <50% canopy	habitat	1.75	5.00
1108	VARIOUS	Unqualified pinewood	Pine of unknown quality >50% canopy	habitat	1.50	5.00
1111		Qualified oakwood	Atlantic oakwood of good quality	2.00	2.00	habitat
1112		Qualified oakwood	Atlantic oakwood of average quality	2.00	2.00	1.00
1113		Qualified oakwood	Atlantic oakwood of poor quality	2.00	2.00	1.50
1201	FE	Mixed broadleaved	mixed bl Pyr earlier 1950 on aw site	2.00	2.00	habitat
1301	SFGS	New native woodlands	oak, nbl, mb, on aw site	5.00	5.00	1.50
1401	VARIOUS	Removed buffer	50m buffer of oakwood habitat	2.00	2.00	1.00
1402	VARIOUS	Removed buffer	50m buffer of ancient pinewood habitat	1.00	1.00	2.00
1501	SSNWI	semi-natural broadleaved	semi-nat bl not nwm 200m	2.00	2.00	1.50
1503	SSNWI	upland farm/parkland		5.00	5.00	5.00
1504	SSNWI	lowland farm/parkland		15.00	15.00	15.00
8	LCS88	Improved grassland/arable	'Arable: no rock farms no trees'	**40.00**	**40.00**	**40.00**
124	LCM2000	Grassland	grass (hay/silage cut)	**40.00**	**40.00**	**40.00**
36	LCS88	Rough unimproved grassland	Undif. Nardus/Molinia: no rock no trees'	**20.00**	**20.00**	**20.00**
55	LCS88	Undifferentiated heath	Undif. heather moor'	20.00	20.00	20.00
73	LCS88	Dunes	'Dune lands: links area - grass'	50.00	50.00	50.00
76	LCS88	Bog	Blanket bog/peatland veg.'	**40.00**	**40.00**	**40.00**
83	LCS88	Wetland	'Wetlands: drains no trees'	**40.00**	**40.00**	**30.00**
87	LCS88	Montane	Montane veg.'	**40.00**	**40.00**	**40.00**
94	LCS88	Inland water	'Water (area)'	50.00	50.00	50.00
96	LCS88	Urban	'Built-up (area)'	50.00	50.00	50.00
5335	Strategi	Road	single carriageway over other feature	50.00	50.00	50.00

