Developing Lowland Habitat Networks in Scotland: Phase 2

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CONTENTS

ACKNOWLEDGEMENTS 5

EXECUTIVE SUMMARY 6

1 BACKGROUND 8

2 OBJECTIVES 9

3 METHODS 9

3.1 Approach 9

3.2 Selection of case studies 10

3.3 Stakeholder engagement 11

3.4 Land cover and species data 11

3.5 Construction of landuse change scenarios 13

3.6 BEETLE modelling approach 15

3.7 Procedure for identifying focal species 16

3.8 Landscape, visual and recreational assessments 18

3.9 Development of BEETLE accumulated cost buffer tool and end-user interface 18

4 RESULTS FROM CASE STUDY AREAS 19

4.1 East Neuk of Fife 19

4.1.1 Background and description of case study area 19
4.1.2 Stakeholder engagement 19
4.1.3 Priorities for habitat and species modelling 20
4.1.4 Data used in the modelling 21
4.1.5 Unimproved grasslands – consolidating priority sites 22
4.1.6 Red Squirrel networks – prioritising action to limit the impact of grey squirrels 30
4.1.7 Corn Bunting networks and targeting of LMC's 36
4.1.8 Conclusions 42

4.2 Strathspey 42

4.2.1 Background and description of case study area 42
4.2.2 Stakeholder engagement 42
4.2.3 Priorities for habitat and species modelling 42
4.2.4 Data used in the modelling 45
4.2.5 Aspen network analysis 45
4.2.6 Wetland connectivity and restoration 50
4.2.7 Conclusions 60

4.3 Tiree 60

4.3.1 Background and description of case study area 60
4.3.2 Stakeholder engagement 61
4.3.3 Priorities for habitat and focal species modelling 61
4.3.4 Data used in the modelling 62
4.3.5 Balancing development of networks for Corncrake and Corn Bunting 63
4.3.6 Modelling habitat networks for Colletes floralis 70
4.3.7 Conclusions 71

5 LANDSCAPE AND VISUAL ASSESSMENT 71

5.1 Introduction 71

5.2 Landscape Character Assessment (LCA)....71
5.2.1 Description of LCA.... 71
5.2.2 Application and limitations of LCA.... 72
5.2.3 Application of LCA in the LHN project.... 72

5.3 Historic Land-use Assessment (HLA)....72
5.3.1 Description of HLA.... 72
5.3.2 Application and limitations of HLA.... 73
5.3.3 Application of HLA in LHN project.... 73

5.4 Application of ArcView 3.2 GIS....74

5.5 Envision 'Brendan' computer generated visualisations....75
5.5.1 Envision 'Brendan' software.... 75
5.5.2 Digital Terrain Models (DTM) in Brendan.... 76
5.5.3 Co-ordinates in 'Brendan'.... 76
5.5.4 Application and limitations of 'Brendan'.... 76
5.5.5 Application of 'Brendan' in LHN project.... 77
5.5.6 Site visit and viewpoint selection.... 77

5.6 Red Squirrel habitat networks....77
5.6.1 Background and area selection.... 77
5.6.2 Landscape Character Assessment.... 78
5.6.3 Historic Land Use Assessment.... 79
5.6.4 Site visit.... 80
5.6.5 Viewpoint selection and perspective photographs.... 83
5.6.6 'Brendan' computer generated visualisations.... 84
5.6.7 Discussion.... 87

5.7 Corn Bunting habitat networks....88
5.7.1 Landscape Character Assessment.... 88
5.7.2 Historic Land Use Assessment.... 90
5.7.3 Landscape effects.... 90

6 HABITAT NETWORKS AND RECREATION AND ACCESS....92

6.1 Introduction....92

6.2 People as a focal species....92

6.3 Interaction between people and semi-natural grassland networks....93

7 DESCRIPTION OF BEETLE SNH/SEERAD TOOL....100

7.1 Purpose....100

7.2 Overview....100

7.3 Using the SNH/SEERAD Tool....100
7.3.1 Pre-requisites.... 100
7.3.2 Installation.... 100
7.3.3 Inputs.... 101
7.3.4 Outputs.... 102

8 DISCUSSION AND LESSONS LEARNED....104

8.1 Engagement with stakeholder groups....104

8.2 Applicability of the BEETLE cost-distance modelling approach....104

8.3 Data availability....105

8.4 Link between LHN modelling and targeting of agri-environment incentives 106

8.5 Consolidation of designated sites....107

8.6 Balancing priorities – integrated habitat networks....107

8.7 Landscape and visual assessment 108
8.8 Habitat networks and recreation 109
8.9 Accessibility of the BEETLE ACBT for land use planners 109
8.10 Implementing networks 110
8.11 Monitoring 112
8.11.1 Approach to monitoring 112
8.11.2 Ecosystem development within habitat networks 112
8.11.3 Ecological process and functional species groups 113
8.11.4 Rapid assessments of biodiversity 114
8.11.5 Genetic evidence 114
9 CONCLUSIONS 115
10 REFERENCES 116
11 APPENDICES 120
Appendix 1 - Description of Rural Stewardship Scheme (RSS)/LMC Tier 3 measures 120
Appendix 2 - Report from East Neuk Case Study Stakeholder workshop 123
Appendix 3 - Strathspey Stakeholder Workshop 128
Appendix 4 – Tiree Stakeholder Workshop 131
Appendix 5 – Cost values (permeability) ascribed to Phase 1 land cover types for the focal species used in the East Neuk study area 132

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FERN – Fife Environmental Records Network – species information for Fife
RSPB – Corn Bunting, Corncrake, northern Colletes data
J Caird and Gwyn Jones, SAC - data on past land use in Tiree
Cairngorms National Park Authority - survey data on aspen woods, grasslands and wetlands within Strathspey
Ross Lilley, SNH Oban

EXECUTIVE SUMMARY

1. The Scottish lowlands have a long history of intensive land-use which has resulted in the loss and fragmentation of semi-natural agricultural habitats and a reduction in biodiversity. The development of habitat networks is seen as an important mechanism for reversing the effects of fragmentation while delivering a range of other environmental benefits such as enhancing local landscape character, and creating more opportunities for public access and recreational enjoyment of the countryside.

2. Agri-environment schemes are designed to maintain and enhance biodiversity in agricultural settings, but the focus of these schemes has invariably been on individual habitats and ecosystems with little consideration of how these interact at the landscape scale, and what the overall consequences for biodiversity might be. Issues such the spatial configuration of different habitats and the resulting impacts on landscape connectivity for different species groups need to be evaluated, with a view to improving the targeting of agri-environment measures.

3. The development of a habitat network approach guided by focal species modelling (using the BEETLE set of landscape analysis tools) has been proposed as method for informing the spatial targeting of agri-environment measures, but needs to be tested in lowland agricultural landscapes.

4. In this project we tested the BEETLE approach (specifically the accumulated cost buffering tool- ACBT) in the East Neuk of Fife, Strathspey, and Tiree, three case study landscapes of contrasting size and landuse. In consultation with local stakeholders, focal species were selected to allow exploration of the impacts of targeting agri-environment (and forestry) incentives on networks for a range of priority species and habitats within each case study area.

5. In the East Neuk, modelling of networks for Corn Bunting, a threatened farmland bird, provided striking illustration of the benefits of targeting agri-environment incentives to specific fields within and adjacent to existing networks as opposed to randomly distributing those incentives in the landscape. Modelling of semi-natural grassland networks pinpointed fields with a high restoration potential where incentives could be targeted to help consolidate existing sites of high conservation value (e.g. SSSIs). Restoration potential was determined from map-based evidence, specifically the OS 1st Edition maps, and by information on the location of priority grassland species.

6. The integration of networks for different focal species was investigated in Tiree and Strathspey. In Tiree, the modelling of networks for Corncrake and Corn Bunting (currently extinct on the island) demonstrated ample scope for targeting of agri-environment incentives to benefit both species, with knock on benefits for cattle grazing and improvement in the quality of Machair (coastal grassland) and wet heath habitats.

7. In Strathspey, priority areas for restoring wetland connectivity and floodplain habitat were identified which would also have benefits for flood attenuation and control. In addition, the inter-digitation of different types of networks was illustrated, to help with strategic planning and balancing of conservation objectives. Two types of aspen networks were modelled, one for a species of moderate dispersal ability (the hoverfly *Hammerschmidtia ferruginea*) and the other for a species of very low dispersal (the black bordered beauty *Aricia artaxerxes*). The modelling showed how forestry incentives for creating new aspen woodland could be targeted to benefit both types of species networks.

8. The modelling work in this project benefited greatly from the availability of good land cover data such as the IACS database with individual field information, Phase 1 survey information on semi-natural areas and the NVC surveys grasslands in Tiree and of wetlands and grasslands in Strathspey. It is recommended that Phase 1 survey be completed for the whole of Scotland.

9. The availability of species data (location and ecology) was also of critical importance in ensuring that the modelling was based on sound information and the outputs realistic. It is recommended that a library of ecological information for a range of focal species should be compiled by region and linked to the species management database HaRPPs (Habitats and Rare Protected and Priority Species)

10. The availability of GIS data on Landscape Character and Historical Land-Use allows consideration of landscape constraints and subsequent refinement of the BEETLE ACBT outputs. 3-D computer visualisations of network development in the East Neuk study proved a useful tool for assessing impacts on the visual aspects of landscape character.

11. The manipulation and interpretation of oblique aerial photographs could be of value as a tool for communicating the visual impact of network development to a wider group of stakeholders, but needs to be tested further.

12. Core path data were obtained for the East Neuk and three different types of "people focal species" identified based on relative mobility. Exploration of the interplay between the people and grassland habitat networks demonstrated that there was no real conflict between the two. Network development for priority habitats and species should not pose any threat to recreational opportunities provided that facilities and paths are sited sympathetically. However, more work is required to validate the assumption that human behaviour can be analysed using a focal species modelling approach.

13. The BEETLE ACBT was developed as an automated procedure within ARC9 GIS complete with a user-friendly interface. The ACBT is designed for use by strategic planners and land use advisors in different regions. In order to be effective, the ACBT needs to have good quality species and habitat input data, and its use informed by local/regional conservation priorities. Further testing and refinement by end-users is recommended.

14. It is recommended that SNH Natural Heritage Futures and Local Biodiversity Action Plans are adopted as the mechanism for determining conservation priorities and also informing the regional prioritisation of Land Management Contract Tier 3 measures for enhancing biodiversity (e.g. SEERAD agri-environment measures, Scottish Forestry Grant Scheme (closed 2006) and SNH Natural Care scheme). The ACBT can help inform the spatial targeting of Tier 3 measures within different regions.

15. The implementation of habitat networks requires the integration of local and national policy conservation priorities and planning mechanisms with network modelling and "on-the-ground" advice and execution. It is recommended that guidelines which encapsulate this integrative process are developed and made accessible to land managers and advisors.

16. It is recommended that the development of networks should be monitored through a variety of approaches such as: assessing habitat condition and ecosystem development; tracking the distribution and dispersal of both focal and functional species; recording evidence of species use of new habitats; undertaking post-hoc genetic analysis to infer patterns of migration.

1 BACKGROUND

The Scottish lowlands have a long history of intensive land-use which has resulted in the loss and fragmentation of semi-natural agricultural habitats and a reduction in biodiversity. There is increasing emphasis on reversing the effects of fragmentation through combining site protection and rehabilitation measures with landscape scale approaches which improve connectivity and general landscape quality (Anon, 2002; Anon, 2004).

The development of habitat networks is seen as an important mechanism for reversing the effects of fragmentation on biodiversity while delivering a range of other environmental benefits such as enhancing local landscape character and creating more opportunities for public access and recreational enjoyment of the countryside. To date the emphasis has been on planning the development of Forest Habitat Networks (Ray et al., 2004; Peterken, 2003), but FHNs only represent a part of biodiversity. There is also a need to consider the potential for developing networks of non-wooded agricultural habitats and to look at ways of integrating these with FHNs in different landscape settings, the overall objective being to balance the needs of different species while also delivering the desired economic and social benefits from agricultural land.

Over recent decades in the UK, a wide range of agri-environment measures have been introduced in the an attempt to address the loss of biodiversity (Kleijn et al., 2006). Much of the emphasis has been on protecting, restoring and creating habitats for threatened or priority species, for example adapting cropping practice for farmland birds, restoring semi-natural grassland and enhancing arable field margins (Donald and Evans, 2006).

Humphrey et al. (2005) reviewed current approaches in agri-environment schemes and concluded that the focus has invariably been on individual habitats and ecosystems with little consideration of how these interact at the landscape scale, and what the overall consequences for biodiversity might be. In addition, issues such the spatial configuration of different habitats and the resulting impacts on landscape connectivity for different species groups has not been evaluated, particularly in a Scottish Lowland agricultural setting. Increasingly, a proportion of agri-environment measures are likely to be spatially targeted (Scottish Executive, 2006b) and it is vital that tools are available to help strategic planners and land-use advisors guide these measures to the right places, both at the landscape and regional scales.

Phase I of the Lowland Habitat Networks project consisted of a desk-based review of the theoretical approaches to spatial targeting of measures for habitat creation, restoration and enhancement (Humphrey et al., 2005). The development of a habitat network approach guided by focal species modelling was recommended as a practical, ecologically robust method for informing the spatial targeting of agri-environment measures. The GIS-based set of landscape analysis tools known as BEETLE (Biological and Ecological Evaluation Tools for Landscape Ecology) developed by Forest Research and SNH have been used in a number of studies to develop plans for habitat networks (e.g. Humphrey et al., 2004). However, before any of the BEETLE tools can be used to aid the targeting of agri-environment measures, there is a need to test them more extensively within lowland agricultural landscapes.

Here we report on work carried out as part of Phase 2 of the Lowland Habitat Networks project. The overall aim was to test the BEETLE approach in a number of case study landscapes in the Scottish Lowlands and evaluate its usefulness in helping with the potential targeting of argi-environment (including forestry) incentives. Specifically, the aim was to test the BEETLE Accumulated Cost Buffer Tool (ACBT) which analyses landscape function (network connectivity) in relation to different land use scenarios. A secondary aim was to develop a user-friendly version of the BEETLE ACBT accessible to those involved in making planning decisions, or who were involved in giving advice to land managers and owners.

Lastly, as the development of ecological networks cannot be considered in isolation from human use and appreciation of the landscape, an important aspect of this project was to develop ways of assessing the potential impacts of network development on landscape character and recreation following recommendations in Humphrey et al. (2005).

2 OBJECTIVES

The specific objectives of the work described in this report were to:

i) Test the usefulness of the BEETLE approach to developing lowland habitat networks by evaluating potential land-use changes in four (subsequently changed to 3) contrasting lowland agricultural landscapes
ii) Develop a GIS-based method for assessing the effects of habitat network development on landscape character (current and historic) and recreational values
iii) Provide a prototype PC (ArcView)- based decision support tool that will allow automation of the BEETLE modelling and will be suitable for testing by SNH and SEERAD end-users
iv) Ensure that project results are fed into the process of reviewing agri-environment incentives and determine the scope for spatial targeting
v) Provide clear and concise guidance on the practical application and relevance of the BEETLE decision support tool at various landscape scales

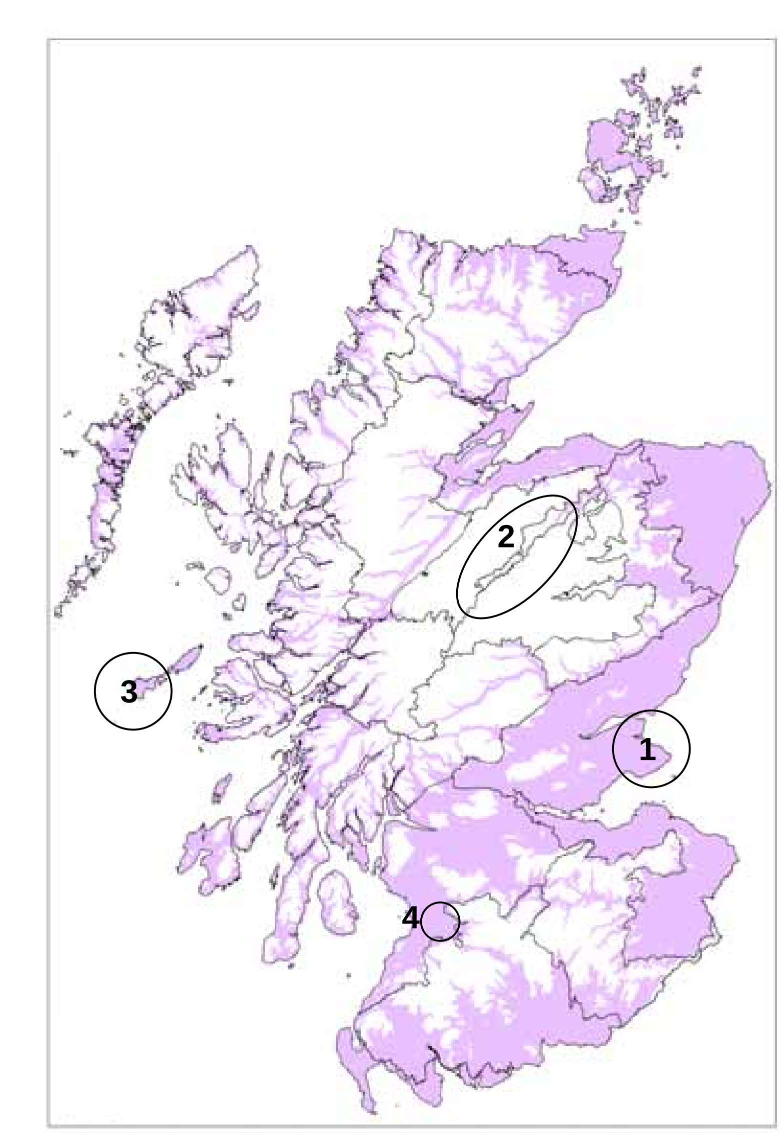
3 METHODS

3.1 Approach

The research was progressed through eight main tasks.

Task 1: identification and establishment of four case study areas
Task 2: engaging stakeholders within the study areas
Task 3: identifying focal species and collating species and habitat data (including testing the usefulness of IACS data)
Task 4: BEETLE analysis of different land use change scenarios
Task 5: assessing the consequences of network development for landscape character and recreation.
Task 6: improving the accessibility of the BEETLE modelling process to end-users through developing a user-interface
Task 7: investigating the potential for integrating, within GIS, the ecological modelling with landscape character and recreation impact assessment
Task 8: guidance on the practical application of the BEETLE model for end users

Figure 1 - Lowland zone (shaded purple) in Scotland based on climate and soil variables. Reproduced from Humphrey et al. (2005) The location of the study areas are circled see Table 1.



Key to study areas:

1 = East Neuk of Fife
2 = Strathspey
3 = Tiree
4 = River Cessnock/Irvine Catchment (not progressed)

3.2 Selection of case studies

Initially four case study areas were identified (Figure 1) and the boundaries established in agreement with the Steering Group and finalised after confirmation by local stakeholders. The case studies were located in Lowland Natural Heritage Futures (Zones) (Scottish Natural Heritage, 2002) and selected to represent areas with contrasting landuse issues to allow testing of the modelling approach in different settings and where there were different environmental priorities (Table 1). These priorities were identified through stakeholder consultation in each locality (see details for each case study area). Unfortunately there were delays in the development of, and hence public engagement with, the wider SEPA –led Diffuse Pollution Priority Catchment Initiative during the lifetime of this project (see section 3.3.) As a result, it was not possible to take forward the intended fourth case study.

Table 1 - Description of case study areas and main issues for biodiversity conservation

Case study	Area (km^2)	Main land use	Main issues
1. East Neuk of Fife	341.3	Intensive mixed arable with grassland on less productive sites	Conservation and enhancement of semi-natural grasslands; conservation of red squirrels and farmland birds
2. Strathspey	722.8	Mix of semi-natural woodland, plantations, heathland, rough and improved grazing and limited arable	Integrating woodland and open ground networks; connectivity of aspen woodland
3. Isle of Tiree	78.4	Extensive grassland with machair and wet heaths	Interaction between grazing and grassland management; impact on key avian and invertebrate species
4. Cessnock/Irvine catchment	Not progressed further in this project		

3.3 Stakeholder engagement

In Fife, Tiree and Strathspey contact was made with relevant LBAPs and key stakeholders. At least two meetings were held with stakeholders in each of these areas. Unfortunately, it was not possible to progress the Irvine/Cessnock case-study within the time period of the project. The Ayrshire LBAP was not operational during the period of this project, and focal species priorities could not be determined. In addition, although SAC were moving ahead with the establishment of an Environmental Focus Farm in the Cessnock/Irvine catchment, during the lifetime of this project there were delays in the development of, and hence public engagement with, the wider SEPA-led Diffuse Pollution Priority Catchment Initiative (of which it is anticipated that the Cessnock/Irvine catchment will form part). This not only placed limitations on the amount of background information on diffuse pollution priorities and concerns in the Cessnock/Irvine which could be made available to this project, but also prevented any engagement with any wider suite of local stakeholders.

In the other three study areas the timing and progress of work was largely governed by the stakeholders, when it has been possible to hold meetings, and other ongoing related projects. The meetings varied in format, but generally comprised a short introduction to the project and the methodological approach by the project team, followed by an iterative discussion to determine species and habitat priorities and land-use issues within the study area. Short reports of the meetings in each of the case study areas were produced and included in the appendices. The specific issues identified in the study areas are outlined in the relevant case-study sections of this report.

3.4 Land cover and species data

The datasets used specifically in this phase of the project are listed in Table 2. This is a short list of the version described and referenced in full in Humphrey et al. (2005). As part of the process of claiming agricultural subsidy payments, all farmers in Scotland are required to submit an annual IACS (Integrated Agricultural Control System) return to SEERAD each year which sets out the use each area of their farm is being put to in that year. SEERAD hold a GIS Field Register of all IACS fields in Scotland. Shape files were obtained for each study area and combined with data from some of the other sources below to construct a composite land cover layer which included the location and extent of both farmed and non-farmed habitats. This is the first time that IACS data have been used in this type of project and it was one of the main objectives of the project to test the usefulness of the dataset for this type of modelling exercise.

Table 2 – Description of land cover datasets used in the project – reproduced in part from Humphrey et al. (2005)

Data	**Description**	**Value**
SAC, SPA, NNR and SSSI boundaries	Boundaries of protected areas/sites	Give indication of areas of high conservation value in general
Phase 1 Habitat Survey	Broad scale field mapping approach giving information on the extent and distribution of natural and semi-natural habitats	Ideal source of good quality habitat information, but limited in coverage to specific regions
Land Cover Map 2000 (LCM)	Satellite derived remote-sensed datasets providing broad habitat definitions	Covers the whole of Scotland, but there are problems with accuracy in mapping some upland habitat types
Land Cover Scotland 1988 (LCS88)	Remote sensed dataset derived from aerial photography taken in 1988; provides broad habitat definitions at 1:25 000 scale	Covers the whole of Scotland focusing on semi-natural habitats, is out of date, but currently being updated ("New Image of Scotland")
National Inventory of Woodlands and Trees (NIWT)	Derived from LCS88 dataset plus updated to 1995 from FC sources; provides information on broadleaved/conifer woodland > 2ha and small woods and trees (0.1-2ha)	Baseline data source on woodland for Scotland
Scottish Forestry Grant Scheme and Woodland Grant Schemes	Regularly updated records of new planting	Gives composition and extent of new woodland areas which can give indication of habitat value
Scottish Semi-Natural Woodland Inventory (SSNWI)	Constructed over the period 1995-2001 using interpretation of aerial photographs taken in 1988. Map of all woodlands > 0.1 ha classified according to degree of semi-natural character	Identifies all semi-natural woodland, useful when combined with NIWT to locate sites of high conservation importance
Scottish Ancient woodland Inventory (AWI)	Map of all ancient (existing since 1750) woodlands over 2 ha in size	Identifies areas of key importance for woodland biodiversity
Unitary Authority boundaries	Locations of Local Authority areas	Establishes link between network modelling, local authority areas and LBAPs

Table 2 – cont…..