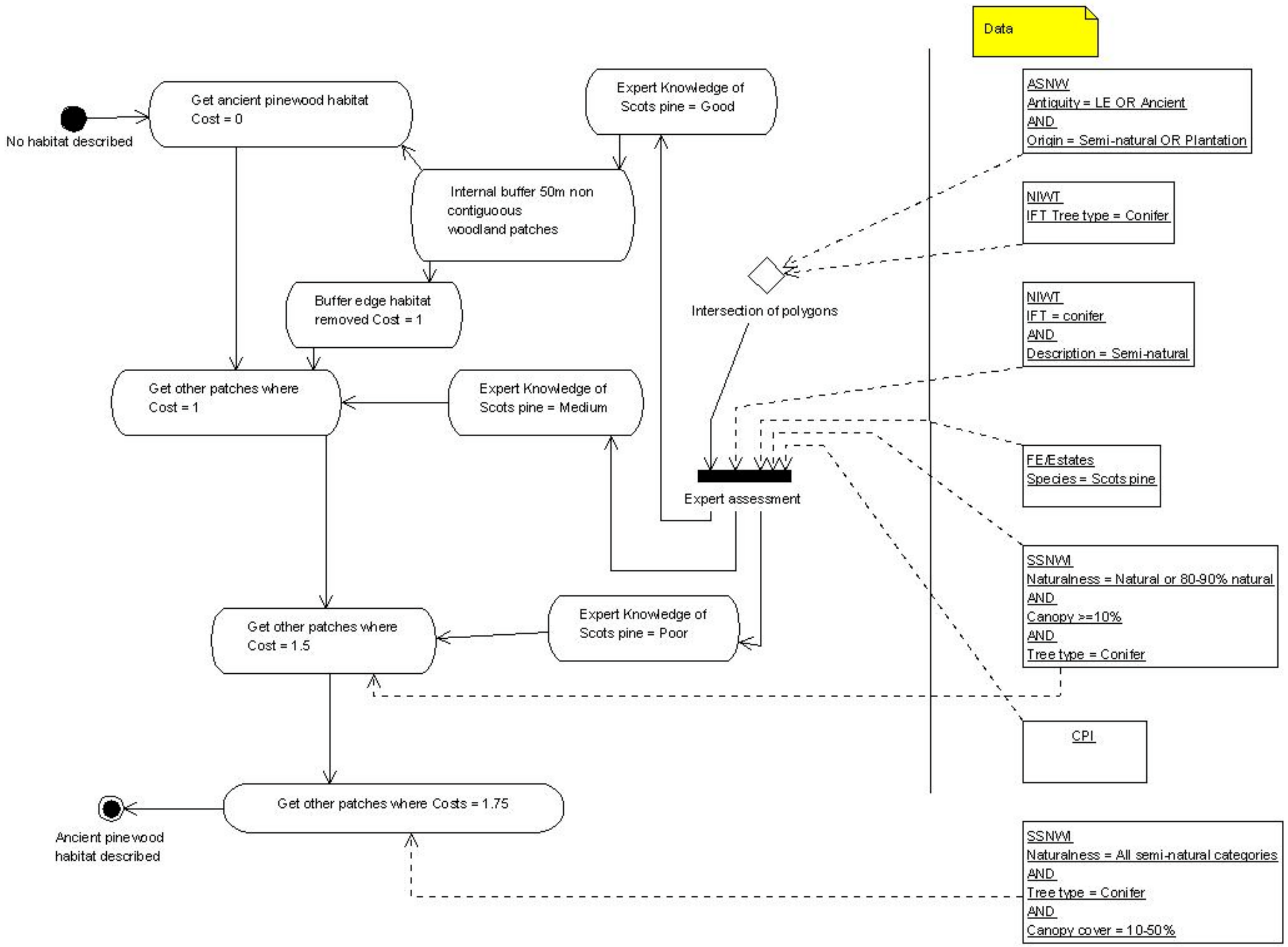
Appendix 2 Flow diagrams of data sources and rules used to derive Atlantic oakwood, Ancient pinewood, and pinewood specialist data.



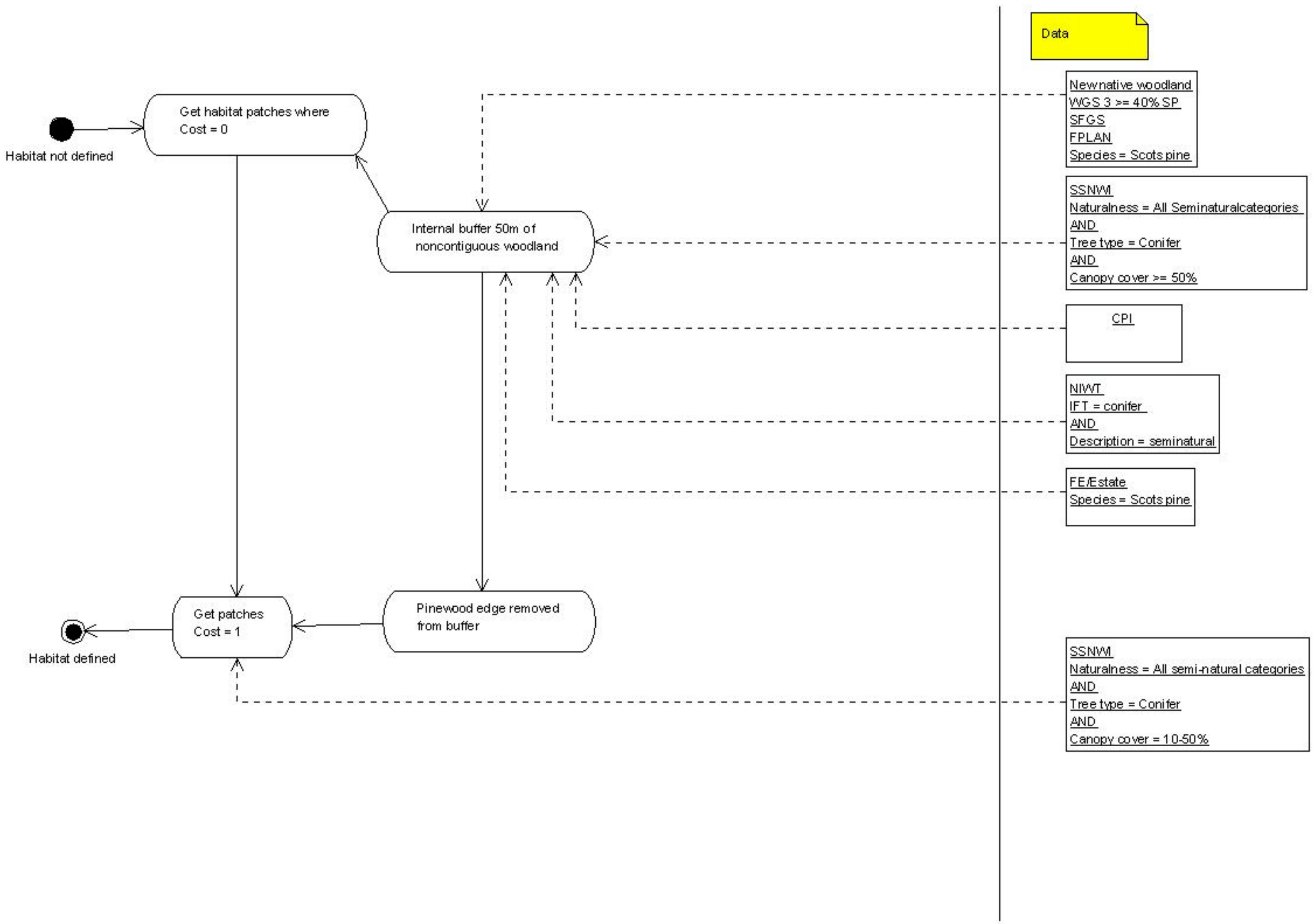
a. Flow diagram showing the data sources and main attributes used for defining woodland data.



b. Flow diagram of sources and rules used to derive Atlantic oakwood specialist data



c. Flow diagram of sources and rules used to derive ancient pinewood specialist data



d. Flow diagram of sources and rules used to derive pinewood specialist data

Appendix 3. Species associated with the Atlantic oakwoods

Species	Common name	Habitat requirements	Dispersal ability	Area requirement	Atlantic oakwood Specialist or Generalist
Adelanthus decipiens	A liverwort	Semi-natural oakwoods	low	small	S
Bazzania trilobata	A liverwort	Western acid oakwoods	low	small	G
Carterocephalus palaemon	Chequered skipper butterfly	Broadleaved woodland edges, scrub and bracken	medium	medium	G
Ficedula hypoleuca	Pied Flycatcher	Mature open deciduous woodland, especially oak	high	small / medium	G
Hyacinthoides non-scriptus	Bluebell	Broadleaf woodland	low	small	G
Hydnellum spongiosipes	Velvet tooth fungus	Broadleaf woodland, particularly oak	low	small	G
Hymenophyllum wilsonii	Wilson's Filmy fern	Shaded rock faces & tree trunks in humid woods	low	small	G
Lobaria pulmonaria	Tree lungwort	Established broadleaf woodland, particularly oak	low	small	G
Lobaria virens	A lichen	Established broadleaf woodland, particularly oak	low	small	G
Martes martes	Pine martin	Broadleaf or conifer woodland	high	large	G
Plagiochila atlantica	A liverwort	Upland sessile oakwoods	low	small	S
Plagiochila killarniensis	Killarney featherwort	Western acid oakwoods	low	small	G
Plagiochila spinulosa	Liverwort		low	small	G
Phoenicurus phoenicurus	Redstart	Mature woods, especially sessile oakwoods	high	small / medium	G
Phylloscopus sibilatrix	Wood warbler	Beech woods and mature upland oakwoods	high	small / medium	G
Scapania gracilis	Liverwort	Acid oak woodlands	low	small	G