Data	Description	Value
Ordnance Survey® Pan-Government product portfolio	Products include: 1) for large scale mapping - OS MasterMap; Land-Line; 1:10 000 Scale Raster; 2) for small scale mapping – 1:50 000 Scale Colour Raster; 1:50 000 Scale Gazetteer; 1:250 000 Scale Colour Raster; Strategi®; Meridian 2	MasterMap is the definitive, large-scale digital map of Great Britain, containing information on roads, tracks, paths etc. Gives accurate representation of woodland areas and boundaries and can identify linear features which can act as barriers to dispersal or as corridors
Ordnance Survey Digital Elevation Model (DEM)	Digital elevation data for whole of the country	Allows construction of elevation maps aiding in deriving ESC climatic and soil quality indices.
SNH BAP priority habitat report and maps	Maps and description of UK BAP priority habitats summary of all previous phase 1 and phase II survey information in Scotland	Provides information on location of key habitats in Scotland
National Vegetation Classification survey data	Various surveys covering SACs, SSSIs and other habitats of high conservation value in Scotland	Coverage is geographically limited and information can be too detailed to make meaningful links with species requirements
Scottish Integrated Agricultural Control System (SIACS)	Contains information on field sizes and crop types for very field in Scotland	Shape files and data available for individual holdings

By focusing on case study areas and engaging with local stakeholders the project benefited from availability of species data collected by various organisations. Data on location, population dynamics and dispersal ecology were available for a range of species and were used to inform the modelling process (see case study sections for details).

3.5 Construction of landuse change scenarios

The landuse change scenarios were determined for each study area in consultation with stakeholders and the details are given in the relevant sections of the report. The current suite of agri-environment measures in Scotland provides a framework for determining possible changes in agricultural practices and the scope for spatial targeting. Land Management Contracts (LMCs) were introduced in 2005. LMCs are a whole farm system of support which makes payments for the delivery of environmental, social and economic benefits for public good.

The LMC concept comprises 3 Tiers of subsidy. Tier 1, the Single Farm Payment Scheme (SFPS) and cross-compliance was introduced to secure a basic level of environmental protection, food safety and animal welfare. Farmers and crofters are expected to adopt “Standards of Good Farming Practice” and comply with a set of General Environmental Conditions. A full list of these conditions is given in (Scottish Executive, 2006b). Tier 2 includes the LMC menu scheme (Scottish Executive, 2006a) for delivering tailored benefits leading to economic, social and environmental enhancement (see Table 3)

The LMC menu scheme is separate from past and existing agri-environment schemes namely the Rural Stewardship Scheme (RSS), the Countryside Stewardship Scheme (CSS), the Environmentally Sensitive Areas (ESA) and Habitats Schemes. In 2007 all these schemes will be superseded by the LMC Tier 3 scheme which will deliver tailored environmental benefits.

Appendix 1 lists RSS measures which may be incorporated into the Tier 3 scheme. The aim of the RSS and its preceding schemes are to encourage the adoption of environmentally-friendly farming practices and to maintain and enhance particular habitats and landscape features. The RSS prescriptions are grouped into those relating to:

a) Farmland birds
b) Creating and managing semi natural habitats such as species-rich grassland and woodland
c) Field margins and boundaries
d) Arable cropping

In addition, incentives are available for capital works such as pond construction which will benefit invertebrates and amphibians such as Great Crested Newt. Uptake of LMC Tier 2 and RSS measures are included within the IACS database and are therefore available for spatial modeling. Stakeholders were interested specifically in how measures could be spatially targeted to consolidate existing designated sites and habitat networks.

Table 3 – Description of LMC TIER2 measures for maintaining and improving biodiversity recorded in IACS

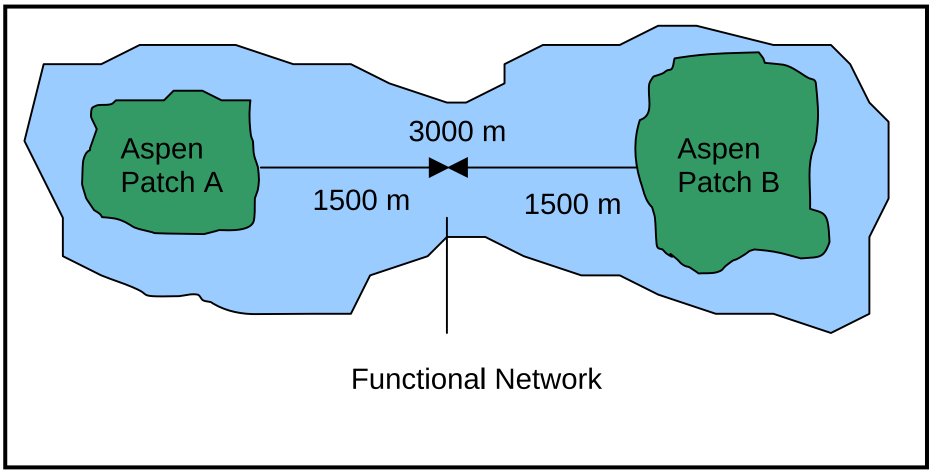
Measure	**Description**
Buffer areas	Buffer area (3 –6 m) in arable fields or on improved grassland along watercourses or around springs, boreholes, areas of wetland, species rich grassland, woodland or archaeological sites
Management of linear features	Managing farm hedgerows, hedgerow trees, ditches (not natural watercourses) and dykes by sensitive cutting, clearing and reinstatement as appropriate.
Management of moorland grazing	Regulation of stock to prevent over-grazing and maintain habitat mosaic
Management of rush pasture	Grazing and cutting to maintain habitat mosaic for birds
Biodiversity cropping on in-bye	Traditional crop rotations in Less Favoured Areas to benefit declining bird species
Retention of winter stubbles	Providing feeding and breeding areas for seed-eating birds over winter by retaining stubble from spring grown crops
Wild bird seed mixture	Creating patches of bird seed and cover through sowing mixtures of seed-bearing crop groups in 6m wide strips at edge of fields or in 0.5 ha blocks
Summer cattle grazing	Restoring the balance between dwarf shrubs and moorland grassland on rough grazings
Nutrient management	Decreasing diffuse pollution on in-bye land by matching nutrient addition to crop requirement
Improving access	Creating and maintaining continuous paths to guide people exercising their right of access to the most appropriate locations
Woodland plan	Integrated approach to the planning of woodland management and expansion on farms
Farm woodland Management	Bringing native and open grazed woodland into active management for environmental and economic benefit

3.6 BEETLE modelling approach

Humphrey et al. (2005) reviewed the different approaches of landscape evaluation for biodiversity, ranging from straightforward assessments of landscape structure (e.g. landscape metrics analysis; neutral landscape analysis) through to functionally based modelling approaches, such as focal species modelling, and population dynamics modelling for individual species. The BEETLE set of landscape evaluation tools incorporates the full range of these different approaches and can be tailored to specific landscapes and ecological questions (Watts et al., 2005).

In this project, the main BEETLE tool used was the “accumulated cost-buffer tool” (ACBT) linked to ecological profiles for focal species selected specifically in each study area. Habitat networks were constructed for specific focal species based on current land use (and hence land cover) and future projections of land use change given improved targeting of agri-environment incentives. Habitat patches were identified for each species and the intervening matrix scored in terms of how permeable (see Appendix 5 for example) it is to species movement and dispersal Watts et al., 2005. The permeability scores were used to calibrate dispersal distances and create buffers of varying distance around habitat patches. Functional connectivity between habitat patches occurs where buffers intersect and habitat networks are defined as areas of connected habitat (Figure 2). Functional connectivity is distinct from structural connectivity. 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 such as species dispersal. For this project, the accumulated cost buffer tool (ACBT) was automated in ArcGIS 9 to allow access by non-specialists. The construction of the ACBT is described in Section 7.

Figure 2 – Illustration of functional habitat network in relation to habitat patches



3.7 Procedure for identifying focal species

Fleishman et al. (2000) define focal species very broadly as any taxon that receives considerable attention from conservation biologists and practitioners. This is the starting point in our methodology for selecting focal species in this project. However, we go further and build on Lambeck' s (1997) definition that focal species are those whose requirements for persistence outline the ecological attributes that are necessary to meet the requirements of the range of species that occur in a given landscape. In this context focal species are of interest not only in their own right, but also as surrogates, or umbrella (Simberloff, 1998) species for a wider range of taxa. Although the empirical evidence for surrogacy is often lacking (Lindenmayer and Fischer, 2002), there have been clear examples where the approach has useful in developing guidelines for habitat creation, restoration and configuration at the landscape scale (Freudenberger and Brooker, 2004). In the absence of extensive knowledge of the ecology of the whole range of species that might be using a landscape and the urgent need to make informed decisions in planning landscape change, Humphrey et al. (2005) recommend the use of focal species as an appropriate tool for analysing the impact of land-use change on biodiversity.

In the case study areas, focal species were selected to be surrogates for the impacts of habitat fragmentation on biodiversity in agricultural landscapes. Figure 3 illustrates how habitat fragmentation has differential impacts on a species' persistence in the landscape, depending on its dispersal ability and habitat area requirements. Species with moderate area requirements and poor dispersal abilities tend to be more sensitive to fragmentation, and hence to population decline and extinction. However, habitat type and quality requirements are also of key importance and form a third axis of selection. We focused on species that would be sensitive to differing agricultural practices and the amount and spatial distribution of those practices, in particular taking account of the current list of grant-aided measures for maintaining and enhancing biodiversity on farms (Appendix 1; Table 3). The stakeholder workshops in each case-study area were also of key importance in selecting species that were indicative of conservation and land management priorities within each area. Conservation priorities are shown in Figure 4 in relation to the ecology of focal species. In this project the focus for spatial targeting of agri-environment measures was on:

- securing and expanding core areas of habitat (e.g. designated sites)
- increasing connectivity between habitats – through adding new habitat and increasing the permeability of the matrix

Selection of species was also informed by the availability of data for the case study area (see Section 3.4). We did not address issues of threshold amounts of habitat within the landscape (e.g. for woodland song birds), improving habitat quality or species introductions (Figure 4). The issue of reducing connectivity to combat the threat of invasive species was touched on briefly through the Grey Squirrel v Red Squirrel analysis in Fife.

Figure 3 – Example of relative sensitivity of species to fragmentation

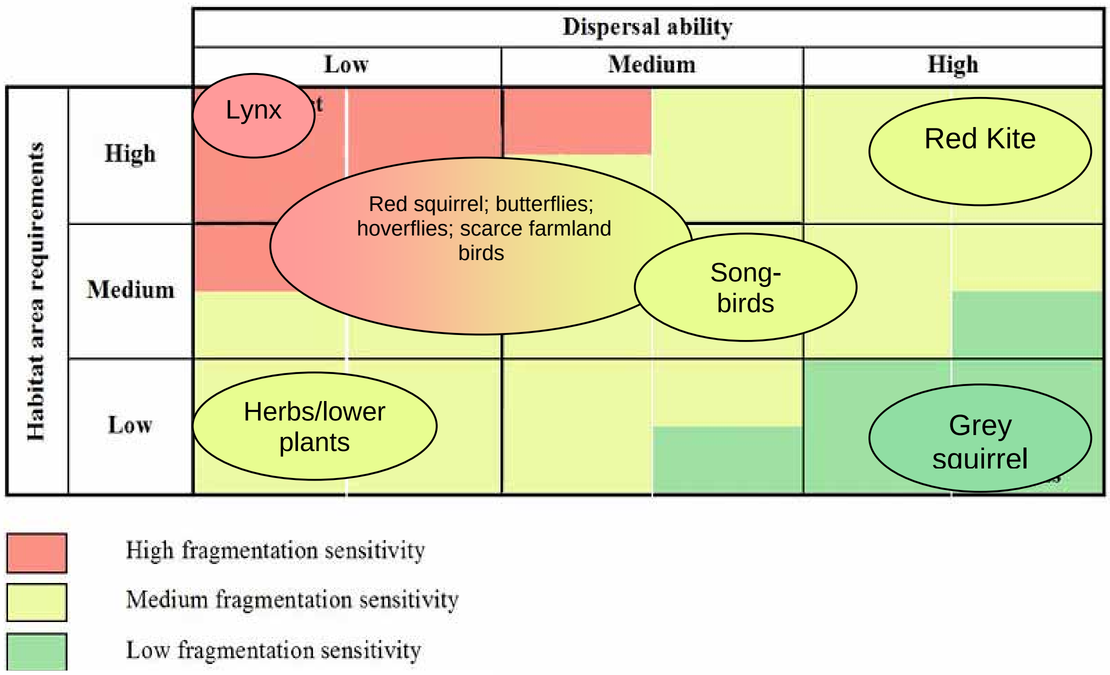
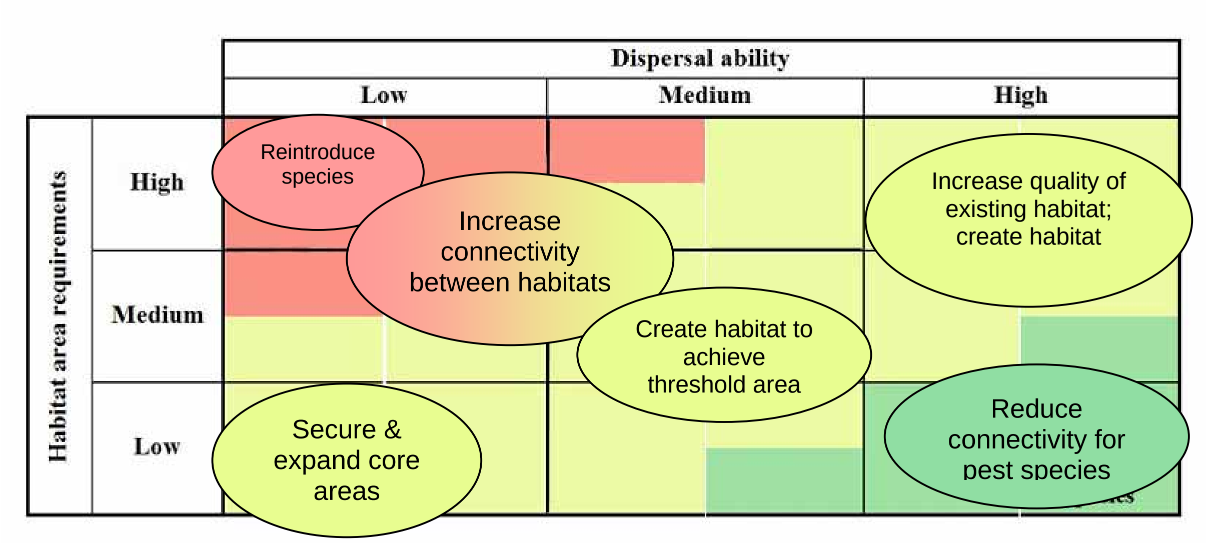


Figure 4 – Conservation priorities based on focal species ecology



3.8 Landscape, visual and recreational assessments

In this task we developed methods for assessing the impact of network development on landscape character and visual qualities. The East Neuk case study was selected as a test case for the landscape and visual assessment (see Section 5). For the recreation assessment we explored the inter-relationships between networks for people and wildlife, by treating people as a focal species (see Section 6).

3.9 Development of BEETLE accumulated cost buffer tool and end-user interface

The aim of this task was to improving the accessibility of the BEETLE modelling process to end-users through developing a user-interface with accompanying guidance (Tasks 6 and 8). Specifically work has been undertaken to provide the ACBT with a suitable inter-interface within the ArcGIS software environment. For ease of reference the tool is referred to as the SNH/SEERAD tool as it has been developed with the needs of SNH/SEERAD advisors in mind. The full description of the tool is given in Section 7.

4 RESULTS FROM CASE STUDY AREAS

4.1 East Neuk of Fife

4.1.1 Background and description of case study area

The East Neuk of Fife forms an area of intensive arable production in eastern Scotland (Figure 5) within the Eastern Lowlands Natural Heritage Futures area (Scottish Natural Heritage, 2002). The landscape is a mix of more expansive open areas to more intimate valleys (dens) cut into the hills. Tentsmuir to the north-east of the study area forms the largest expanse of coastal sand dunes in Britain with important coastal grasslands immediately inland. Precipitation is low (650 – 800 mm/annum) compared to the rest of Scotland and this has an impact on the characteristics and distribution of species and habitats. The soils of the area are mostly brown earths and form some of the most fertile areas for farming in Scotland.

Semi-natural habitats are rare and are largely restricted to narrow riparian zones, field margins and in association with linear features such as hedgerows. Woodland cover is represented by shelterbelts, more extensive coniferous areas such as at Tentsmuir, and in small remnant semi-natural woods next to streams and in steeper cleughs and gullies. More than 80% of these remnant woodlands are less than 5 ha in size. In recent decades, Grey Squirrel populations have increased at the expense of the Red Squirrel, but there has been an active programme of Grey Squirrel control which appears to have given the Red Squirrel a stay of execution.

In terms of access and recreation, enclosed farmland and commercial forestry limit accessibility, but the Fife Coastal Path is a key resource for walkers and also intersects many wildlife rich areas. Significant older woodlands are valued for their recreation e.g. at Tentsmuir. Intensification of agriculture has had a profound influence on the biodiversity of the East Neuk, resulting in the loss and fragmentation of semi-natural habitat and reduction in habitat quality through application of fertlisers and pesticides. In recent years these trends have begun to be reversed through agri-environment measures such as tree planting, protection and restoration of semi-natural habitats and management of field boundaries and buffer strips.

4.1.2 Stakeholder engagement

Three meetings were held with the Fife stakeholder group (see meeting report Appendix 2). The focus was on identifying key issues of conservation concern in relation to land-use change drivers and effects on priority habitats and species. The group (a total of10 plus the project team) comprised representatives from FWAG, SNH, FC, RSPB, FERN, Fife Council and Fife ranger service.

4.1.3 Priorities for habitat and species modelling

Targeting of agri-environment incentives, climate change, and biofuels (short rotation coppice impacts) were seen by the stakeholders as key issues where network modelling could make an important contribution. Not all of these issues could be addressed in the time available and it was agreed that the BEETLE modelling should focus on the issue of targeting of agri-environmental (and forestry) incentives, in particular constructing habitat networks for:

- Unimproved grassland; focal species Northern Brown Argus (*Aricia artaxerxes*) as a surrogate for a range of grassland species of limited dispersal capabilities
- Conifer woodlands; focal species Red Squirrel (*Scuiris vulgaris*) as a conservation target in its own right
- Arable fields/cropping; focal species Corn Bunting (*Miliaria calandra*) as a conservation priority in its own right and as a surrogate for threatened farmland birds

Figure 5 – Map of East Neuk of Fife study area marked by black boundary

4.1.4 Data used in the modelling

In addition to the nationally available land cover datasets (Table 2), data on the location of unimproved grasslands was obtained from the Phase 1 Habitat Survey North East Fife 2003. Locations for the focal species were obtained from the Fife Environmental Records Centre (FERN). The RSPB provided the Corn Bunting location and population data. Ecological profiles for the focal species are shown in Table 4. These were based on available literature, the UK Biodiversity Action Plans for each species. The "cost values" ascribed to all the land cover types recorded in the study area are listed in Appendix 5.

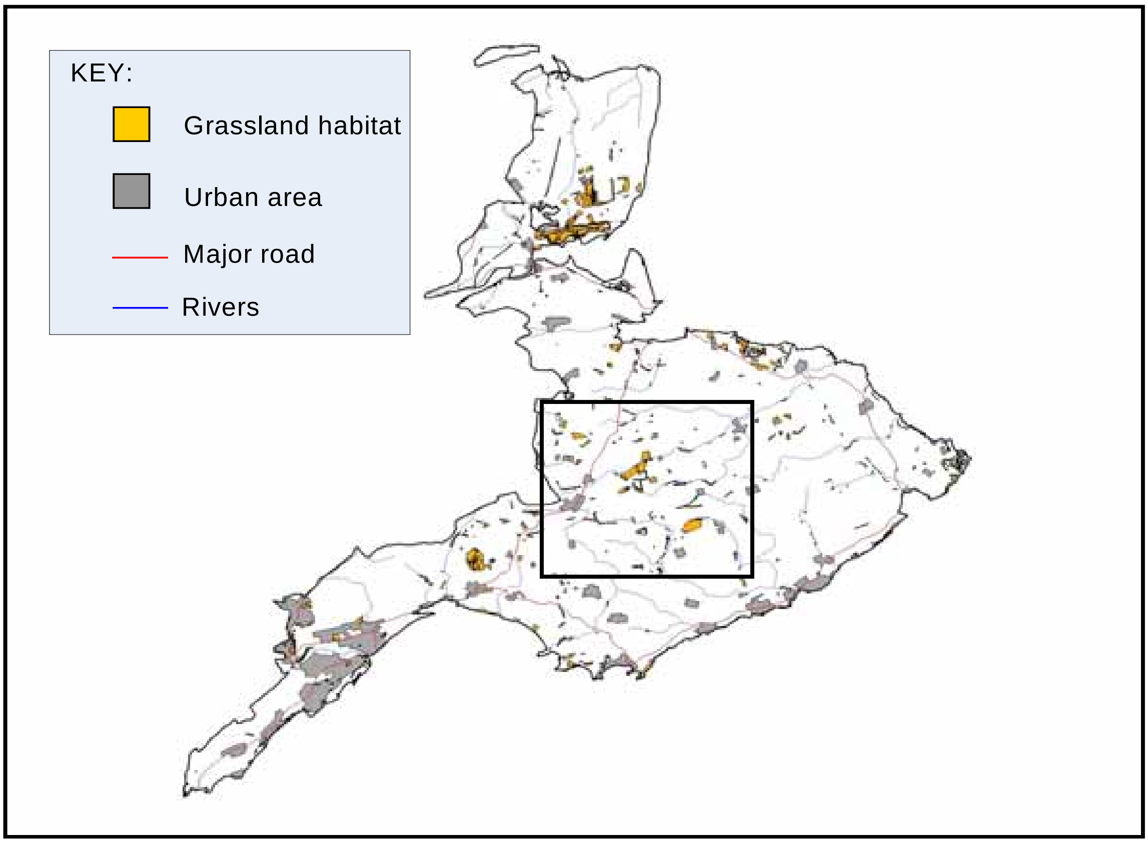
Table 4 – Focal species profiles used in the East Neuk case study area

Focal species	**Habitat requirements**	**Dispersal distance**	**Illustration**
Northern Brown Argus *Aricia artaxerxes*	Unimproved grassland with common rock rose *Helianthemum nummularium* for larvae and nectar sources such as thyme *Thymus polytrichus* and bird's-foot trefoil *Lotus corniculatus* for adult dispersal to patches of common rock rose	1 km	 © Robert Goodison (www.defra.gov.uk)
Red squirrel *Scuirus vulgaris*	Conifer woodland	5km	 © Forestry Commission Forest Life
Corn Bunting *Miliaria calandra*	**Summer**: cover of un-harvested crops, set-a-side spring sown cereals **Winter**: Stubble	2km 4km	 © Mark Hamblin (RSPB Images)

4.1.5 Unimproved grasslands – consolidating priority sites

The Northern Brown Argus *Aricia artaxerxes* occurs on well-drained, and usually base-rich, sites on thin soils that are commonly south facing and up to 350 m altitude (Ellis, 2002). Its larvae feed on common rock rose *Helianthemum nummularium*. Primarily occurring on limestone grassland, it is also associated with coastal valleys and quarries, limestone pavement and outcrops (Ellis, 2002; Wilson et al., 2002). The lightly grazed or ungrazed grassland habitat often has a profusion of the larval food plant, nectar sources such as thyme *Thymus polytrichus* and bird's-foot trefoil *Lotus corniculatus*, and patches of bare ground resulting from grazing, landslips, footpaths or rock outcrops. In Scotland, the Northern Brown Argus is also found on sites with relatively low pH dominated by heathers, but these are always well-drained. Maximum dispersal distance is thought to be in the region of 1 km (Wilson et al., 2002).