Appendix 4. Species associated with the Scottish pinewoods

Species	Common name	Habitat (Pinewood, Native Pinewood, Ancient Pinewood)	Woodland Specialist or Generalist	Data source
Mammals				
Sciurus vulgaris	Red Squirrel	Mainly (>50ha) mature coniferous forest, particularly Scots Pine.	S	W Lothian final rep
Birds				
Loxia scotia	Scottish crossbill	AP and P > 100 yrs	S	Trees for life website
Parus cristatus	Crested tit	P and AP	S	Trees for life website
Parus ater	Coal tit	NP and planted conifer	S	Cairngorm lbap
Tetrao tetrix	Black Grouse	Woodland edge	G	W Lothian final rep
Tetrao urogallus	Capercaillie	P and occasionally other conifers (oak in summer)	S	Trees for life website
Aquila chrysaetos	Golden eagle	Native pinewood	S	Cairngorm lbap
Falco columbarius	Merlin	NP and planted conifer	S	Cairngorm lbap
Asio flammeus	Short-eared owl	NP and planted conifer	S	Cairngorm lbap
Caprimulgus europaeus	Nightjar	NP and planted conifer	S	Cairngorm lbap
Regulus regulus	Goldcrest	NP and planted conifer	S	Cairngorm lbap
Carduelis spinus	Siskin	NP and planted conifer	S	Cairngorm lbap
Loxia curvirostra	Common crossbill	NP and planted conifer	S	Cairngorm lbap
Loxia pytyopsittacus	Parrot crossbill	AP	S	Cairngorm lbap
Vascular plants				
Juniperus communis	Juniper	Associated with NP but also found elsewhere		Managing the pinewoods of Scotland
Arctostaphylos uva-ursi	Bearberry	Montane edge, in SP stands where forest edge meets		Plantlife – flowers of the forest
Goodyera repens	Creeping ladies tresses	NP & P but very occasionally with birch. Characteristic NP species		Trees for life website, Pitkin et al. (1995)
Linnaea borealis	Twinflower	AP and P, mostly NE Scot, but some in Cairngorms	S	Pitkin et al. (1995)
Moneses uniflora	One-flowered wintergreen	NP Particularly associated with Caledonian Forest	S	http://www.treesforlife.org.uk/tfl.scpine.html
Orthilia secunda	Serrated wintergreen	NP Occasional in Highlands. Also in broadleaved and mixed forests	G	JNCC website: protected sites Pitkin et al. (1995)
Pyrola media		NP v. rare outside Highlands. Woodland and heath, but commonest in Scottish pinewoods.		Pitkin et al. (1995)

Lichens				
Alectoria sarmentosa	Witch's hair	Almost completely restricted to old conifer forests in Scottish highlands. Pockets in Northumberland	S for highlands	
Bryoria furcellata	Forked hair-lichen	NP and planted conifer	S	Coppins & Coppins, 2005 Cairngorm lbap and JNCC website: protected sites
Buellia sanguinolenta		NP	S	Coppins & Coppins, 2005
Chaenothecopsis pusiola		NP	S	Coppins & Coppins, 2005
Cladonia botryes	A stump lichen	Preferentially old Scots pine, but will migrate to plantation pine		
Cladonia cenotea		NP	S	Coppins & Coppins, 2005
Cliostomum leprosum		NP	S	Coppins & Coppins, 2005
Hypocenomyce anthracophila		NP	S	Coppins & Coppins, 2005
Lecanora cadubriae		NP	S	Coppins & Coppins, 2005
L. mughicola		NP	S	Coppins & Coppins, 2005
Lecidea leprarioides		NP	S	Coppins & Coppins, 2005
Lecidea porphyrospoda		NP	S	Coppins & Coppins, 2005
Lecidella subviridis		NP	S	Coppins & Coppins, 2005
Melaspiles lentiginosula		NP	S	Coppins & Coppins, 2005
Micarea contexta		NP	S	Coppins & Coppins, 2005
M. elachista		NP	S	Coppins & Coppins, 2005
M. eximia		NP	S	Coppins & Coppins, 2005
Pannaria ignobilis	A lichen	NP	S	JNCC website: protected sites
Pycnora leucococca		NP	S	Coppins & Coppins, 2005
P. xanthococca		NP	S	Coppins & Coppins, 2005
Rinodina laevigata		NP	S	Coppins & Coppins, 2005
Bryophytes				
Daltonia splachnoides	a bryophyte	NP. Found on 6 sites on west coast of Scotland	S	JNCC website: protected sites
Mosses				
Ptilium crista-castrensis	Ostrich-plume feather moss	AP / P (restricted to NVC type W18)	S	JNCC pdf 'guide to woodland'
Buxbaumia virdis	Green shield moss	NP (on decaying logs)	S	Cairngorm lbap
Invertebrates				
Acanthocinus aedilis	a longhorn beetle, Timberman			Trees for life website, NBN
Blera fallax	pine hoverfly	AP or NP and planted conifer	S	http://www.ukbap.org.uk/UKPlans.aspx?ID=147

Formica aquilonia	Scottish wood ant	Native pinewoods	S	http://www.forestry.gov.uk/forestry/hcou-4u4j2c
Formica exsecta	Narrow headed woodant	P (only loch morlich, cairngorm)	S	Trees for life website
Formica sanguinea	A wood ant	AP	S	Trees for life website
Formica lugubris	Hairy woodant	NP and planted conifer	S	Cairngom lbap
Judolia sexmaculata	a longhorn beetle	Old pine woodland	S	W Lothian final rep
Osmia uncinata	A mason bee	AP and old P	S	http://www.ukbap.org.uk/UKPlans.aspx?ID=493
Rhagium inquisitor	a longhorn beetle			Trees for life website
Wesmaelius malladai	a brown lacewing	Pine forest	S	W Lothian final rep
Lapia flava	A robber fly	Native pinewood	S	Cairngorm lbap
Clubonia subsultans	A spider	NP and planted conifer	S	Cairngorm lbap
Dipoena torva	A spider	NP and planted conifer	S	Cairngorm lbap
Haplodrassus soerenseni	A spider	NP and planted conifer	S	Cairngorm lbap
Pelecopsis elongata	A spider	Native pinewood	S	Cairngorm lbap
Fungi				
Hydnellum aurantiacum	orange tooth fungus	AP (restricted to native pinewoods)	S	Trees for life website
Hydnellum caeruleum	blue tooth fungus	AP (restricted to native pinewoods)	S	Trees for life website
Sarcodon glaucopus	greenfoot tooth fungus	AP (only Abernethy, Glen Affric and Strathfarrar)	S	Trees for life website
Suillus flavidus	Poroid fungus	NP	S	Cairngorm lbap
Calocybe onychina	Agaric fungus	NP	S	Cairngorm lbap
Chrysomphalina chrysophylla	Agaric fungus	NP	S	Cairngorm lbap
Collybia acervata	Agaric fungus	NP	S	Cairngorm lbap
Collybia prolixa	Agaric fungus	NP	S	Cairngorm lbap
Collybia putilla	Agaric fungus	NP	S	Cairngorm lbap
Collybia racemosa	Agaric fungus	NP	S	Cairngorm lbap
Cantharellus pallens	Agaric fungus	NP	S	Cairngorm lbap
Cortinarius caledoniensis	Agaric fungus	NP	S	Cairngorm lbap
Cortinarius camphoratus	Agaric fungus	NP	S	Cairngorm lbap
Cortinarius corrosus	Agaric fungus	NP	S	Cairngorm lbap
Cortinarius durus	Agaric fungus	NP	S	Cairngorm lbap
Cortinarius fervidus	Agaric fungus	NP	S	Cairngorm lbap
Cortinarius subtortus	Agaric fungus	NP	S	Cairngorm lbap
Cortinarius talus	Agaric fungus	NP	S	Cairngorm lbap
Entoloma roseum	Agaric fungus	NP	S	Cairngorm lbap
Fayodia bisphaerigera	Agaric fungus	NP	S	Cairngorm lbap
Inocybe jacobi	Agaric fungus	NP	S	Cairngorm lbap