Figure 6 - Distribution of grassland habitats in the East Neuk study area; inner square shows location of larger scale map in Figure 7



The current distribution of semi-natural grassland habitats in Fife is shown in Figure 6. Centres of distribution occur in the Tentsmuir area (NE part of the study area) and in the middle of the study area. Based on the permeability scores of the matrix and the dispersal distance of 1 km, grassland networks were constructed (Figure 7). These show the current fragmented character of the resource.

Figure 7 – Map of existing grassland networks in the central part of the East Neuk study area

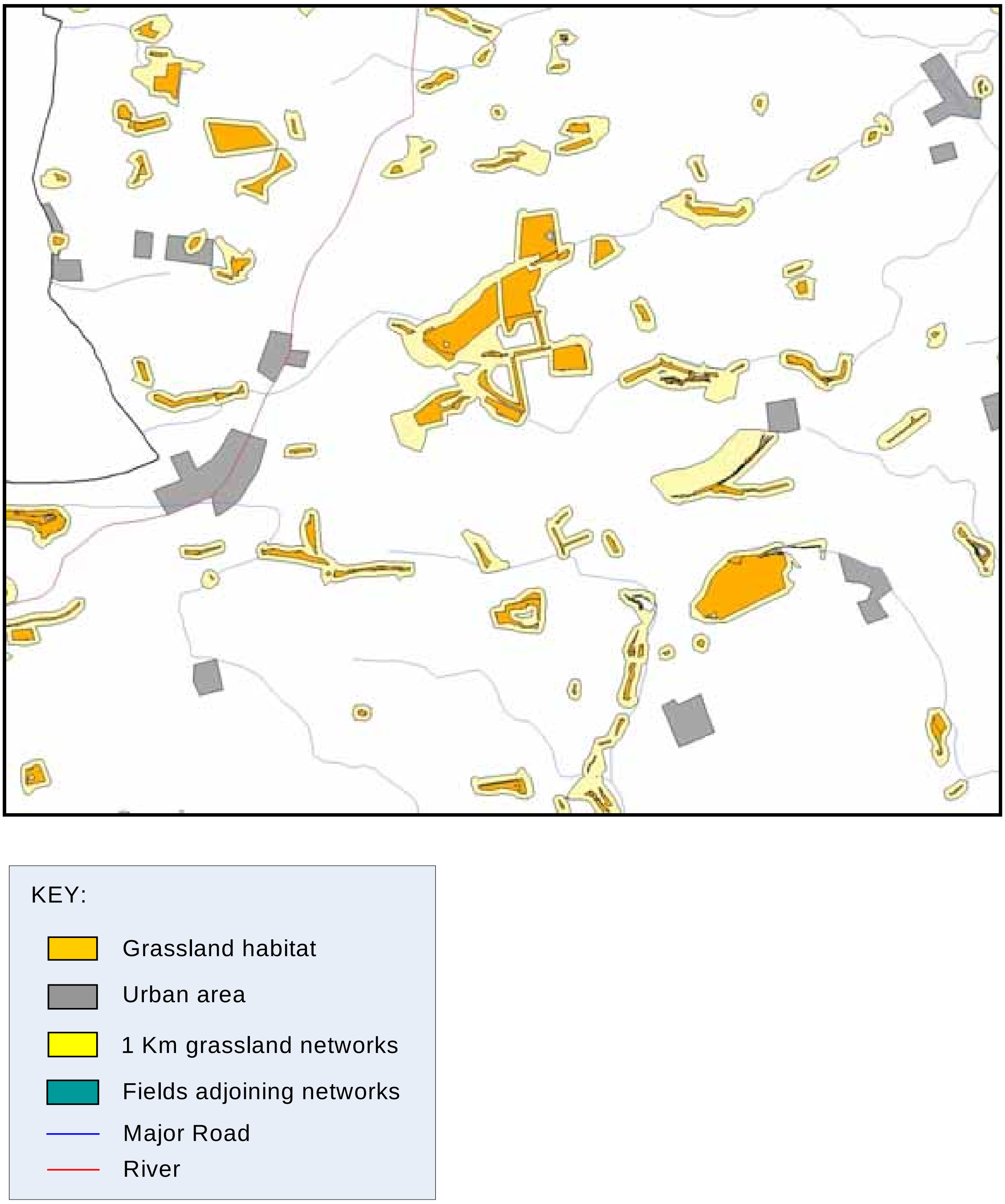
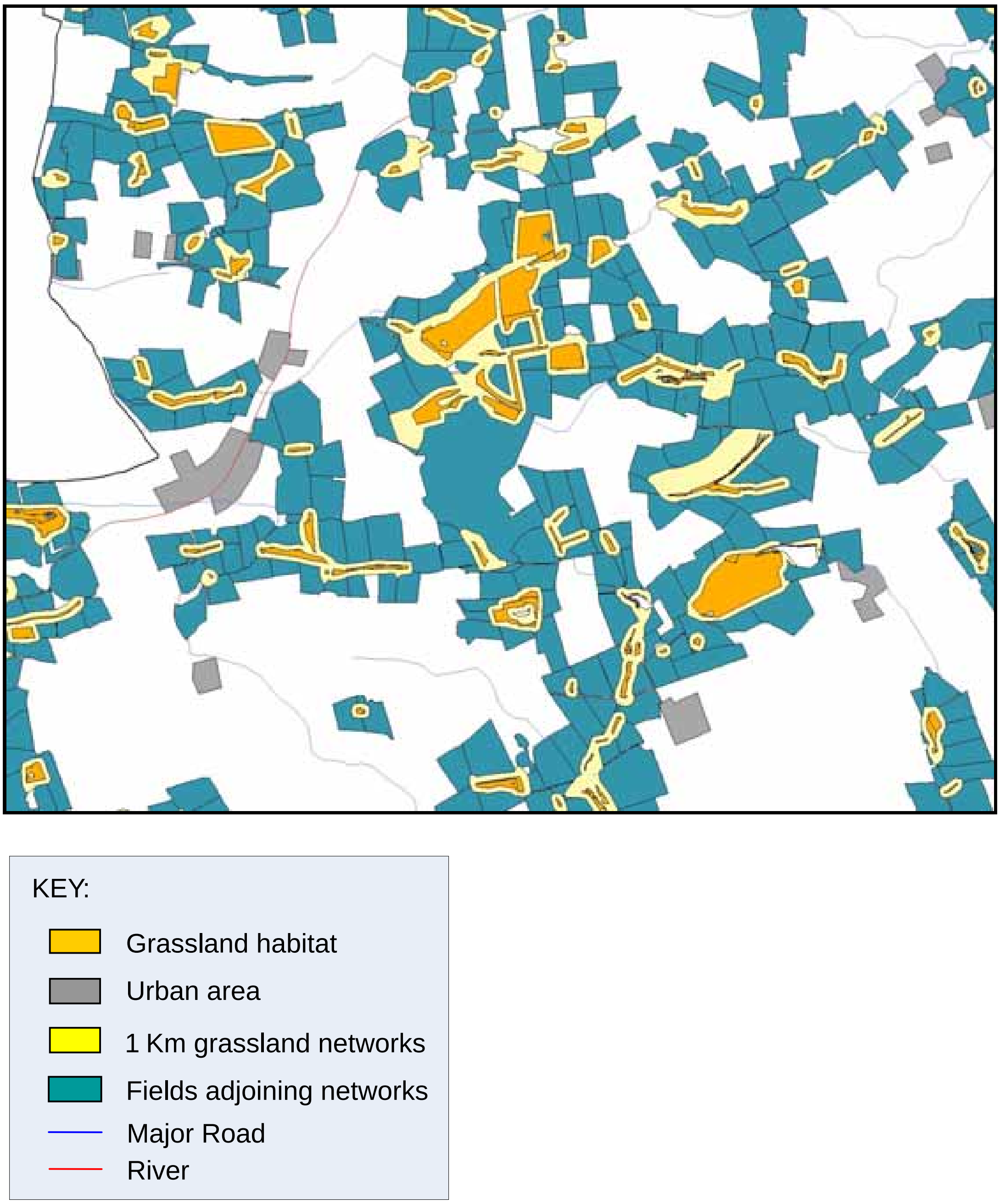


Figure 8 – Existing grassland networks with adjoining fields



The fields immediately adjoining the networks are shown in Figure 8. Field boundaries were obtained from the IACS data for the area. All fields that adjoined the 1 Km grassland network have the potential to contribute to the habitat network. However it is not feasible or practical for this to be the case. A large proportion of this land will be intensively managed arable fields, which have had high nutrient and pesticide inputs and so restoration or conversion to unimproved grassland would not be practical either ecologically or economically.

It is possible to use other techniques to try and identify where there may be grassland ecological processes persisting and this was addressed in two ways:

- Use of OS first edition maps
- Coincidence mapping of grassland plant species

The OS first edition maps (1860) show areas of unimproved grassland (Figure 9) a large proportion of which persist as unimproved grassland today as seen by the coincidence of these areas from the 1st edition with phase 1 survey information (Figure 10). A large proportion of this coincidence is related to the distribution of old quarries and their associated spoil where the parent material is at or near the surface. This gives rise to the right conditions for unimproved grasslands to develop and persist. These areas are also less likely to have been improved as a result of the difficulty in getting machinery onto such sites.

Figure 9 – Example of OS 1st Edition map for a part of the East Neuk study area showing putative areas of unimproved grassland (and example is circled red)

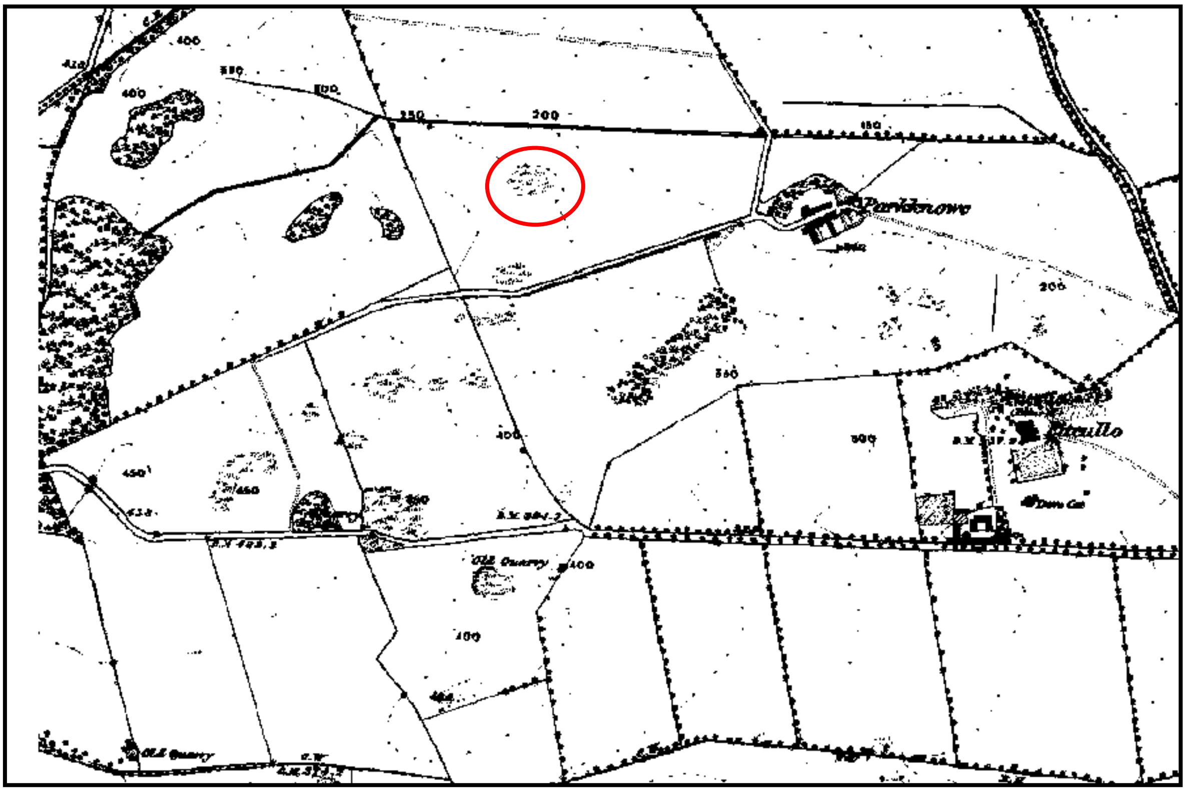
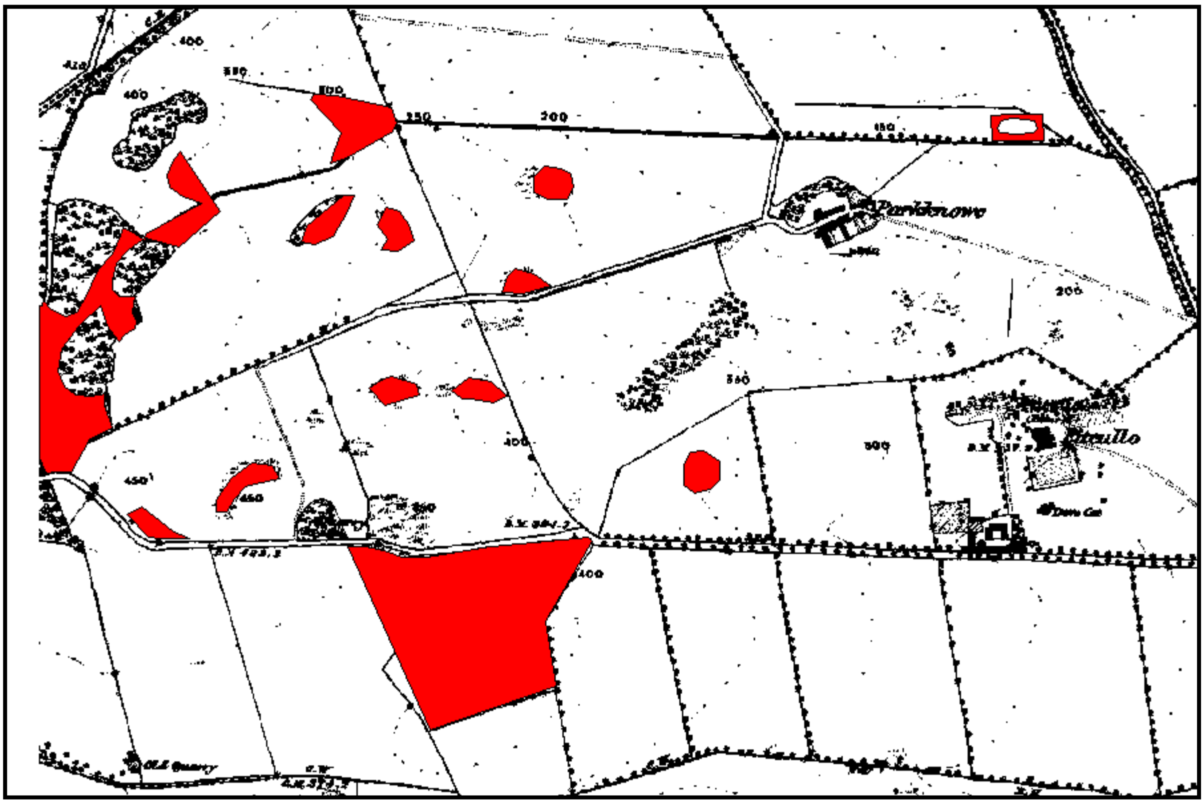


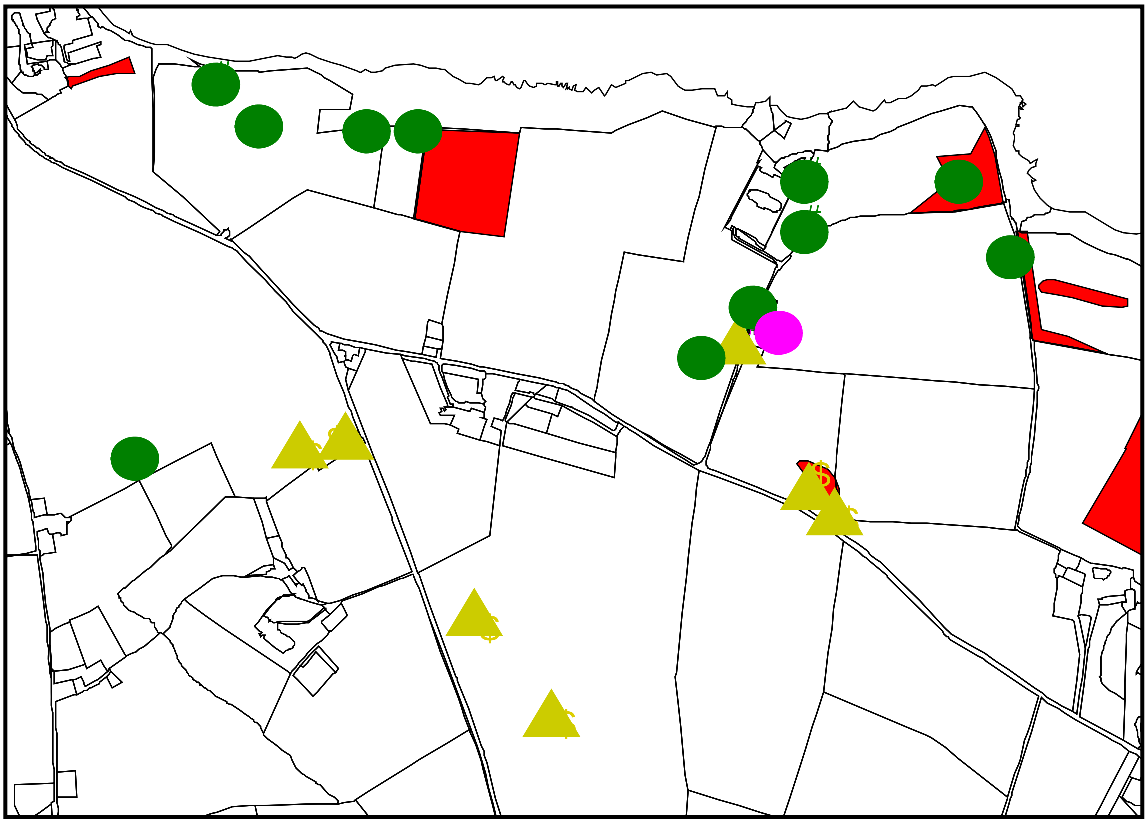
Figure 10 – Coincidence mapping of OS 1st Edition putative unimproved grassland and grasslands recorded during the Phase 1 habitat survey (coloured red)



Using this coincidence mapping it is possible to identify areas on the OS 1st Edition which may have held unimproved grassland in the past but now longer exist. These areas could offer increased opportunities for restoration. Coincidence mapping using the presence of species was used as a further aid to selecting locations where grassland processes may still exist. Grassland quality indicator plants were selected from the JNCC Common Standard Monitoring Guidelines for Grassland SSSIs (JNCC, 2004). The point data (Grid Reference) for these species distribution was extracted from the digital data held by the Biological Records Centre for Fife.

Figure 11 shows the location of unimproved grassland, old quarries and grassland species. These locations can be thought of as "nodes" in the landscape where habitat restoration could be targeted. In Figure 12 these nodes are overlapped with fields adjoining existing grassland networks.

Figure 11 – Example of co-incidence mapping of unimproved grassland from Phase 1 survey, old quarries from OS 1st Edition and location of grassland quality indicator plants



KEY:

- OS 1st Edition 'old Quarry
- Phase 1 unimproved grassland
- Grassland species from coincidence mapping
- Maiden pink (*Dianthus deltoides)* LBAP priority species

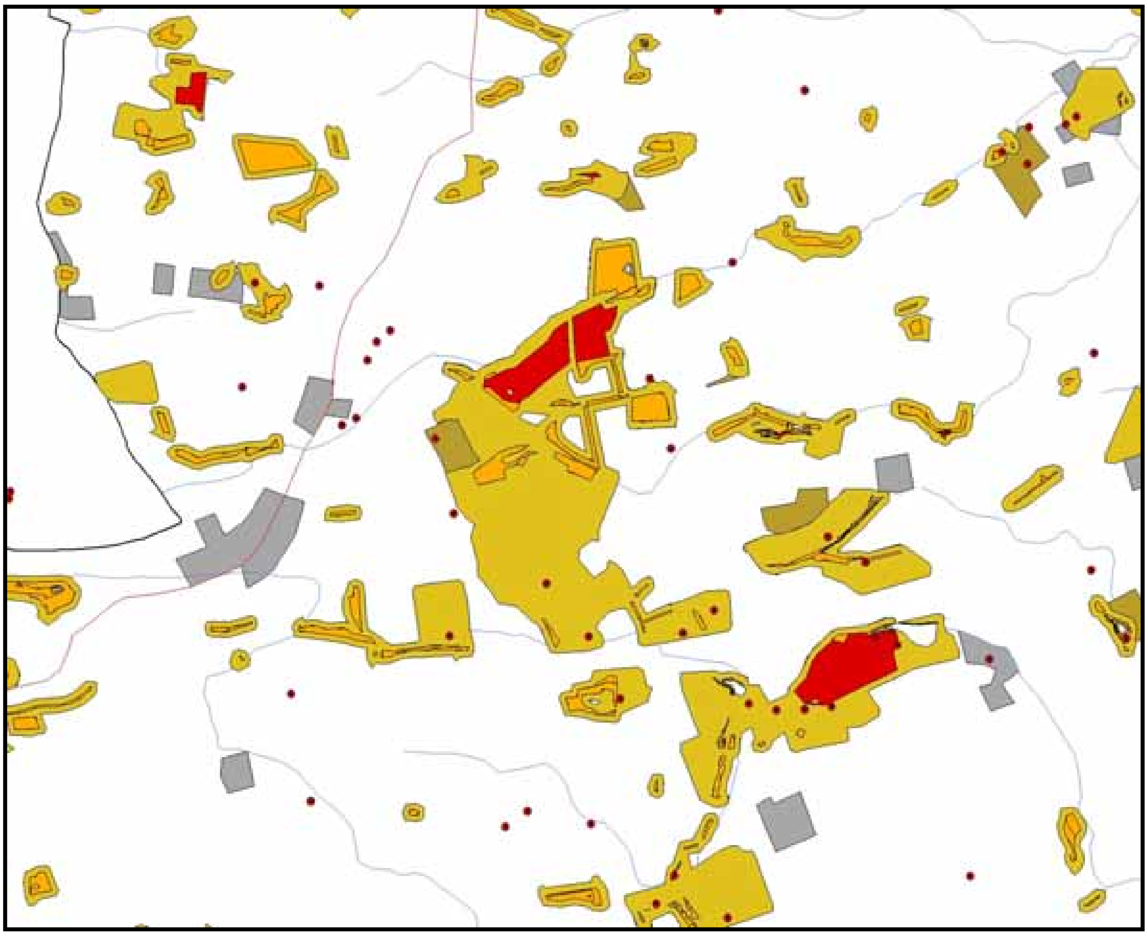
Figure 12 – Distribution of “nodes” and priority fields for restoration in the central part of the East Neuk study area

KEY:

- Grassland habitat
- 1 Km grassland networks
- Fields adjoining networks
- ‘Nodes’ for restoration
- Field targeted for restoration

Where a node coincides with a field that adjoins the grassland network area, then irrespective of whether that field is under grass or arable management, the potential for restoration is highest as it is more likely that there are remnants of grassland processes together with functional connectivity to nearby existing grasslands.

Figure 13 – Development of grassland networks through targeted restoration of fields



KEY:

Increased network area as a result of restoration

Designated grassland site

Areas for restoration should be targeted to reverse habitat fragmentation and recreate larger areas of grassland and transitions with other semi-natural habitats (Figure 13). Sites that have this potential for contributing to greater eco-integrity may be more suitable for restoration. Connectivity can be developed at three levels that relate to core, secondary and tertiary sites (Smith, 2002). This may provide a useful criterion for the selection of sites for restoration or the creation of new grassland habitats

Core Sites: These are high quality (often designated sites) providing good examples of grassland communities of high conservation value. The priorities for these sites are protection, maintenance and the diversification of grassland communities.

Secondary sites: These are sites that might be prioritised for restoration of remnant habitat to consolidate existing high value areas. The two main networks shown in Figure 13 containing the designated grassland sites are good examples of how restoration might be targeted.

Tertiary sites: These are sites that will require restoration of degraded habitat and / or creation of new habitat. Selection of such sites would be based on the occurrence of “nodes”, but would not be linked to designated sites. The aim would be to develop examples of the range of habitats found in the area and to increase connectivity and ecological integrity on a much wider scale, e.g. top right corner of Figure 13. Increased connectivity in this situation will contribute to creating a landscape of higher biodiversity/conservation value.

LMCs could be spatially targeted on the basis of this three level priority system, with habitat creation/restoration incentives targeted towards consolidating core sites in the first instance.

4.1.6 Red Squirrel networks – prioritising action to limit the impact of grey squirrels

The Red Squirrel (*Sciurus vulgaris*) is native to Britain and was formerly widespread throughout England Scotland and Wales. It is now restricted primarily to Scotland, the north of England, and small pockets in Wales and southern England (Pepper et al., 2001; Poulsom et al., 2003) identified key sites where management to benefit red squirrels will be a priority to maintain viable populations. Although relatively isolated from populations in the rest of Scotland, Tentsmuir is listed by Poulsom et al. (2003) as a priority site in the area for targeting management action. Red Squirrels favour mature conifer stands as a habitat, particularly of Scots pine or Norway spruce and will disperse more than 3.5 km (Lurz et al., 1997).

Figure 14 shows Red Squirrel records obtained from Fife Environmental Recording Network (FERN), together with the current distribution of conifer woodland. The Red Squirrel habitat networks in Figure 15 illustrate where there is connectivity between areas of conifer woodland.

Figure 14- Locations of Red Squirrel sightings and distribution of conifer woodland habitat.

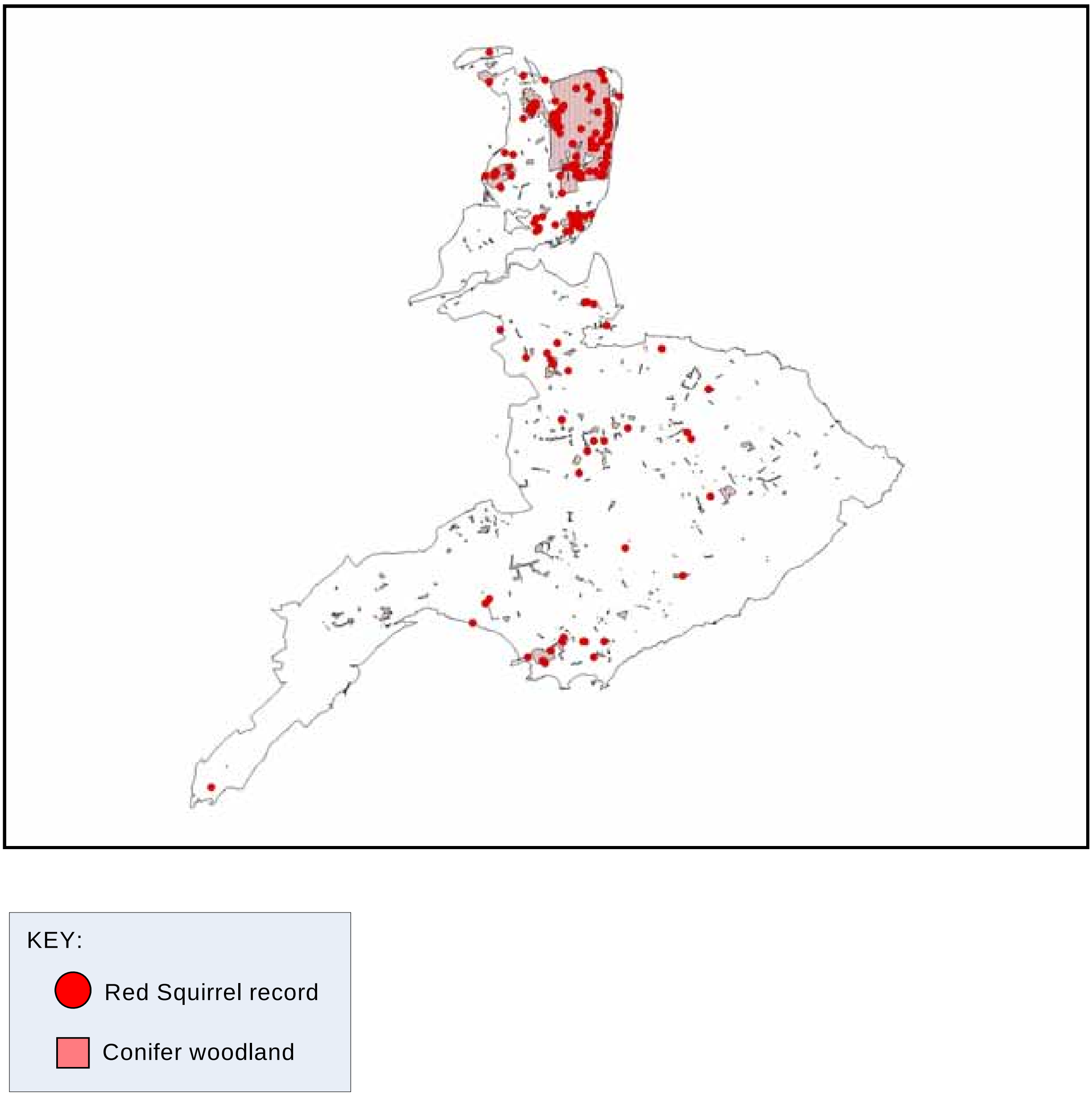
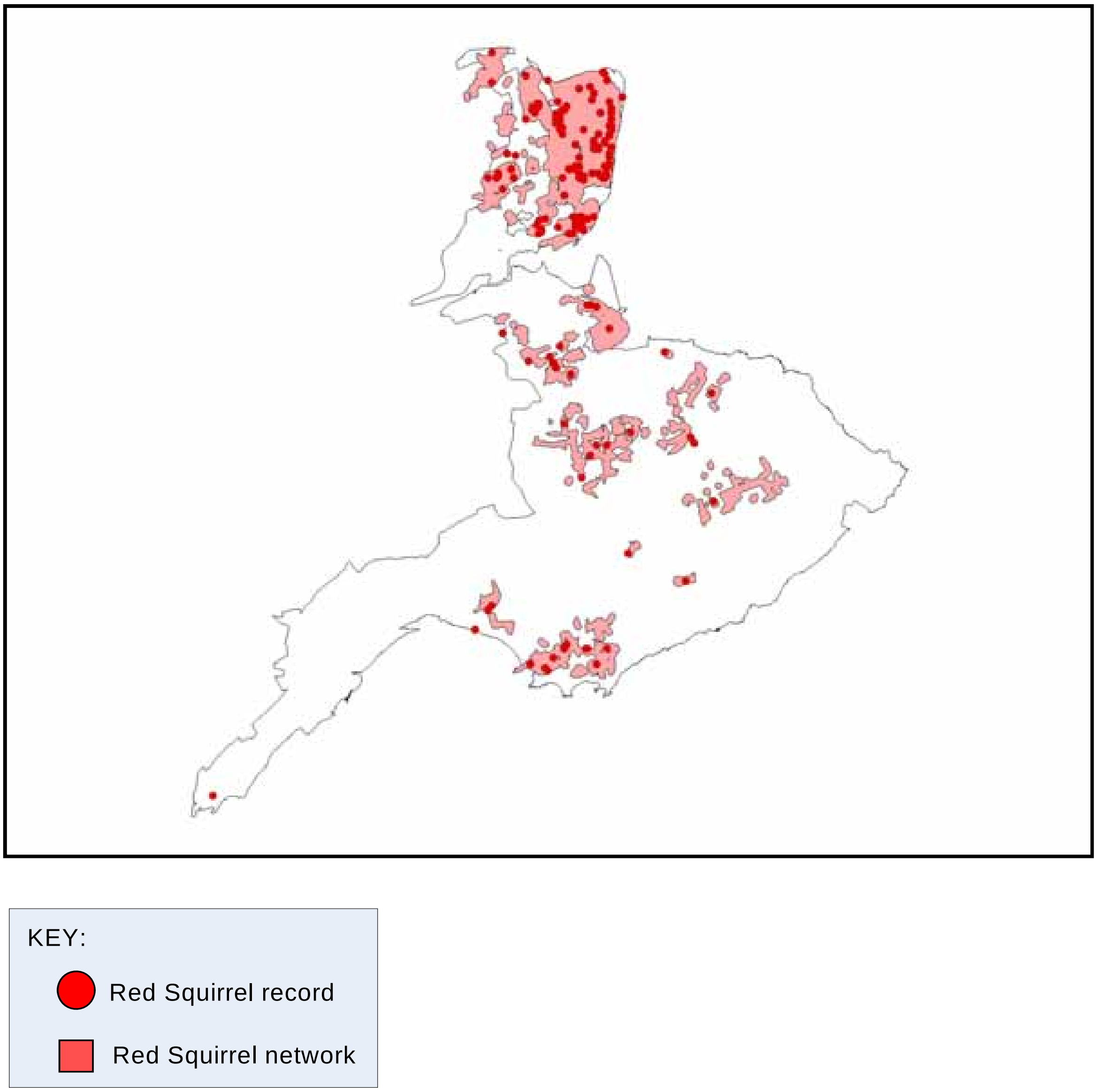


Figure 15 - Red squirrel networks in the East Neuk study area



Surprisingly, the results (Figure 15) show at least 8 sizeable networks within the East Neuk which we believe that Red Squirrels are using. The question arises as to how populations of Red Squirrels be maintained when Grey networks encroach onto the Red Squirrel network, given that existing Grey Squirrel networks overlap extensively both with current distribution of Red Squirrels (Figure 16) and the existing Red Squirrel networks (Figure 17).

Figure 16 - Grey Squirrel networks in relation to Red Squirrel sightings

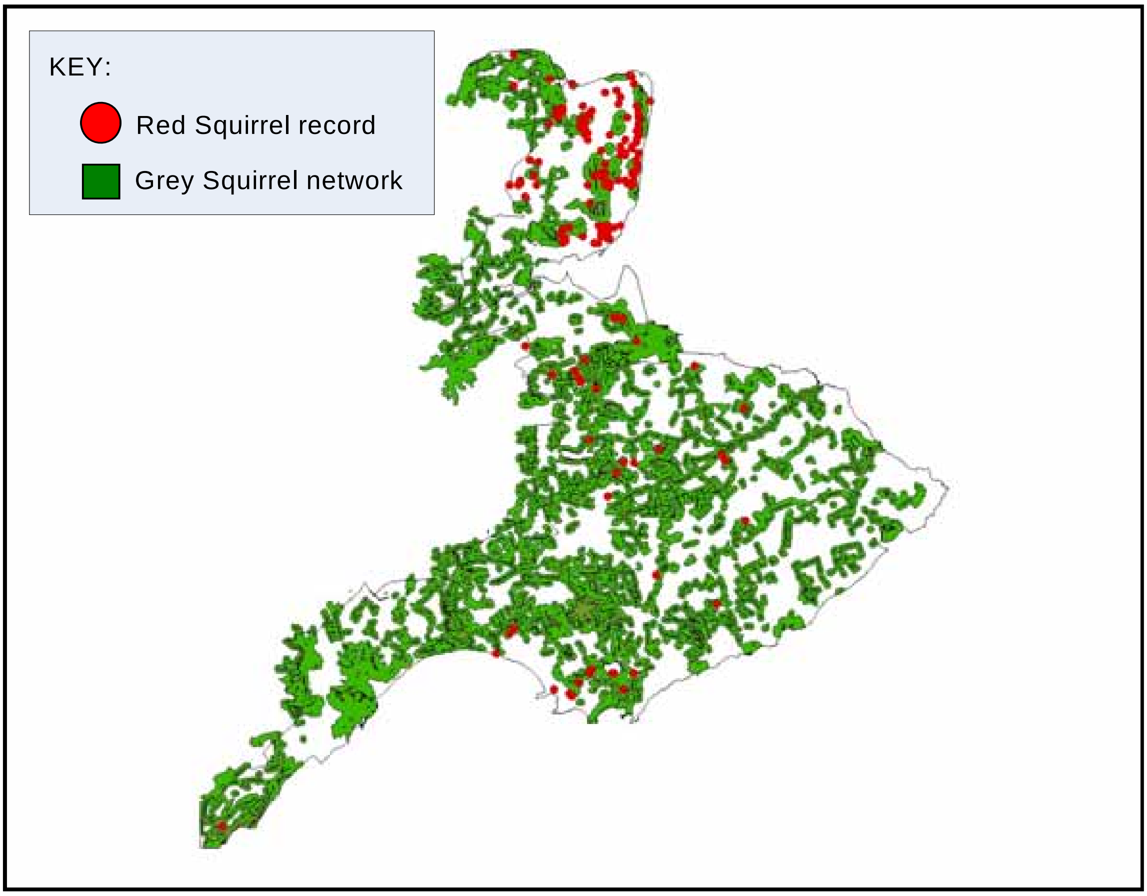
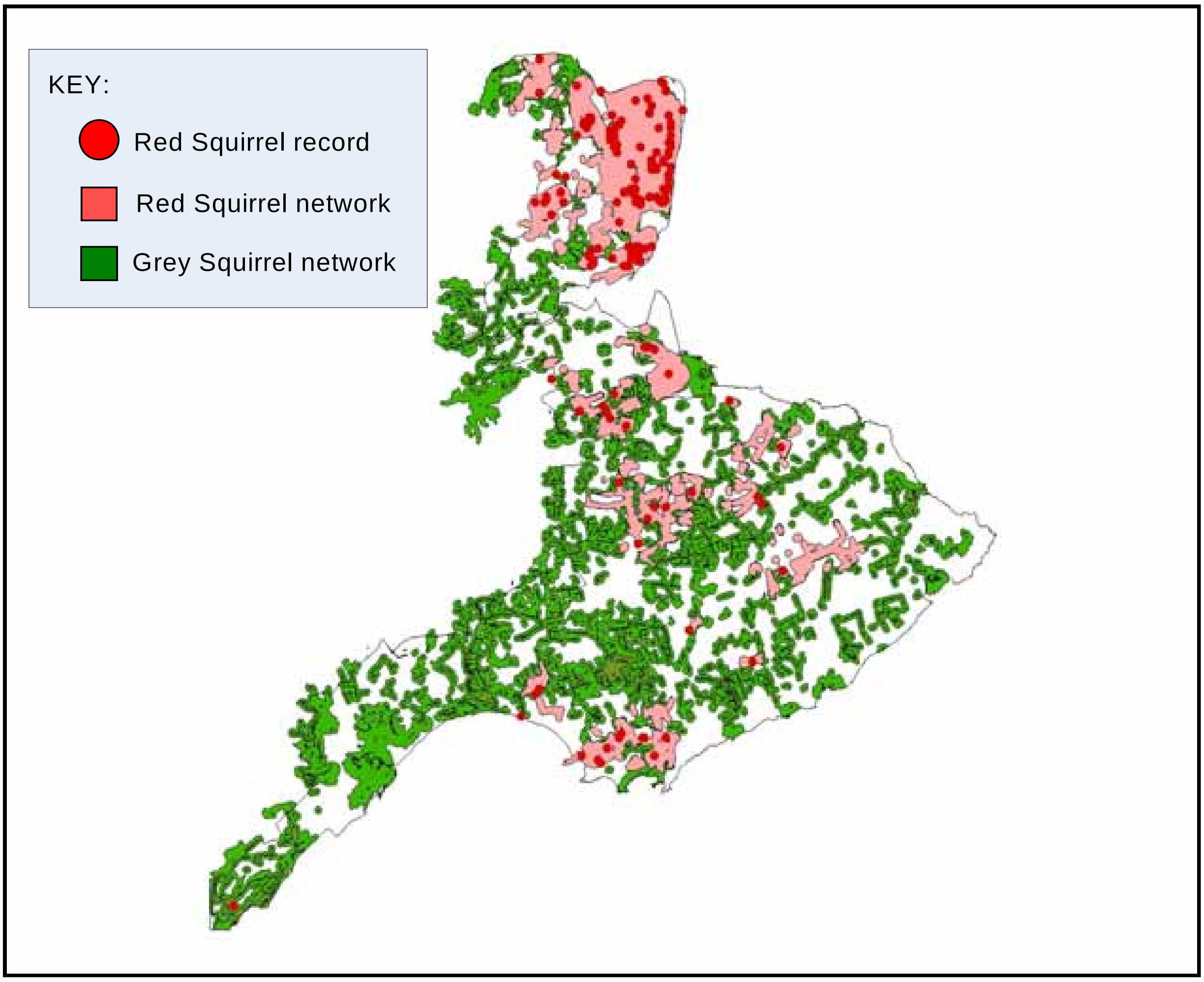


Figure 17 - Existing red and grey squirrel networks



Land use changes planned or possible in Fife include measures such as increasing short rotation coppice and extending hedgerows in field margins. These measures would have little impact on the Red Squirrel since the analysis (Figure 17) indicates that most of the study area is a network for Grey Squirrels. Therefore it would not be a priority to curtail these types of land-use change to limit the impact of Greys on Reds.

However, unless there are other types of intervention the end of Red Squirrels within the East Neuk may be imminent. There is potential for a Red Squirrel reserve in Tentsmuir by converting the broadleaved woodland (Figure 18) to conifer within the red squirrel habitat network area. This would also require control of any Grey Squirrels moving into the resulting increased Red Squirrel network area (Figure 19). This woodland conversion would also result in a decrease in the Grey Squirrel network. It is estimated that the area of conifer woodland in Tentsmuir could support a population of up to 500 red squirrels.

Figure 18 - Distribution of conifer and broadleaved woodland and largest Grey Squirrel network around Tentsmuir forest

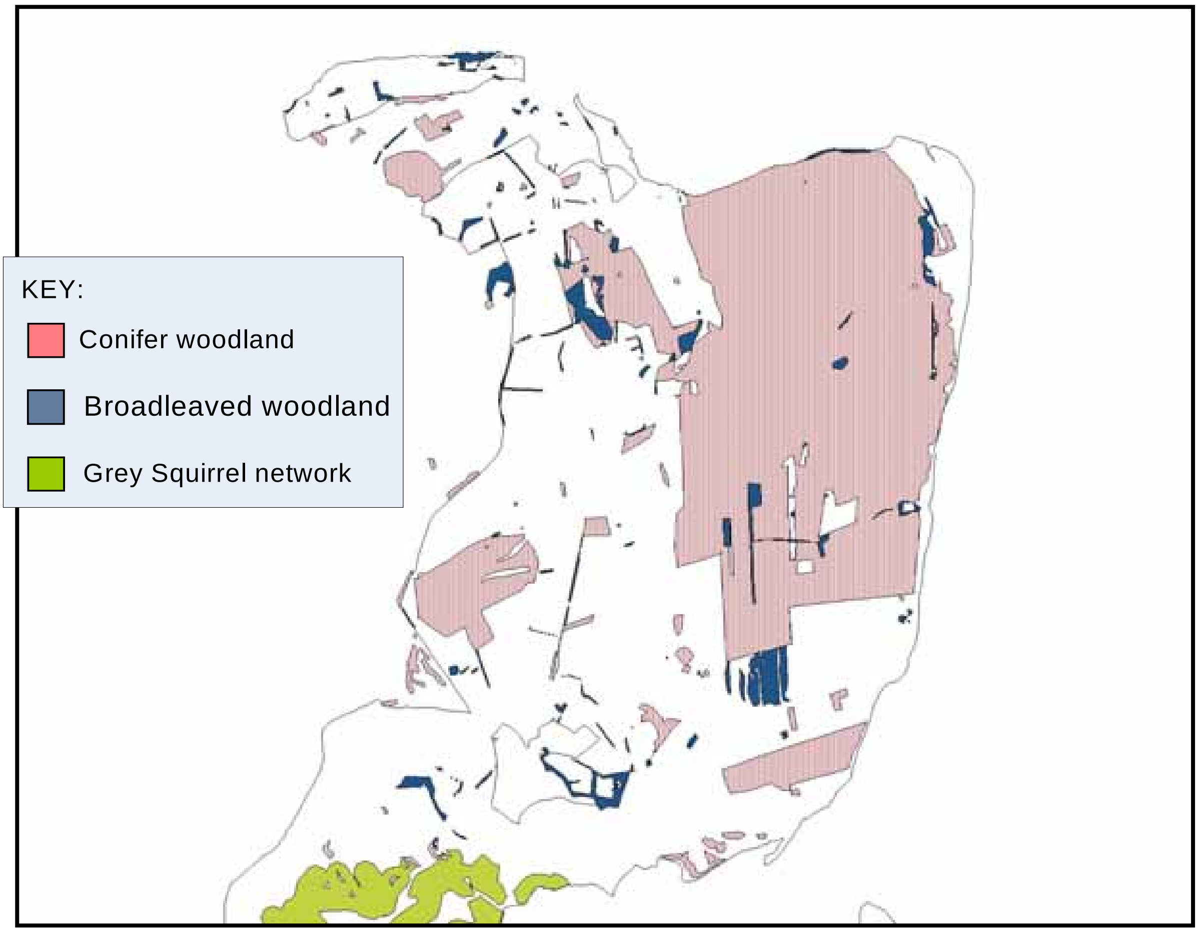
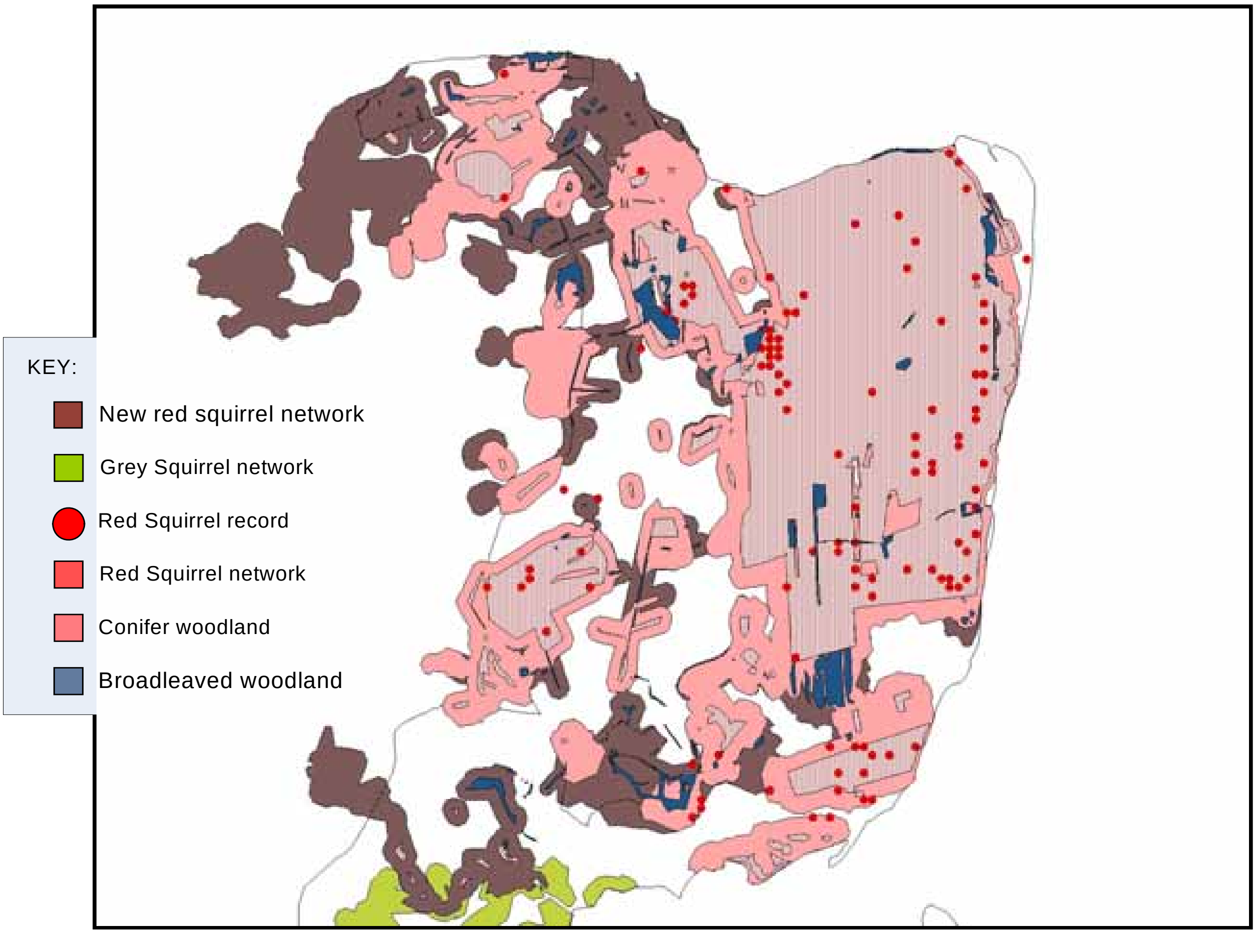


Figure 19 - Location of new Red Squirrel networks after simulating conversion of broadleaved woodland to conifer



The modelling reported here raises issues of conservation conflict where potentially high conservation value broadleaved woodlands are replaced by pine woodland on areas of land that were previously heath, and marsh (before they were converted to broadleaved woodland). Historically most of Tentsmuir was comprised of these habitats and this also raises the question of whether there was any native coastal Scots Pine here as found on parts of the North Sea and Baltic Sea coastlines.