Lactarius terenopus	Agaric fungus	NP	S	Cairngorm lbap
Mycena viridimarginata	Agaric fungus	NP	S	Cairngorm lbap
Psathyrella rannochii	Agaric fungus	NP	S	Cairngorm lbap
Russula badia	Agaric fungus	NP	S	Cairngorm lbap
Russula cessans	Agaric fungus	NP	S	Cairngorm lbap
Russula fusconigra	Agaric fungus	NP	S	Cairngorm lbap
Russula polychroma	Agaric fungus	NP	S	Cairngorm lbap
Russula vinosa	Agaric fungus	NP	S	Cairngorm lbap
Russula vinosobrunnea	Agaric fungus	NP	S	Cairngorm lbap
Russula xenochlora	Agaric fungus	NP	S	Cairngorm lbap
Stropharia hornemannii	Agaric fungus	NP	S	Cairngorm lbap
Tephrocybe fuscipes	Agaric fungus	NP	S	Cairngorm lbap
Tricholoma apium	Agaric fungus	NP	S	Cairngorm lbap
Tricholoma robustum	Agaric fungus	NP	S	Cairngorm lbap
Tricholoma stans	Agaric fungus	NP	S	Cairngorm lbap
Xeromphalina caulicinalis	Agaric fungus	NP	S	Cairngorm lbap
Bankera fuligineoalba	Tooth fungus	NP	S	Cairngorm lbap
Hydnellum aurantiacum	Tooth fungus	NP	S	Cairngorm lbap
Hydnellum auratile	Tooth fungus	NP	S	Cairngorm lbap
Hydnellum concrescens	Tooth fungus	NP	S	Cairngorm lbap
Hydnellum ferrugineum	Tooth fungus	NP	S	Cairngorm lbap
Hydnellum peckii	Tooth fungus	NP	S	Cairngorm lbap
Phellodon confluens	Tooth fungus	NP	S	Cairngorm lbap
Phellodon melaleucus	Tooth fungus	NP	S	Cairngorm lbap
Phellodon niger	Tooth fungus	NP	S	Cairngorm lbap
Phellodon tomentosus	Tooth fungus	NP	S	Cairngorm lbap
Sarcodon glaucopus	Tooth fungus	NP	S	Cairngorm lbap
Sarcodon imbricatus	Tooth fungus	NP	S	Cairngorm lbap
Sarcodon scabrosus	Tooth fungus	NP	S	Cairngorm lbap
Cudonia circinans	Cup fungus	NP	S	Cairngorm lbap
Cudonia confusa	Cup fungus	NP	S	Cairngorm lbap
Gyromitra infula	Cup fungus	NP	S	Cairngorm lbap
Ramaria suecica	A fairy club fungus	NP	S	Cairngorm lbap
Stereopsis vitellina	A bracket-like fungus	NP	S	Cairngorm lbap
Hapalopilus salmonicola	A bracket fungus	NP	S	Cairngorm lbap
Osmoporus odoratus	A bracket fungus	NP	S	Cairngorm lbap
Squamanita pearsonii	A parasitic agaric fungus	NP	S	Cairngorm lbap
Squamanita contortipes	A parasitic agaric fungus	NP	S	Cairngorm lbap

Physarum rubiginosum	A slime mould	NP	S	Cairngorm lbap
Leccinum vulpinum	A poroid fungus	NP	S	Cairngorm lbap

‘Native pinewood’ is considered as the NVC *Pinus sylvestris – Hylocomium splendens* classification, a habitat containing Scots pine and deciduous/broad-leaved species such as birch, rowan, holly, etc.

References

Coppins, B.J. and Coppins, A.M. (2005) The Lichens of Native Pinewoods. Forthcoming publication in Forestry.

Pitkin, P.H., Lusby, P.S. and Wright, J. (1995) Biodiversity and the ecology of pinewood plants. *In* Aldhous, J.R. (ed.) *Our Pinewood Heritage* (Proceedings of a Conference held at Inverness, October 1994): 196–205. Jointly published by Forestry Commission, The Royal Society for the Protection of Birds, Scottish Natural Heritage.

Addendum

Updated datasets

Following revisions to the cost profiles (a reduction in dispersal costs through non-woodland landcover as the originals were thought to be excessively high) and obtaining additional data, the landcover matrix was updated and the woodland networks re-run in March 2006. These represent the final datasets distributed to Forest Enterprise. The differences in the networks are small, and primarily reflect the greater ease in dispersal through adjacent non-woodland.

Atlantic oakwood specialists

Restricted dataset

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	1 625	29 493	18.1	502
500	1 312	38 625	29.4	597
1000	1 020	53 174	52.1	869

Ancient pinewood specialists

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	298	28 863	96.9	5 731
500	229	33 425	146.0	6 398
1000	161	40 511	251.6	7 499

Pinewood specialists

Max. dispersal distance (m)	Number of networks identified	Total area of networks (ha)	Mean area of networks (ha)	Area of largest network (ha)
250	1728	144 872	83.8	11 500
500	1265	169 486	134.0	12 288
1000	921	206 037	223.7	13 127