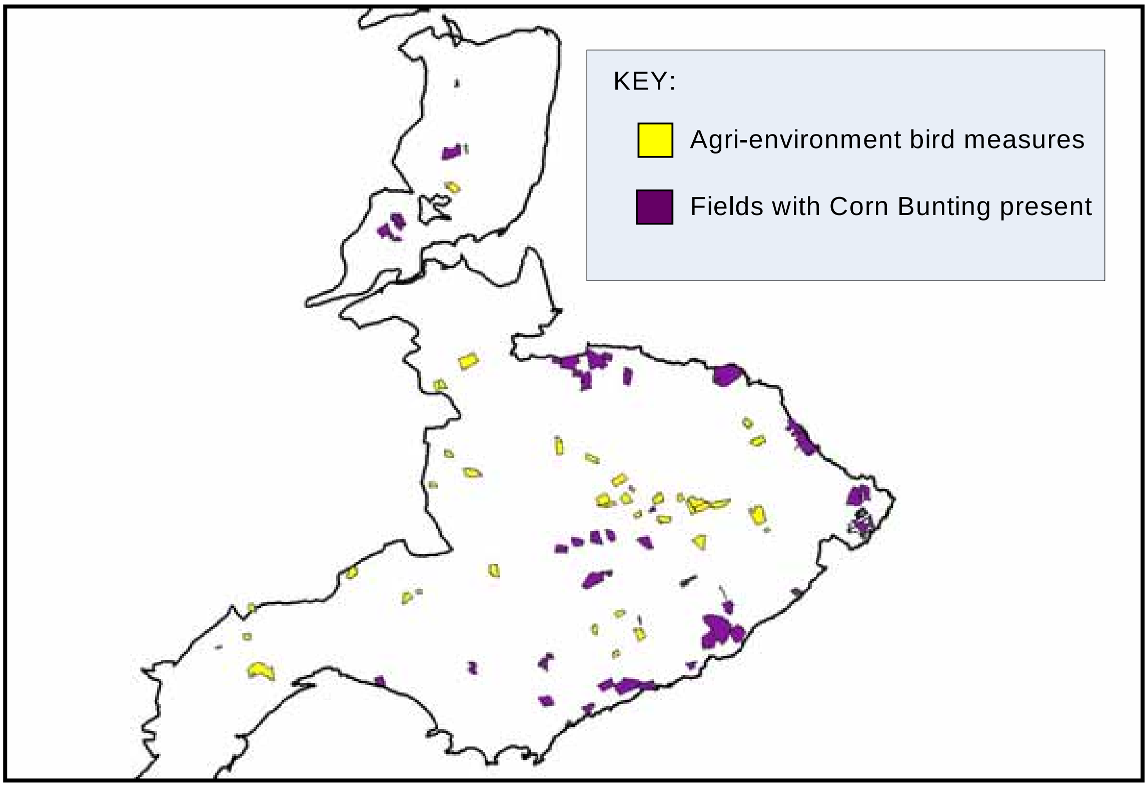
The usefulness of the modelling approach in this situation is that it provides greater transparency in terms of assessing the effects of landscape scale measures on species conservation and can make the process of decision making more robust. Future modelling could explore the impact of culling Grey Squirrels, by perhaps increasing the cost of dispersal across the matrix to reflect reductions of Grey populations in locations near Red networks.

4.1.7 Corn Bunting networks and targeting of LMC's

Corn Bunting (*Miliaria calandra*) is the main arable bird species of conservation concern in the East Neuk of Fife and was selected as the focal species to investigate the targeting of agri-environment bird measures. These measures have been designed for all arable bird species but here the focus is on the Corn Bunting (see Appendix 1 for details). The UK population declined by over 60% between 1970 and 1990 and this is likely to be a result of reduced winter food supplies arising from the switch to winter sown cereals. This switch in cropping impacts on the population in two ways: an increase in nest-loss through earlier harvesting and the loss of winter stubble the Corn Bunting's primary winter habitat. The species is relatively sedentary in its behaviour and work by the RSPB in the East of Scotland indicates low dispersal ability that differs between summer and winter as do the habitats that are used.

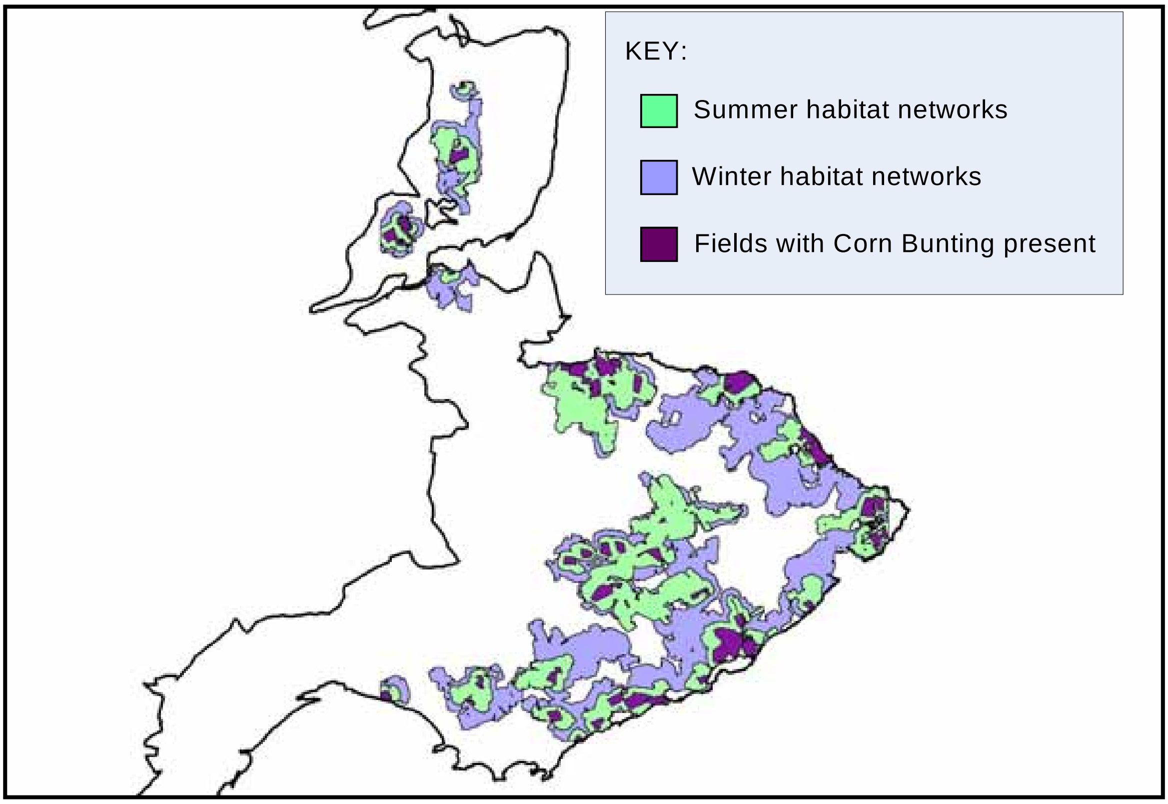
Surprisingly, the present distribution of agri environment bird measures is currently determined by the desire of applicants and this bears little relationship to the fields with Corn Bunting present in 2005 (Figure 20) and as a result are likely to have had little impact in helping to enhance Corn Bunting populations. In detail, 42 fields with a total area of 438 ha had some sort of agri environmental measure to help support graniverous arable bird species, the area of these measures amounted to some 40 ha with an average of 1 ha per field being put under these measures.

Figure 20 – Fields with Corn Bunting present in 2005 (RSPB data) and with agri-environment measures geared towards birds



Based on the knowledge of the distribution of Corn Bunting and their summer and winter habitat requirements it is possible to derive summer and winter habitat networks (Figure 21). The winter networks are larger reflecting the observed increase in dispersal. This is explained by the fact that the birds forage in the fields with winter cereal stubble and these become increasingly fewer and more dispersed as the winter progresses.

Figure 21 – Fields with Corn Bunting present in the East Neuk study area and the location of summer and winter habitat networks



In order to test whether targeting of fields for bird measures would impact significantly on habitat networks, two scenarios were chosen each simulating the addition of summer bird measures (wild flower strips for increased cover and food supply) to fields within the study area. For both scenarios, the same amount was added (42 fields of roughly 400ha). In the first scenario the bird measures were targeted to fields within and adjoining the Corn Bunting summer network area. In the second scenario field locations were selected in the GIS purely at random. The network analysis was re-run to compare between the two scenarios.

Figure 22 – Example of simulated targeting of summer bird measures to fields within existing Corn Bunting networks

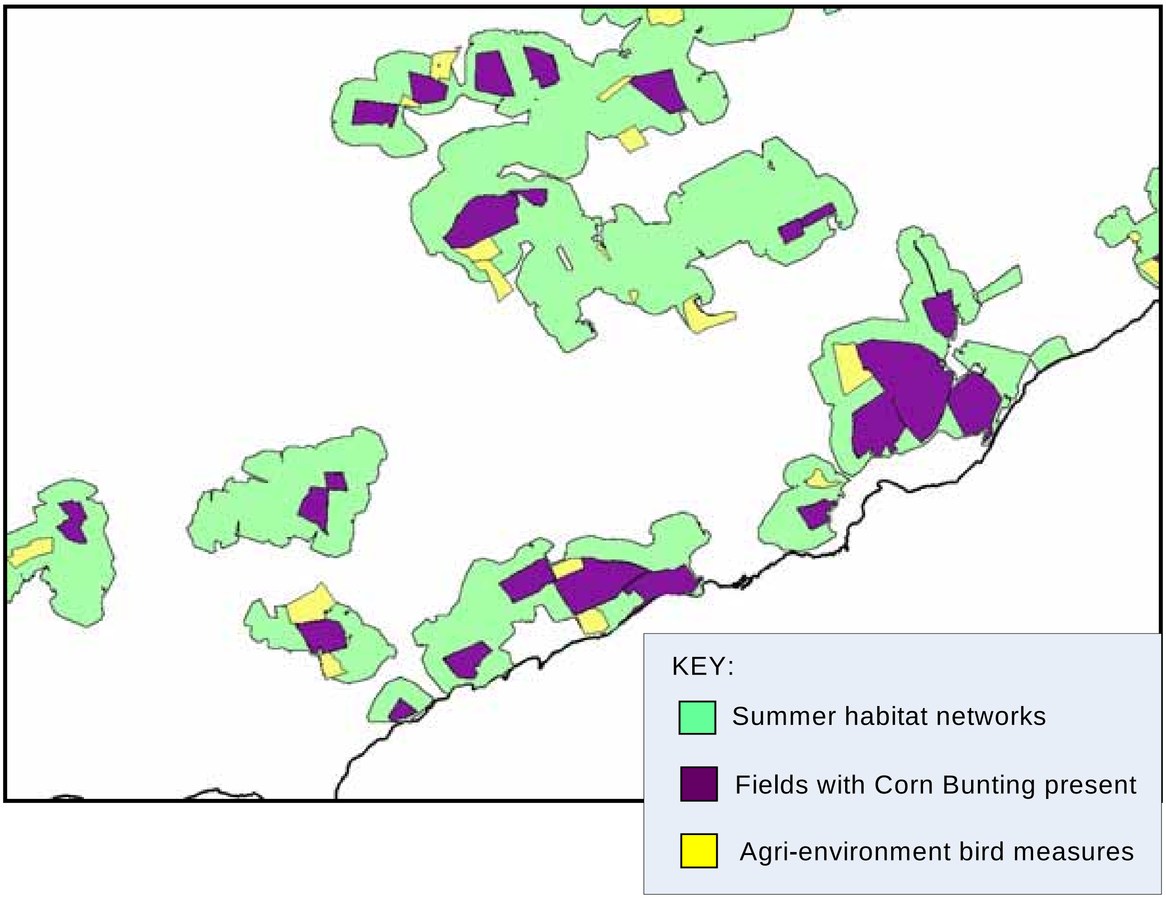


Figure 22 illustrates the simulated targeted addition of fields to summer networks, and the impact on network expansion is shown in Figure 23. The implementation of this scenario resulted in an increase in the summer network area (Table 5) but also an increase in the density of suitable Corn Bunting habitat within the existing network area (Table 5). This gives the opportunity for more potential broods to be raised within the existing population distribution (consolidation of existing populations) as well as their expansion into the network area. Connectivity also increases between previously isolated populations. In the scenario where bird measures were randomly applied across the study area, the resultant increase in summer network area was much less (Figure 24) and there was a reduced density of suitable summer Corn Bunting habitat within networks (Table 5).

Figure 23 – Example of increase in Corn Bunting summer network area after simulated targeted addition of bird measures to fields within existing Corn Bunting networks.

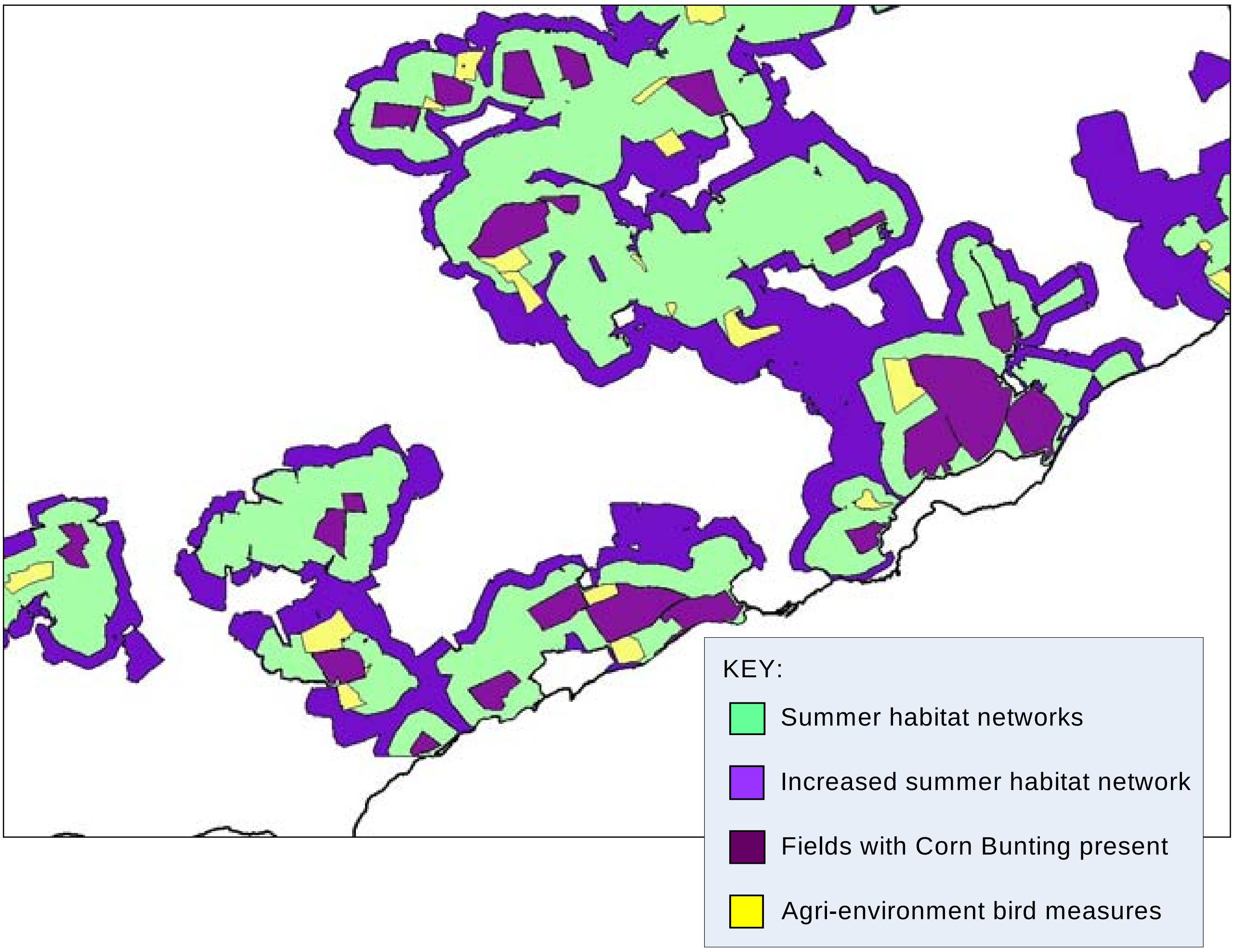


Figure 24 – Example of increase in Corn Bunting summer network area after simulated addition of bird measures at random to fields.

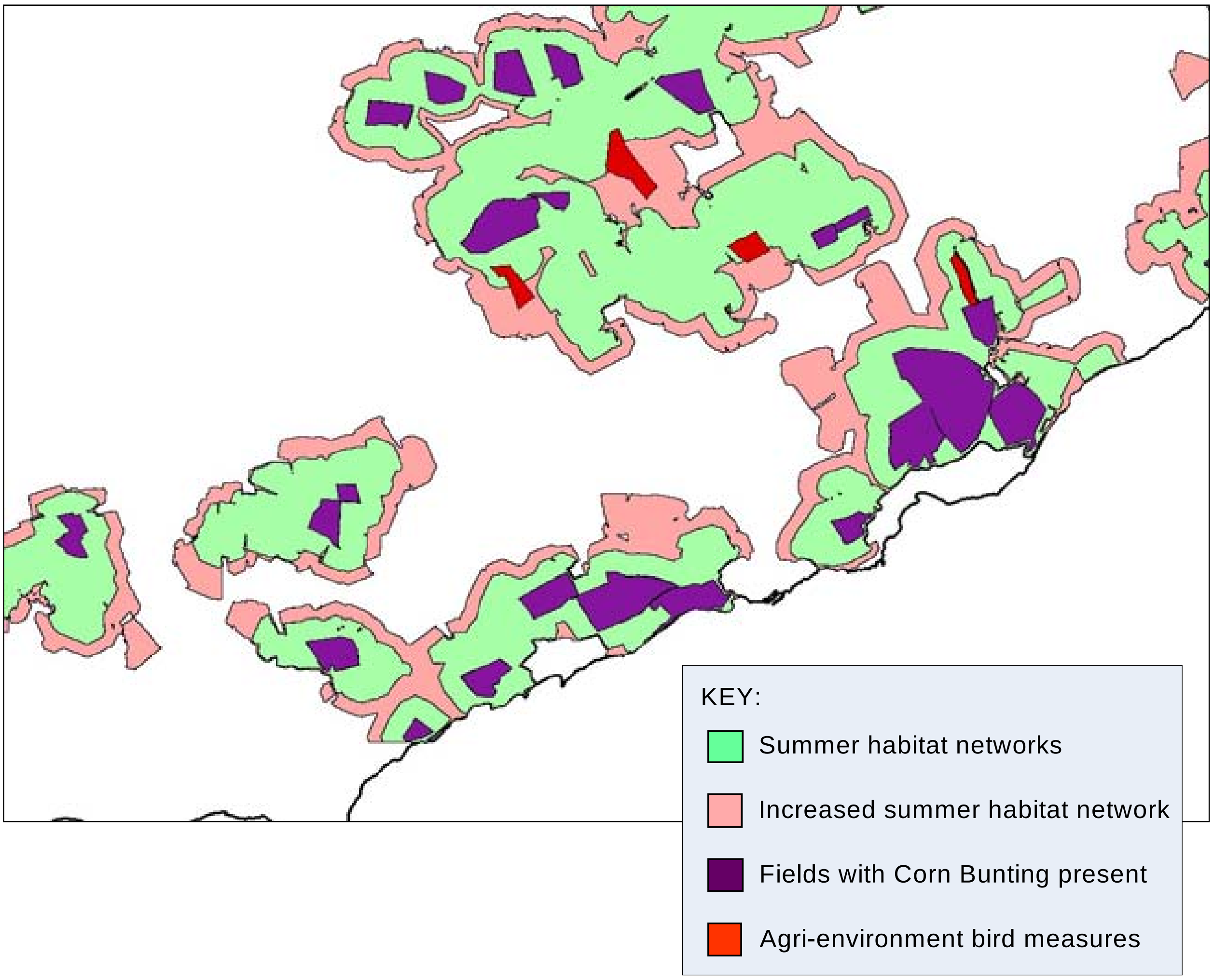


Table 5- Corn Bunting summer network statistics showing relative impact of targeted and non-targeted (random) addition of agri-environment bird measures to fields within the East Neuk study area

Network	No of Networks	Total network area (ha)	Area of habitat (fields) within network	Density of habitat (within summer habitat network)
Existing	18	5065	867	0.17
Targeted	13	8349	1161	0.23
Untargeted	15	7667	946	0.18

4.1.8 Conclusions

The East Neuk modelling confirms the applicability of the BEETLE accumulated cost distance buffering approach to the development of networks in "real life" situations. For all three case study focal species, the modelling has helped to reveal potential priorities for the spatial targeting of agri-environment, forestry and conservation incentives. Due to time constraints it has not been possible to examine potential overlaps/conflicts between the different networks. This issue is dealt with in more detail in the Strathspey case-study. The impact of network development on landscape character, visual quality and recreation within the East Neuk study area is dealt with in sections 5 and 6 respectively.

4.2 Strathspey

4.2.1 Background and description of case study area

The Strathspey study area covering over 720 km2 (Figure 25) is situated wholly within the Cairngorms National Park but excludes the main Cairngorm mountain area. The study area incorporates a wide range of different habitats and land-uses. These range from extensive native pinewoods and plantations in Glenmore, Inshriach, Rothemurchus and Abernethy to broadleaved woodlands of birch and aspen and important wetland habits such as the Insh Marshes (Thompson et al., 2006; Hall, 2006). Although not "lowland" in the sense that Fife might be described, the study area does include a range of agricultural habitats akin to what might be found further south. These include enclosed farmland of arable/horticulture, improved grassland, and semi-improved neutral, calcareous, and acid grassland (Rowse, 2006).

Over the 1940 to 1980 period there was a significant decline in the cover of semi-natural woodland (both conifer and broadleaved), mainly due to conversion to plantations, and reduction in the amount of managed grassland through conversion to arable. In contrast, the amount of rough grassland increased, mostly through conversion of heather moorland (Mackey and Shewry, 2006). These historical changes are likely to have had a significant impact on habitat quality, availability and connectivity for a wide range of species groups. In recent decades, there has been an active programme of habitat restoration and creation, through the conversion of plantations on ancient woodland sites back to native woodland (Peterken and Stevenson, 2004) and establishment of new native pine woods and broadleaved woodland (Humphrey et al., 2006).

4.2.2 Stakeholder engagement

The start up meeting for the Strathspey stakeholder group took place in May 2006. The Cairngorm National Park Authority (CNPA) is the key stakeholder in the area, although there were also representatives at the meeting from SNH, RSPB FC SEPA, Highland Birchwoods, Scottish Native Woodlands and the Highland Aspen Group (HAG). The CNPA employ the LBAP officer as well as their own ecologists. The CNPA have investigated the BEETLE model to address fragmentation issues within the national park (Schwarz et al., 2006) and are also keen to broaden the current focus of conservation effort on lowland issues within the park and to include agricultural priorities.

4.2.3 Priorities for habitat and species modelling

There are some existing ecological/conservation projects which relate directly to species associated with the lowland areas of Strathspey. In particular the LBAP process has been on-going for a number of years (Cosgrove, 2002) and species priorities have been well defined (Table 6). This helped with selecting the focal species for the area (Table 7). The stakeholder group identified flood plain/wetland management and restoration and the development of aspen habitat networks as two of the most important conservation issues in lowland Strathspey. In addition, the management and restoration of areas of unimproved grassland was also of interest. However there was not enough time to consider this in detail in the current study.

There are approximately 21 remnant aspen stands of 1.5 ha or more in the Highlands covering around 159.5 ha in total (Hall, 2006). Recent advances in remote sensing (Parrott, 2006) suggest that that the extent of the resource has almost certainly been underestimated. The largest stands and area of aspen woodland is in Strathspey where it forms a distinctive boreal broadleaved ecosystem supporting a suite of characteristic species including the BAP Priority hoverfly *Hammerschmidtia ferruginea* and the Dark Bordered Beauty Moth *Epione paralellaria.*

The wetlands of Strathspey support a diverse range of species and support the largest inland population of wading birds in the UK. Floodplain management is also increasingly on the public agenda. A series of severe flooding incidents in recent years has encouraged interest in the potential role of land use such as wetland and woodland in mitigating flooding. There is therefore potential environmental as a well as ecological benefits in targeting areas for wetland and wet woodland restoration and expansion.

Table 6 – List of priority species in the Cairngorms LBAP

Farmland & Grassland Key species: Common name	**Latin Name**	**Type**
Twite	*Carduelis flavirostris*	bird
Snow bunting	*Plectrophenax nivalis*	bird
Redshank	*Tringa totanus*	bird
Lapwing	*Vanellus vanellus*	bird
Northern brown argus	*Aricia artaxerxes*	butterfly
Mason bee	*Osmia inermis*	invertebrate

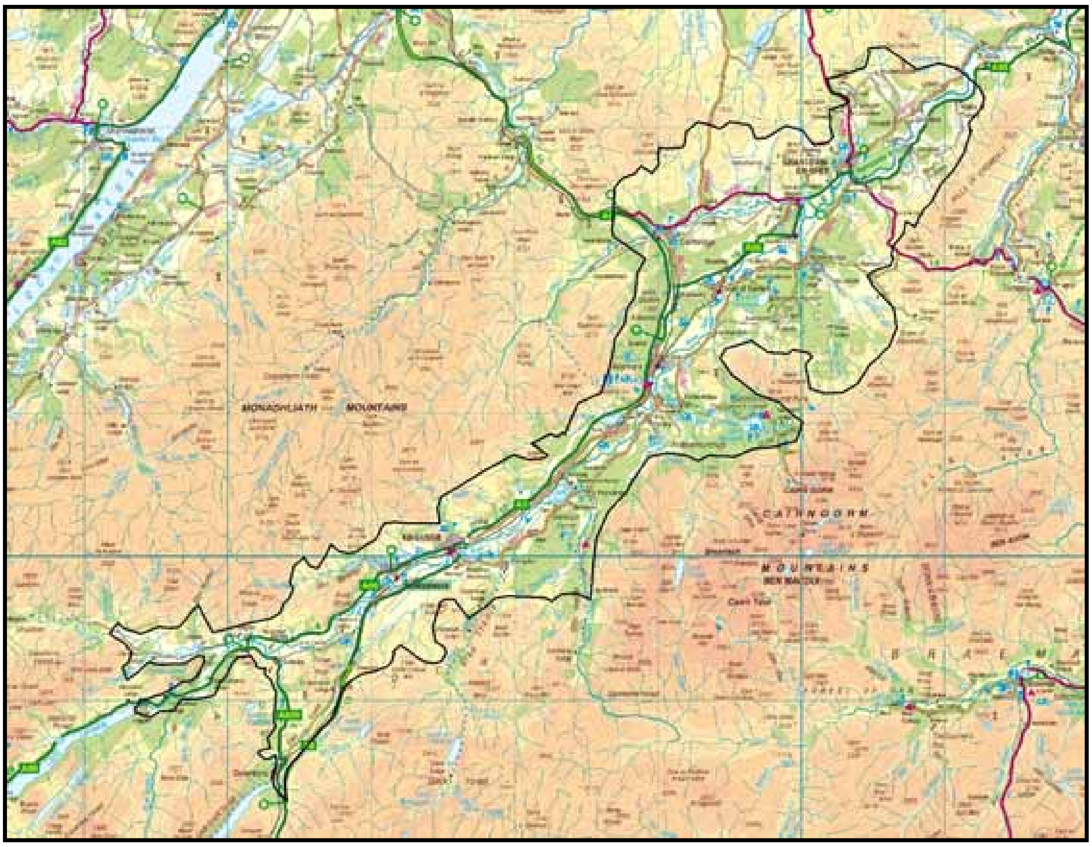
Montane, Heath & Bog Key species: Common name	**Latin Name**	Type
Woolly willow	*Salix lanata*	flowering plant
Alpine sulphur tresses	*Alectoria ochroleuca*	lower plant
Baltic bog moss	*Sphagnum balticum*	lower plant
Oblong woodsia	*Woodsia ilvensis*	lower plant
Netted mountain moth	*Macaria carbonaria*	moth

Wetland & Water Key species: Common name	**Latin Name**	**Type**
Goldeneye	*Bucephala clangula*	bird
Atlantic salmon	*Salmo salar*	fish
Northern damselfly	*Coenagrion hastulatum*	invertebrate
Freshwater pearl mussel	*Margaritifera margaritifera*	invertebrate
River jelly lichen	*Collema dichotomum*	lower plant
Water vole	*Arvicola terrestris*	mammal

Table 6 cont..

Woodland Key species: Common name	**Latin Name**	**Type**
Scottish crossbill	*Loxia scotia*	bird
Capercaillie	*Tetrao urogallus*	bird
Pearl bordered fritillary	*Boloria euphrosyne*	butterfly
Twinflower	*Linnaea borealis*	flowering plant
Aspen bracket fungus	*Phellinus tremulae*	fungus
Pine hoverfly	*Blera fallax*	invertebrate
Narrow-headed woodant	*Formica exsecta*	invertebrate
Aspen hoverfly	*Hammerschmidtia ferruginea*	invertebrate
Blunt-leaved bristle moss	*Orthotrichum obtusifolium*	lower plant
Red squirrel	*Sciurus vulgaris*	mammal
Kentish glory	*Endromis versicolora*	moth
Dark-bordered beauty	*Epione paralellaria*	moth
Cousin German	*Protolampra sobrina*	moth

Figure 25 – Map of Strathspey study area (black outline)



4.2.4 Data used in the modelling

The CNPA carried out a habitat survey on the lowland areas of Strathspey focusing on unimproved grassland and wetland habitats. These data were made available for network modelling. In addition, the CNPA has been mapping stands of aspen across the national park with particular reference to the Forest of Spey and aerial photographs were taken in spring 2006 to identify further stands. This was highly successful and provided a GIS database on location and size of all stands within the Grantown area (Parrott, 2006). These land cover data were integrated with the national land cover data sets (Table 2) to provide a bespoke composite land cover map of the area. Use was also made of the data compiled for the analysis of forest habitat networks in Highland region (Moseley et al., 2005). This was based on existing woodland datasets plus a ground survey of the ecological quality of native pinewood areas. Networks were constructed for a generic woodland species, broadleaved woodland specialist, and pinewood specialist species (see Moseley et al., 2005) for details of the approach. The aspen and wetland habitat networks were constructed using the focal species described in Table 7.

Table 7 – Ecological profiles of focal species used in the Strathspey case study area

Focal species	**Habitat requirement**	**Dispersal**	**Illustration**
Hammerschmidtia ferruginea	Large diameter (<25cm) decaying aspen trucks –used presence of aspen patches from aerial photographs	3 km	 © Malloch Society
Epione vespertaria	Young aspen shoots (bronzed)- used presence of aspen patches from aerial photographs	100m	
Great crested newt	Ponds and wetlands	1 km	 © Woodland Trust

4.2.5 Aspen network analysis

The focal species used in the aspen network analysis differed markedly in their dispersal capabilities but have similar sensitivity to the intervening matrix (Table 7). This allowed the construction of contrasting networks to allow exploration of conservation priorities and the relative benefits of expansion of core sites against connecting up isolated sites. The land cover layer was scored in terms of its permeability to species movements (Figure 26) and habitat patches identified (Figure 27). The resulting network outputs are shown in Figure 28 and Figure 29. The analysis was restricted to the northern part of the study area as the remote sensing of aspen stands was not available for the other areas at the time when the work was being carried out.

Figure 26 – Map of Strathspey study area showing relative permeability of the landscape to dispersal of the two aspen focal species. The square shows the approximate location of the more detailed network analysis shown in subsequent figures

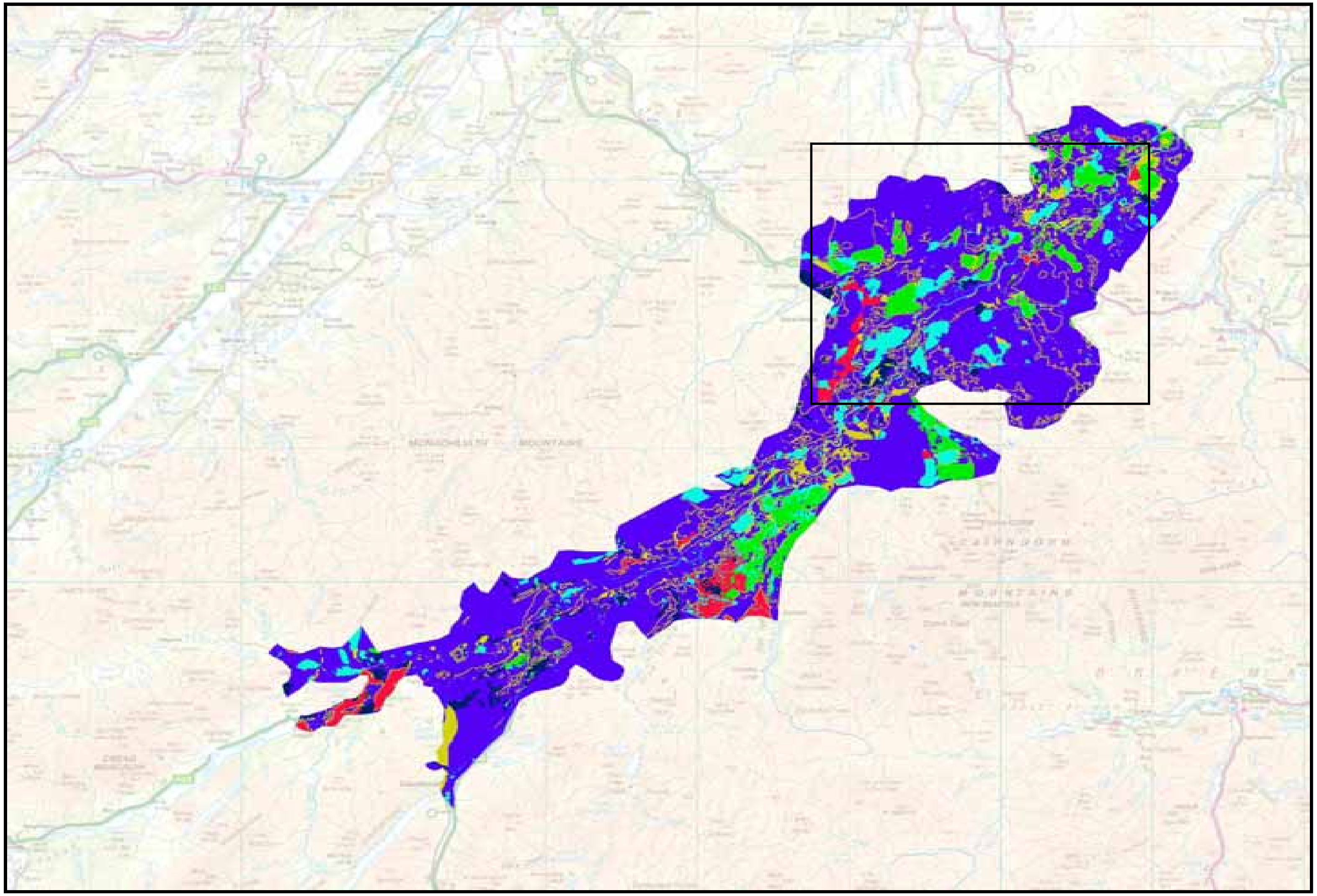


Figure 27 – Location of habitat patches (red) for the aspen focal species within the northern section Strathspey study area

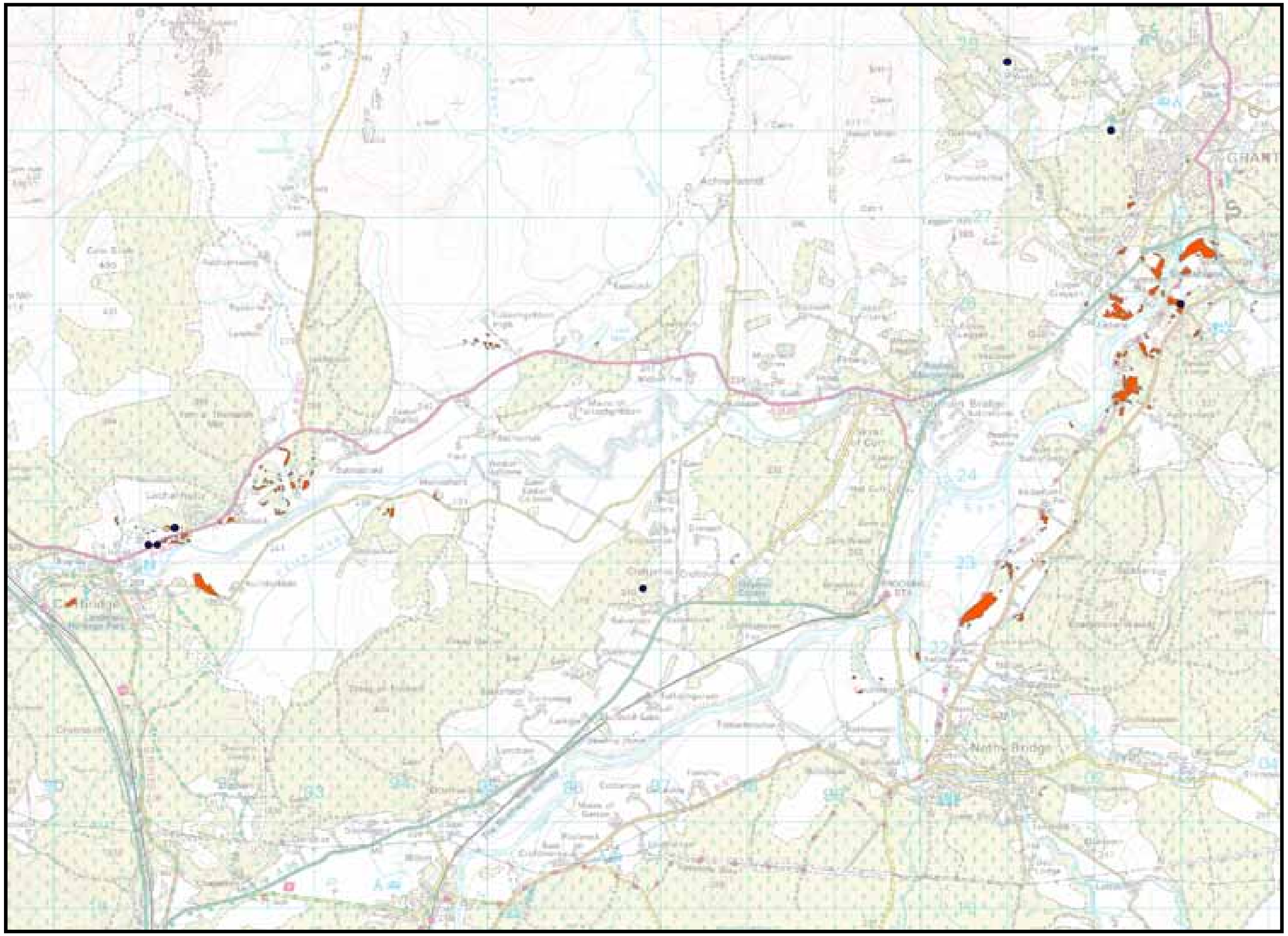


Figure 28 - Hammerschmidtia ferruginea networks within the northern section of the Strathspey study area. Small square shows the location of the Epione vespertaria networks shown in the next figure

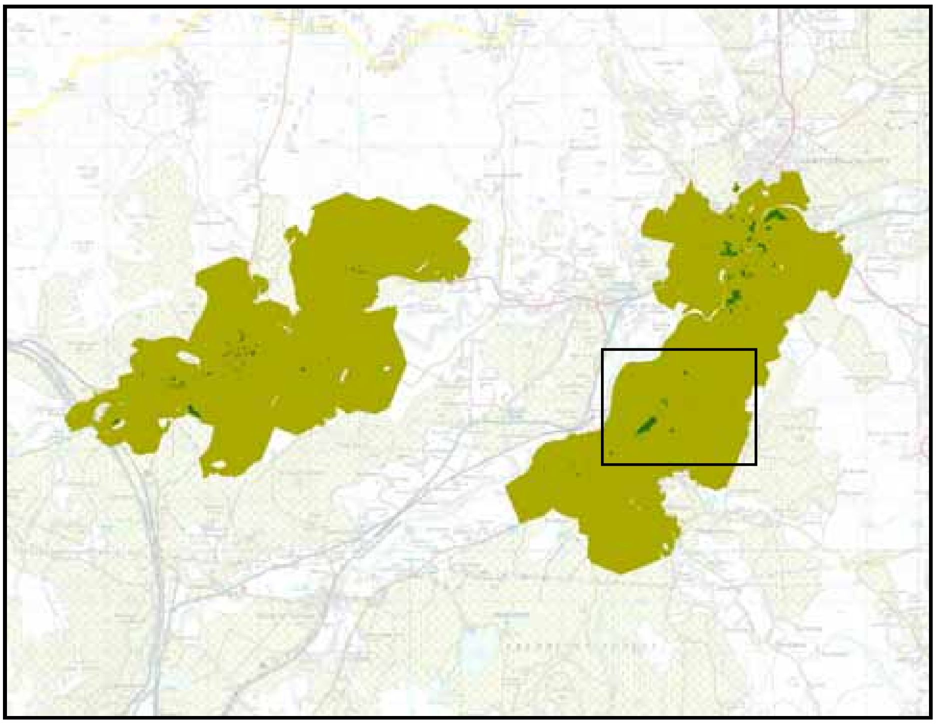


Figure 29 - Epione vespertaria networks within the northern section of the Strathspey study area

Two distinct networks for *Hammerschmidtia ferruginea* were identified within the study area, illustrating functional connectivity across many of the habitat patches (Figure 28). The priority here therefore would be to consolidate these existing networks by initially increasing the number of aspen stands within the network areas to support, over time, any existing populations. To create connectivity between the two networks, new stands of aspen would need to be planted between them and eventually these would become functionally linked as the stands mature and the large deadwood that the hoverfly requires becomes available.

On the other hand there appears to be very little functional connectivity between the aspen stands for the much more sedentary *Epione vespertaria* (Figure 29). Priorities for this species may entail regenerating and expanding the existing stands supporting the species coupled with translocations of individuals to new suitable stands (i.e. those created to consolidate the *Hammerschmidtia* networks). In this way it should be possible to use these network analyses to develop an integrated approach to targeting conservation priorities.

4.2.6 Wetland connectivity and restoration

For the analysis, wetland was defined as all wetland habitats identified in the wetland and grassland NVC survey ranging from small open water bodies to wet woodlands, i.e. wet habitats most associated with the river Spey floodplain and tributaries. This does not include running water or major lochs as ecologically these function in different ways. The Great Crested Newt (*Triturus cristatus*) was selected as the focal species to assess connectivity of the wetland habitats of the Strathspey flood plain (Table 7). There are thought to be two sites in Strathspey and possibly a third in Abernethy forest, but not formal surveys have been undertaken and it is likely that the species is under-recorded in the area (Bowles et al., 2006). Although Great Crested Newts are not a priority species within the Cairngorms they are a suitable surrogate for wider wetland biodiversity. Improving connectivity for this species would greatly benefit the habitats for a wide range of other wetland species many of with are of conservation concern within Strathspey.

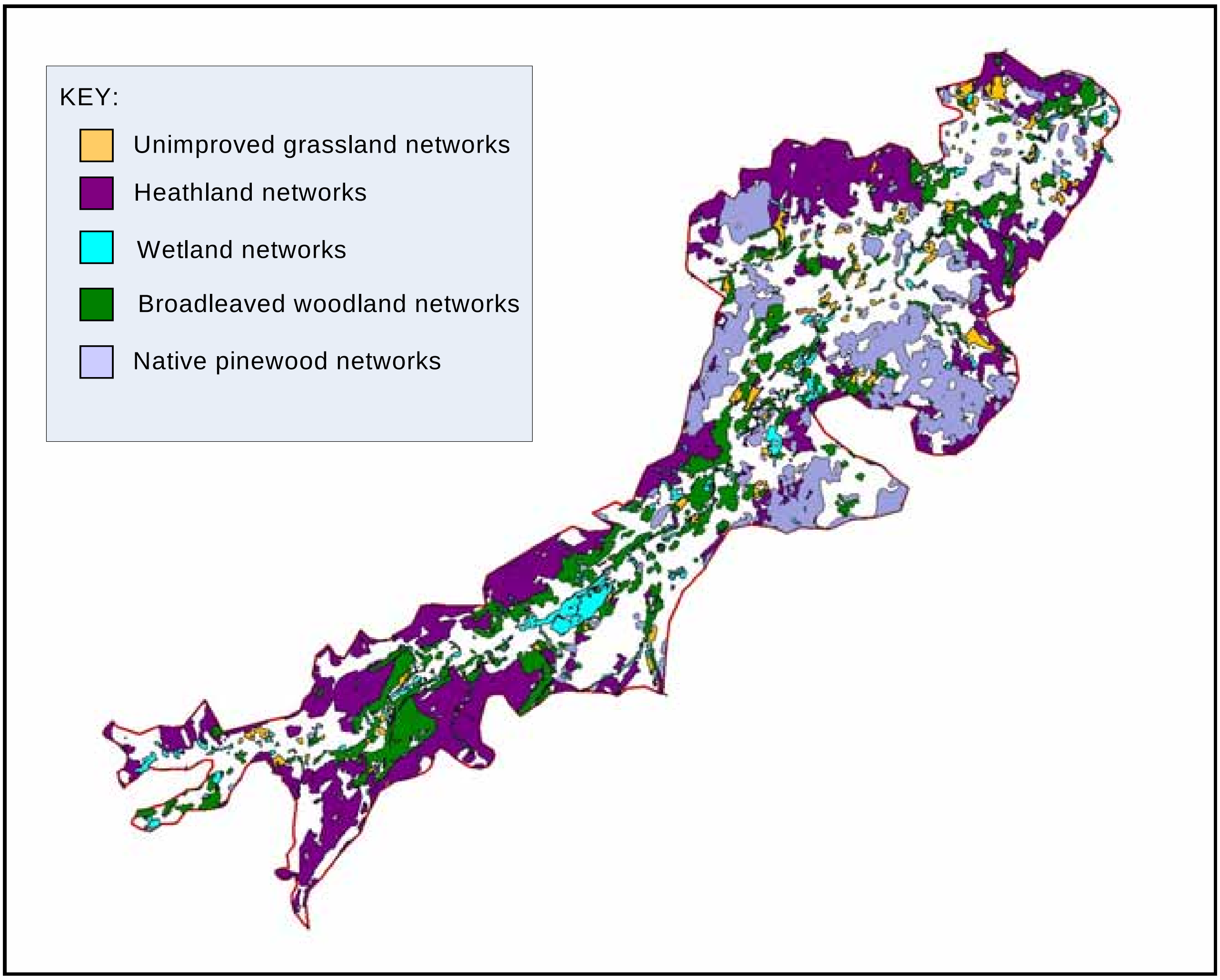
Great crested newts breed in deep persistent nutrient-rich ponds still water bodies that are large enough to contain prey for their larvae but do not contain predatory fish which eat the larvae (Bowles et al., 2006; Skei et al., 2006). Great Crested Newt populations have declined, due in part to loss of ponds to development, agricultural change and agrochemicals, but also to the ‘degradation, loss and fragmentation’ of terrestrial habitats (Anon, 1995). In the floodplain analysis in Strathspey it is these more terrestrial part of the newt life cycle that are used to develop the ‘cost layer’ for their dispersal to assess the connectivity of wetland habitats. Great Crested Newts have been the subject of sufficient research to be able to set realistic dispersal distances (e.g. Arntzen and Wallis, 1991; Kupfer and Kneitz, 2000).

Over 60% (45.5 km^2) of the of Strathspey case study area (72 km^2 in total) is covered by some form of semi-natural habitat network indicating a high degree of ecological functionality within the landscape (Figure 30; Table 8) conifer plantation networks cover a further 15 km^2 of the study area.

Table 8 – Area of semi-natural networks within the Strathspey study area

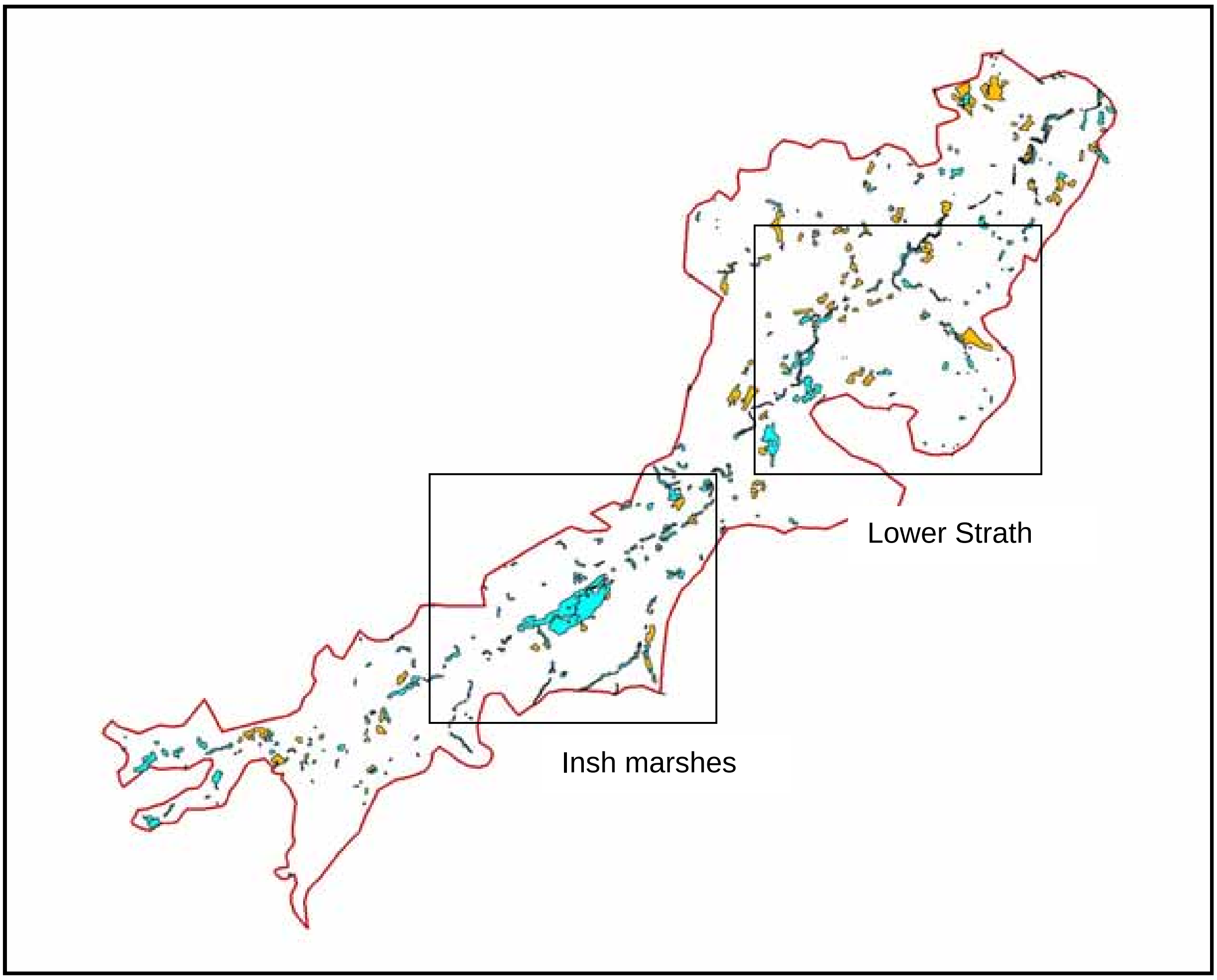
Habitat	**Network area (ha)**
Heathland	19 839
Broadleaved woodland	10790
Native pinewood	9483
Grassland	2517
Wetland	2915
Total	45 544

Figure 30 - Strathspey case study area showing extent of existing semi-natural habitat networks



Although there are numerous records of wetland, and associated semi-natural grassland habitats in Strathspey, the resulting networks appear very fragmented (Figure 31) in what is though to be the least ecologically fragmented floodplain in Scotland.

Figure 31 – Location of wetland (cyan) and grassland (yellow) networks within the Strathspey case study area. Small squares shows location of detailed analyses shown in subsequent figures



The more detailed map of the networks in the Insh marches area shows that this very important SSSI is itself isolated to some extent from other wetland networks (Figure 32). Outside of the SSSI, the wetland resource is fragmented and intimately mixed with a range of other types of network (Figure 33).

Figure 32 - Details of wetland networks (cyan) centred on the Inch marshes SSSI (large block in the centre)

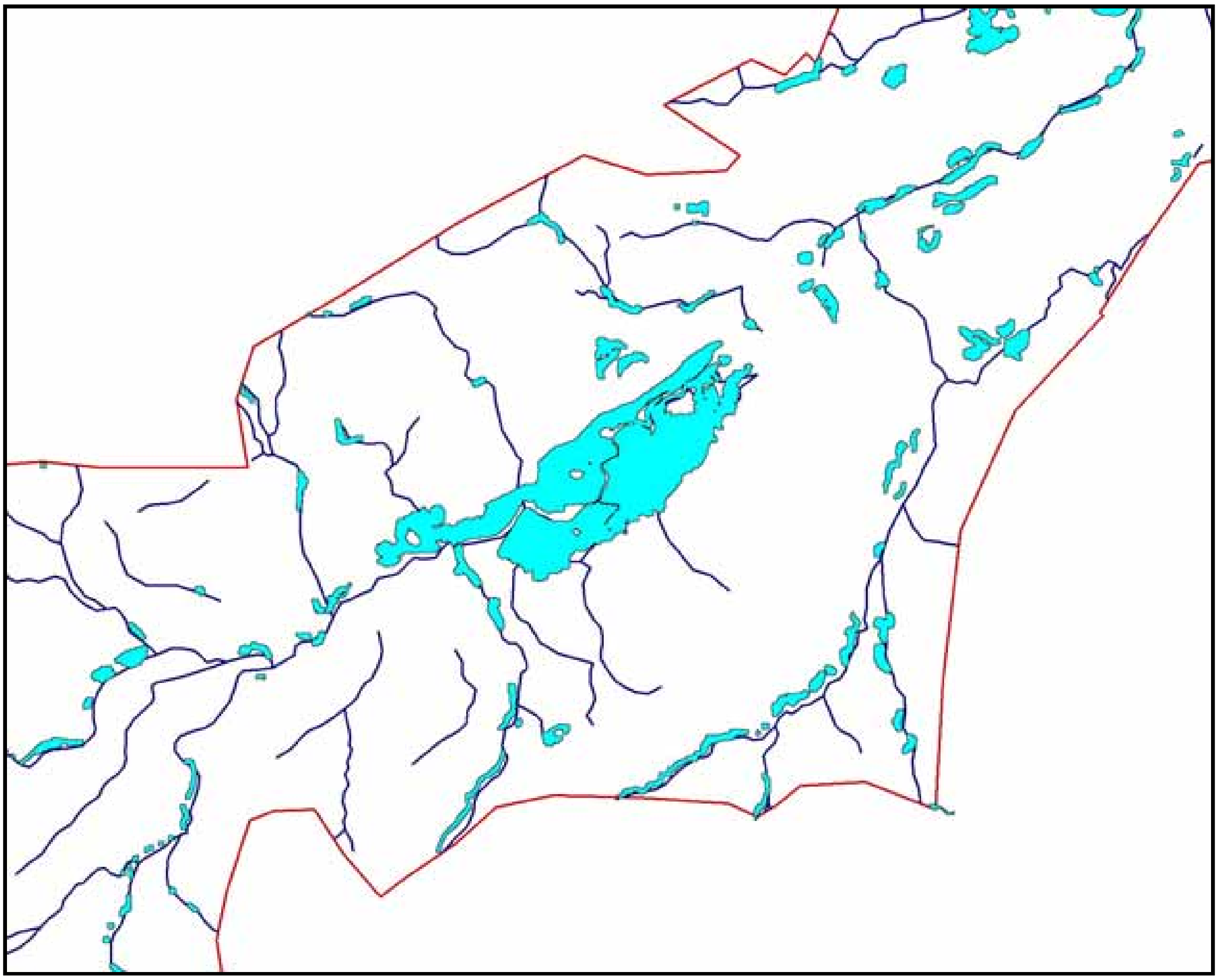


Figure 33 – Details of wetland habitat networks in the Insh marches area in relation to other types of habitat network

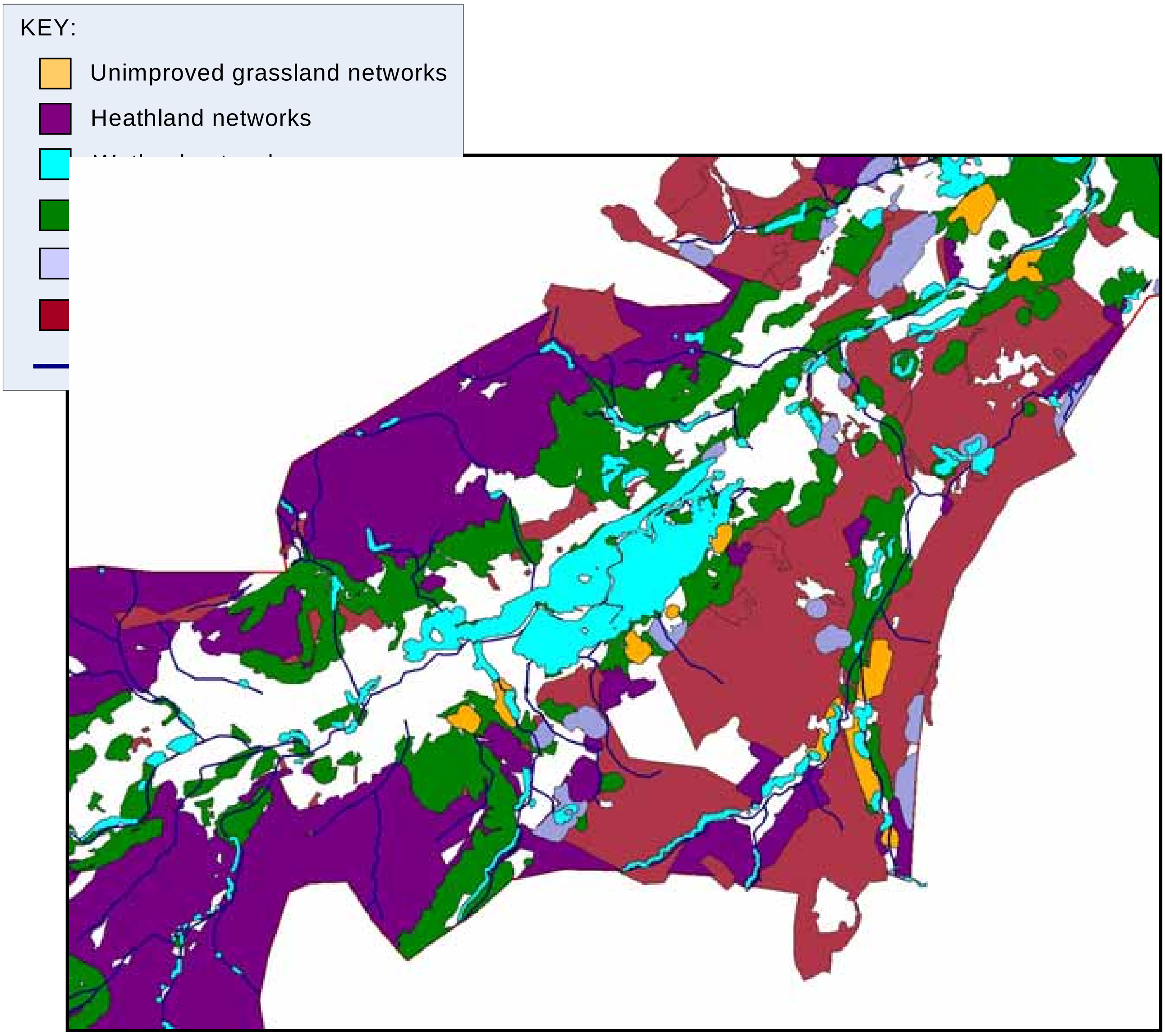


Figure 34 illustrates in more detail the potential for increasing wetland network connectivity. The map shows potential pinch points along riparian corridors where conversion of conifer to wetland habitats could be encouraged. Restoring wet wood, fens, carr and wet meadows would increase connectivity of wetland habitats, begin to restore floodplain functionality, and help consolidate the Inch marshes SSSI.

Figure 34 – Wetland and other habitat networks in the Insh marshes area showing priority areas for wetland restoration to improve connectivity

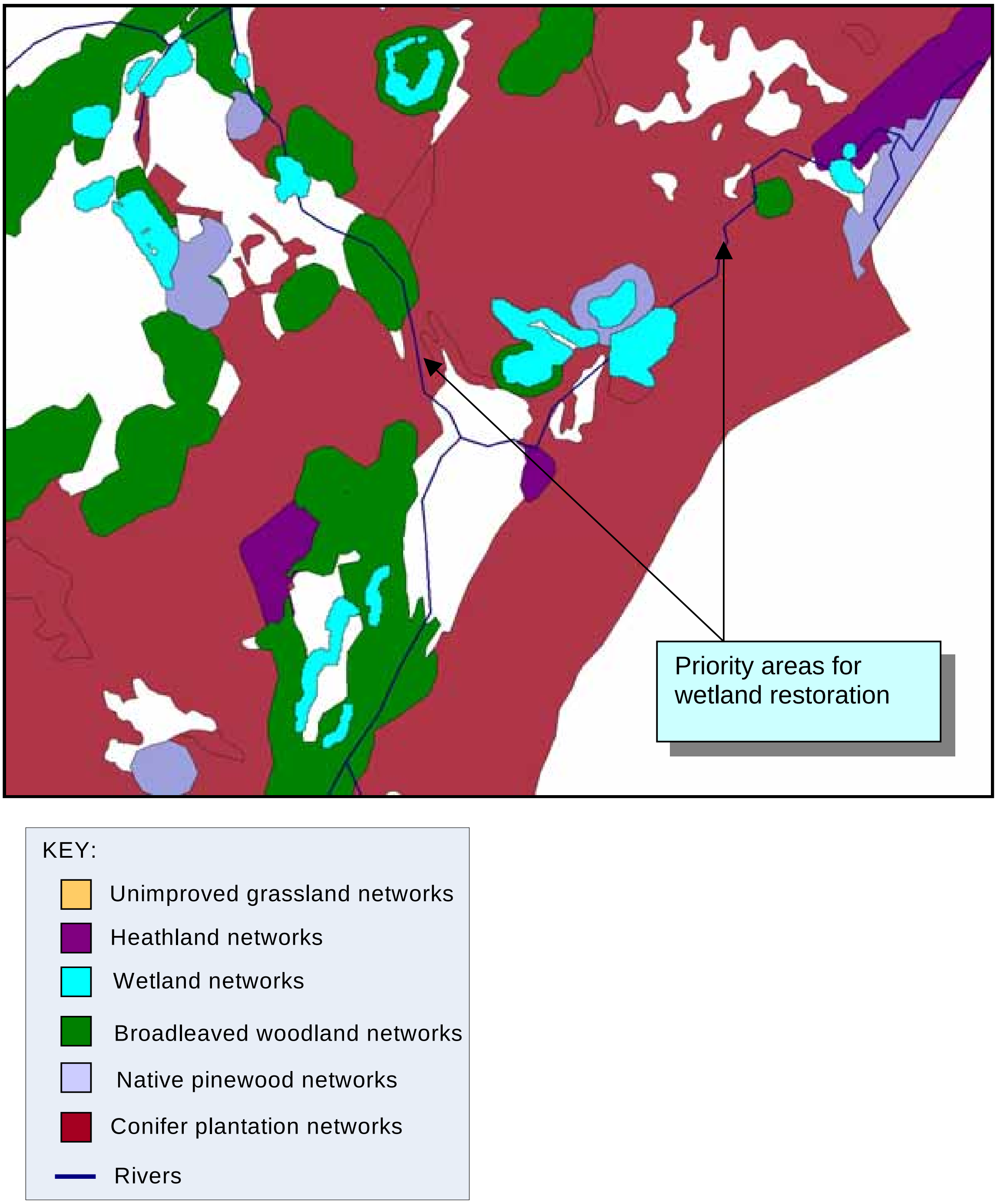
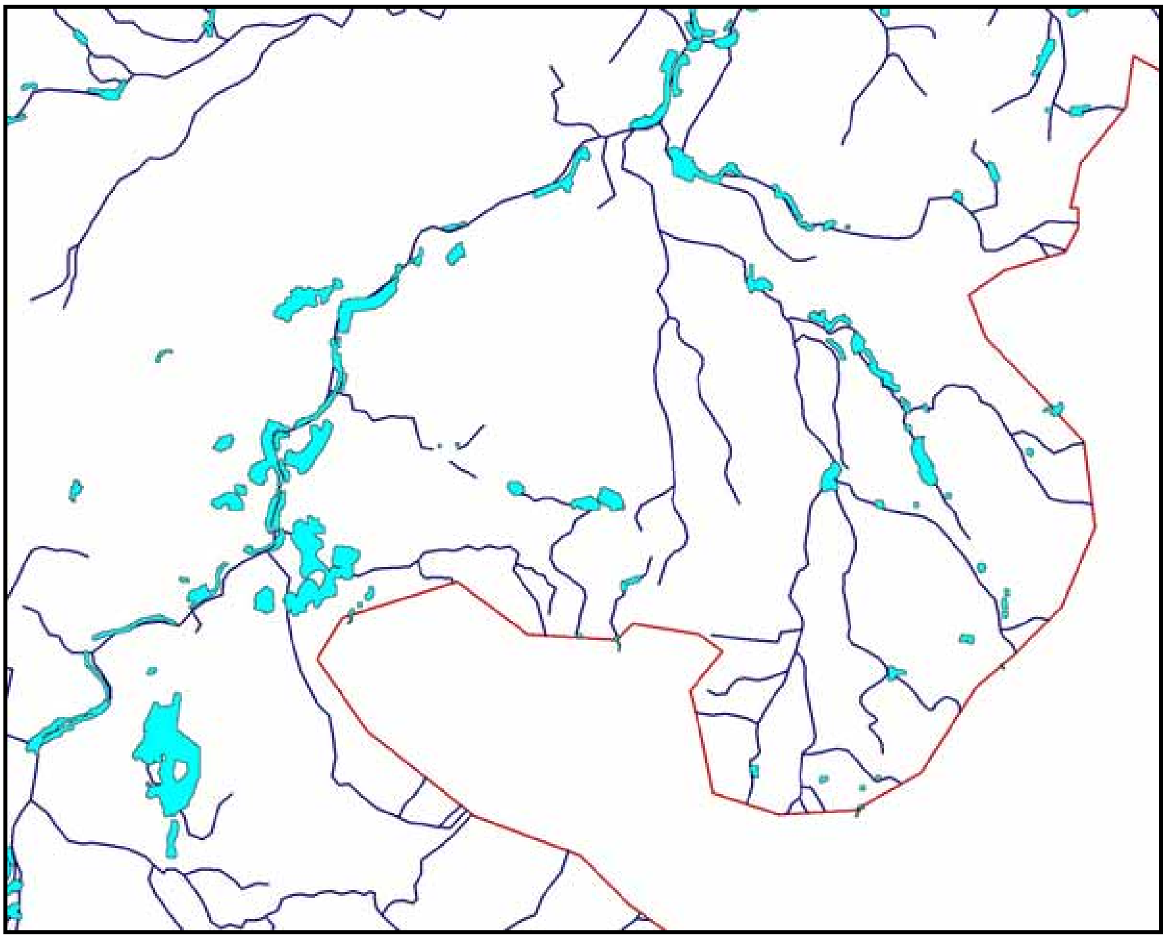


Figure 35 – Wetland networks (cyan) in the lower Strath study area



Wetland networks in the lower Strath are equally, if not more fragmented as those in the Insh Marshes areas (Figure 35). There are also large sections along the river Spey that do not interact with other networks and are associated with more intensive agricultural (not recorded as semi-natural habitat in the NVC survey) and this is one of the areas where floodplain restoration incentives could be targeted (Figure 36).

Figure 36 – Relationship between wetland networks and other habitat networks in the lower Strath area

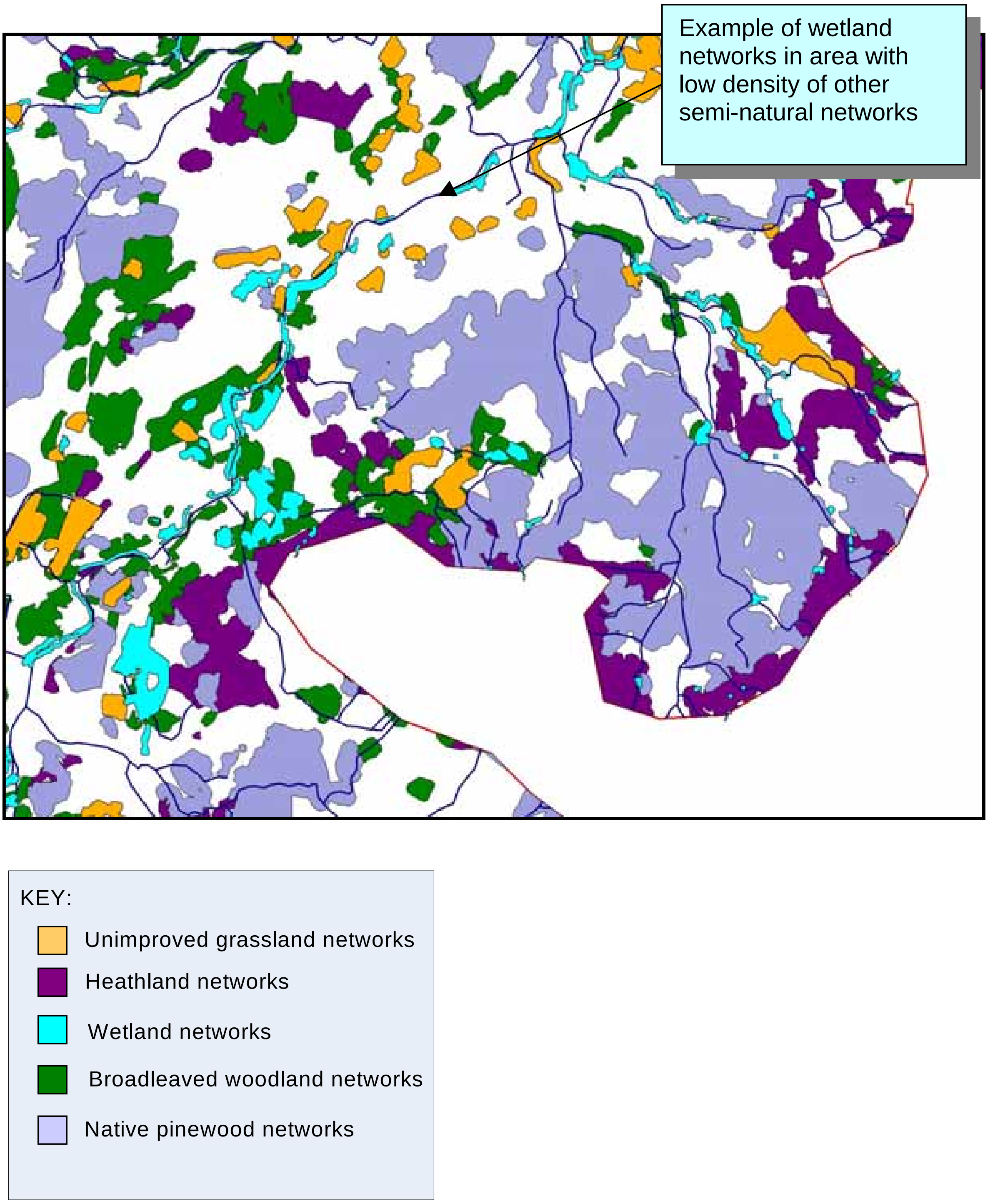
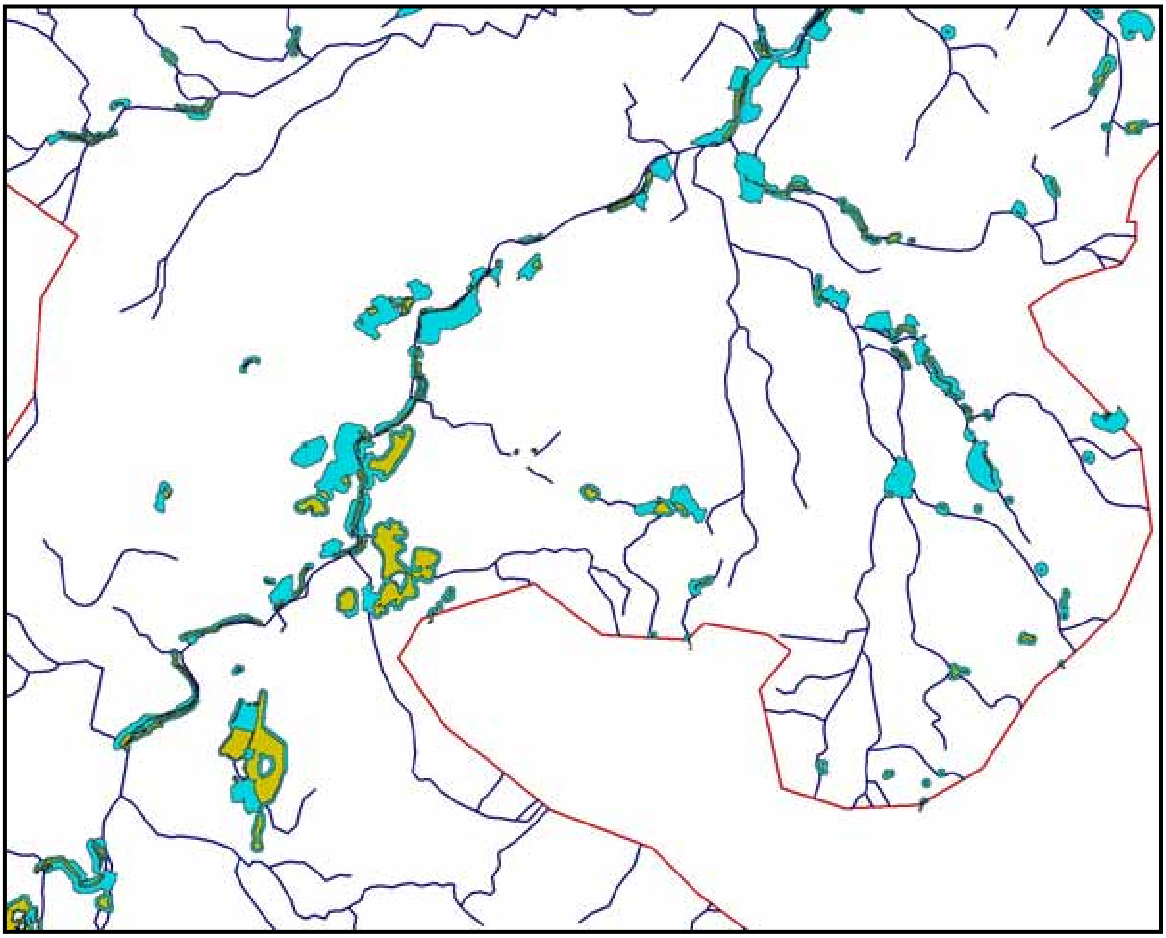
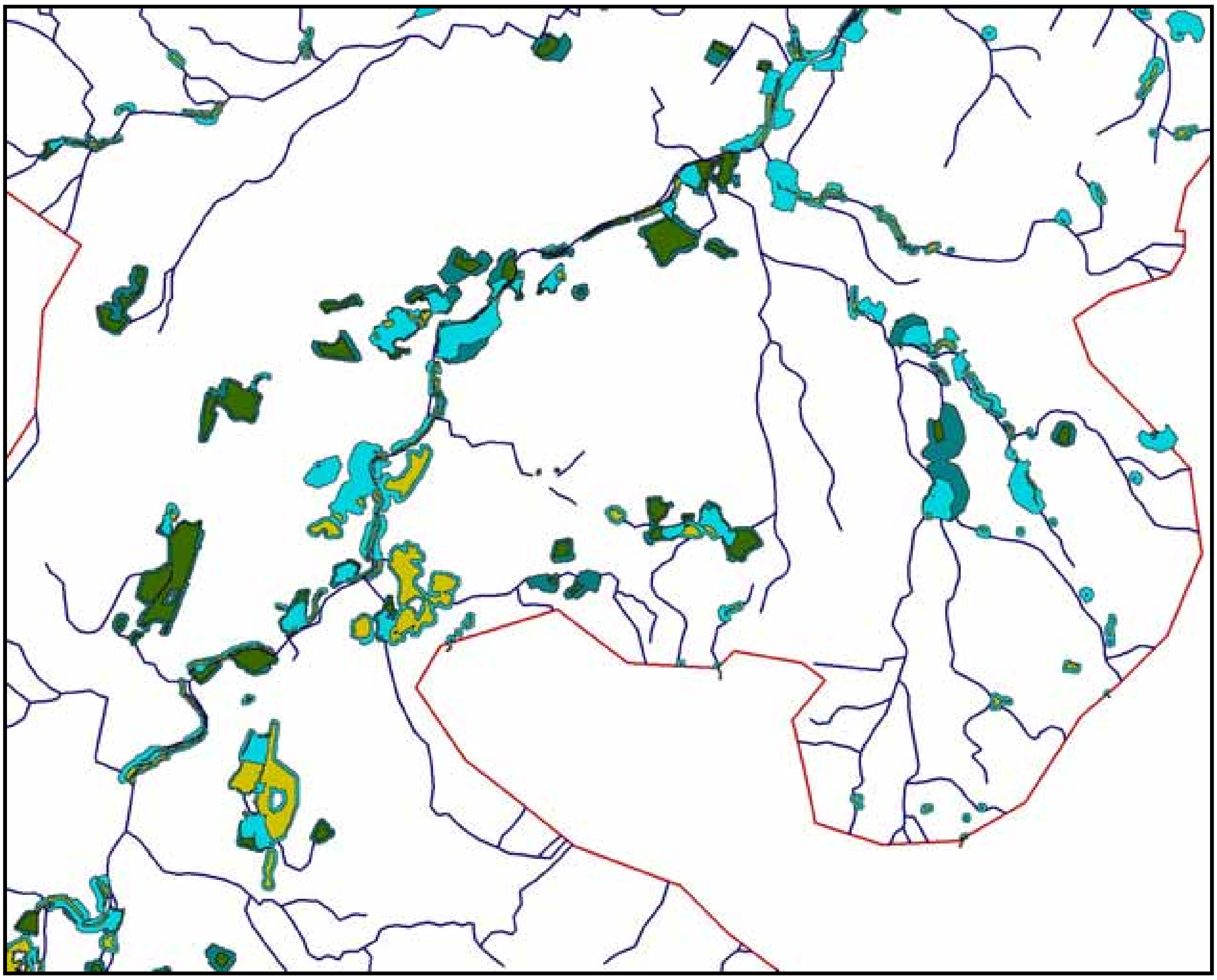


Figure 37 – Distribution of wetland habitat (yellow) and associated wetland networks (cyan) in the lower Strath study area



The existing wetland habitats and networks are shown in Figure 37. The 2006 NVC survey of wetlands and unimproved grasslands recorded fields with remnant habitat within them. As in the Fife case study these fields could form "nodes" of potential restorability. If agri-environment incentives were targeted towards nodal fields which intersect the existing networks then these networks could be enhanced. This was tested following the Fife methodology by restoring target fields and recalculating the network statistics. If all wetland nodes were restored to habitat there would be a resultant rise in network area from 2915ha to 6735 ha which would go a long way to restoring flood plain functionality in Strathspey (Figure 38). The expansion in wetland connectivity would also have wider environmental benefits by helping to alleviate flood events as discussed previously.

Figure 38 – Distribution of existing wetland networks and new wetland networks achieved through restoring fields coinciding with "nodes"



KEY:

- Wetland habitat
- Restored wetland habitat
- Wetland networks
- New Wetland networks
- Rivers

4.2.7 Conclusions

The connectivity of semi-natural habitat networks in Starthspey does not appear to be as well developed as expected given the high biodiversity value of the area, especially wetland and aspen networks two high conservation priorities in the area. The modelling approach was successful in identifying where habitat restoration and creation could be best targeted to foster network development. In the case of wetland restoration, there are knock on benefits for flood mitigation and control and the modelling approach has clear applicability to the development of River Basin Management Plans required under Water Framework Directive legislation. The integration of different kinds of networks is also a key theme in Strathspey and the modelling has shown where there may be cases for reducing the extent and connectivity of some network types (e.g. general conifer networks) to benefit wetland networks. The BEETLE approach is valuable in that it can highlight possibilities, however, the decision on what to do on the ground is ultimately made at a political level (LBAP and local planning authority areas). The modelling can only inform the decision making process, not present the solution.

4.3 Tiree

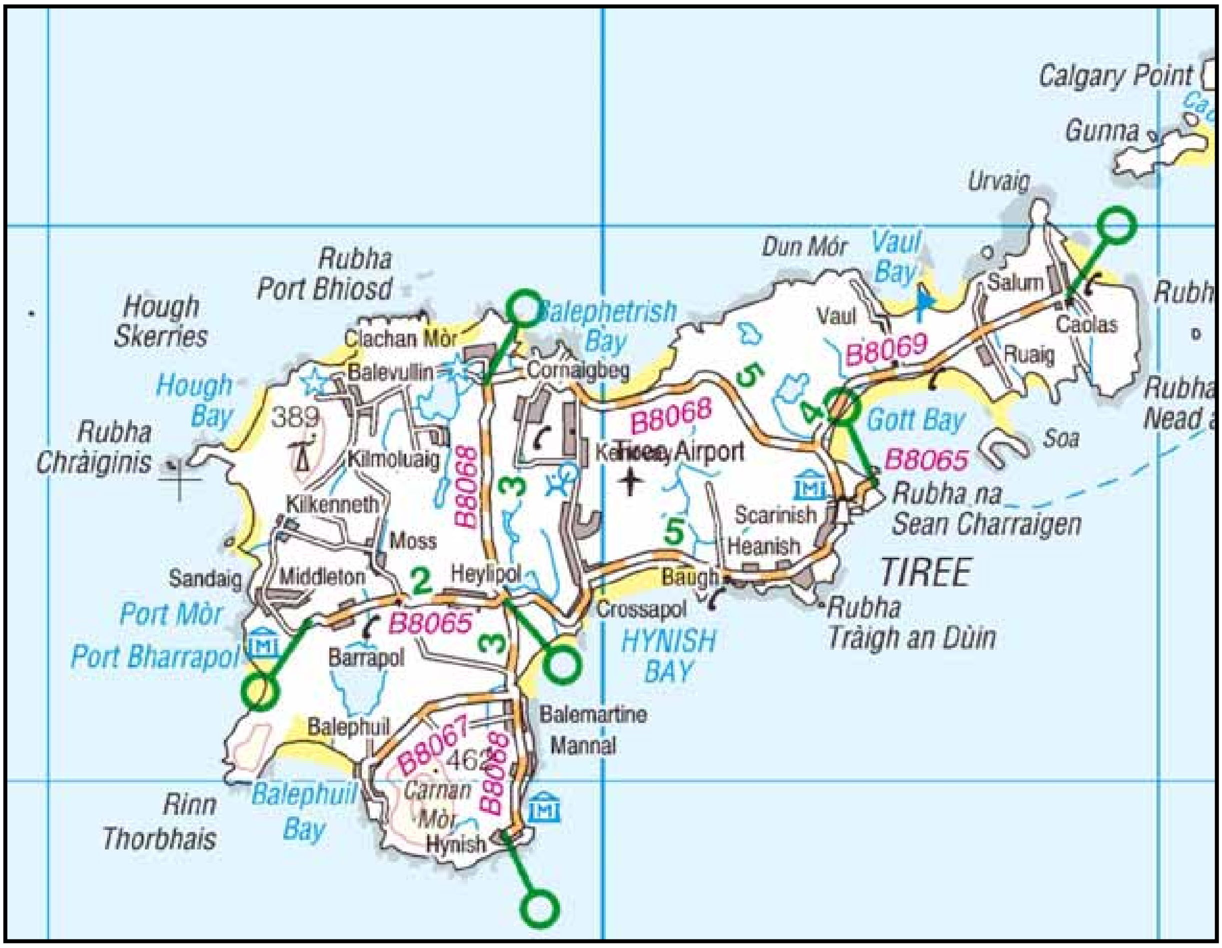
4.3.1 Background and description of case study area

The Isle of Tiree, covering approximately 80 km^2 is situated some 50 km from the Western Scottish mainland (Figure 39). Topographically the island is low-lying with the highest point 140 m above sea level. Tiree has a unique climate; although benefiting from the Gulf Stream, precipitation at 1100 mm/annum is much lower and temperatures are generally higher and more equable through the year than on the mainland. Extensive agriculture using the traditional crofting system is the main form of land-use on the island. This is based round small townships with groups of smallholdings sharing common grazings. These common grazings are made up of the Machair, unimproved coastal grasslands, and the *Carex nigra* dominated wet heaths that are found on thin peat further inland. The enclosed land historically was made up of small fields which were often further sub-divided by the crops grown on them; barley oats and potatoes being the most common but also with patches of hay meadow intermingled between the crops.

Over that last 40 years land use has changed the balance on the enclosed in-bye land notably through the introduction of black bag silage and increased use of non-organic fertilisers. Tiree is an important area for breeding Corncrake (*Cerex cerex*) in Scotland and agri-environmental schemes for the protection of this species has contributed to this land use change with close to 10% of agricultural land being under such schemes in 2005. The scheme involves the late cutting of silage to allow for a second brood and the maintenance of *Iris pseudacorus* dominated mires and pastures, used as early season cover for the birds. Over this same period cropping, mainly the growing of barley and oats and hay meadows has declined significantly with only 20 ha under cropping in the whole island and hay cutting abandoned in all but the driest of summers.

There has been a resultant decline in species associated with cropping and hay meadows such as arable weeds and graniverous birds most notably the corn bunting (*Miliaria calandra)* which became extinct on the island in 2000 though is still present, but declining, on nearby islands. Winter cattle feed has now to be imported to the island from the mainland threatening the sustainability of cattle production and therefore the use of grazing as a conservation tool on the Machair and *Carex nigra* heaths.

Figure 39 - Map of Tiree study area



4.3.2 Stakeholder engagement

A meeting with the Tiree stakeholders was held in the SNH offices, Oban in December 2005 and attended by representatives from SNH, SEERAD, SAC and RSPB together with the local LBAP officer. Discussions centred around the usefulness of the project with respect to conservation issues on Tiree. It was felt that the project would be able to provide the stakeholders with a common approach and give a visualisation of the landscape ecology issues on the island. There is the opportunity to put the theoretical and modelled outputs into practice as much of the current island's agri-environment schemes will be changing over from being part of ESAs to entering Land Management Contracts in 2007. The first stakeholder meeting was followed up by further meetings, correspondence and a site visit to the island.

4.3.3 Priorities for habitat and focal species modelling

Cattle grazing, and agricultural measures to benefit Corncrake and Corn Bunting were identified as two of the most important issue for the conservation and management of habitats and species of conservation concern on the island. The habitats that were identified by stakeholders as being sensitive to changes in grazing regime were:

- Machair
- *Carex* dominated wet heaths on thin peat
- Inbye grasslands
- Coastal grasslands
- Machair lochs and margins.

The management of these areas is interlinked both ecologically and economically.
The focal species chosen to enable exploration of some of these inter- linked conservation issues on the island are listed in Table 9.

Table 9 – Ecological profiles of focal species selected for habitat network modelling on Tiree

Focal species	**Habitat requirements**	**Dispersal**	**Illustration**
Corncrake (*Cerex cerex)*	Wet meadows dominated by *Iris/Juncus* and tall grass meadows	500 m (breeding season)	 © Chris Gomershall (RSPB Images)
Corn Bunting	Ecological Profile as per the Fife case study		
Northern Colletes (*Colletes floralis*)	boreo-alpine species of bee requiring herb-rich dune grasslands and machair	500m	 ©Bill Neill

The dispersal distances were derived from the detailed field data gathered by the RSPB on Corncrake and Northern Colletes. For Corncrake, the locations of different individual birds have been recorded (up to 5 records per bird) and the maximum distance between these points was taken to be the maximum that these birds are likely to disperse from the initial Iris cover they utilise. This information also gave an indication of the habitats that were utilised (and their requirement for cover). There were no records for Corncrake on the wet heaths. A similar method was used for the Northern Colletes where the maximum distance between new and existing sites on the reef was taken to be the maximum distance the bee would disperse to start new colonies.

4.3.4 Data used in the modelling

Digital NVC and Phase 1 survey information were obtained for the whole of the study area. In addition, the locations of individual Corncrakes were made available by RSPB. Data on the Bumblebee *Colletes floralis* were also made available again courtesy of RSPB.

Data on past land use was taken from maps produced by Dundee University as part of a project on land use in the Hebrides in the early 1960's and was provided courtesy of Dr J Caird and Gwyn Jones of SAC. This provides a very useful tool when combined with the

IACS data on land use change and there is a wide range of potential further applications of this especially when combined with species data from the two time periods.

The NVC data were taken from the 1992 survey commissioned and digitised by SNH. This was manipulated so that the different communities were amalgamated to form habitat units, as this is the most useful form in which to undertake the analysis. It may however, be possible to use NVC sub-community data to give some score on quality of certain habitats. For example certain sub communities are more species rich than others as a result of management practices (or lack of them) rather than environmental influences.

It was also emphasised by the stakeholders that most local strategic conservation planning decisions are made by local expert knowledge and that this should be brought together to inform the modelling process. Discussions were therefore conducted with experts to fill in some of the ecological information needed for the modelling that was not obtainable through literature searches and other published material.

4.3.5 Balancing development of networks for Corncrake and Corn Bunting

Corncrake (*Crex crex*) was selected as a focal species on Tiree as a large amount of conservation effort has been put into its protection through agri environment measures. The Corncrake is a migratory species over-wintering in Southern Africa. It therefore can disperse extremely large distances, but becomes much more sedentary when resident in Tiree. It breeds in tall grass meadows but is heavily dependent on the *Iris/Juncus*-dominated wet meadows for cover on arrival (Figure 40). The birds move from the *Iris/Juncus* areas into adjacent grass meadows once the grass reaches over 20cm in height (towards the end of June). From the detailed RSPB records individual birds did not disperse more than 500 m and often much less than this. As a result 500 m was selected as the dispersal distance for the modelling and the landcover cost-layer reflected that habitats that Corncrake were observed to use. The location of Corncrake sightings is shown in Figure 40 in relation to the areas of *Iris/Juncus* meadow generated from the NVC survey of the Island.

The Corncrake breeding habitat network shows the areas that are most likely to be utilised by Corncrake as they move from the *Iris/Juncus* -dominated wet meadows to suitable breeding sites (Figure 41). Of the Tiree records for Corncrake, 75% of individuals were recorded in, or within 50 m of this network (taken as the margin of error from using 6 figure grid references). At present there is 628 ha of Corncrake measures in 107 fields. This compares to 1541 ha (310 fields) that coincides with the network area and has the potential for Corncrake measures. There is therefore increased scope for targeting additional Corncrake measures to suitable fields within the current network.

Figure 40 – Distribution of corncrake locations (red points) and wet rush pastures (green shading) in Tiree. Detailed study area shown in the nested square

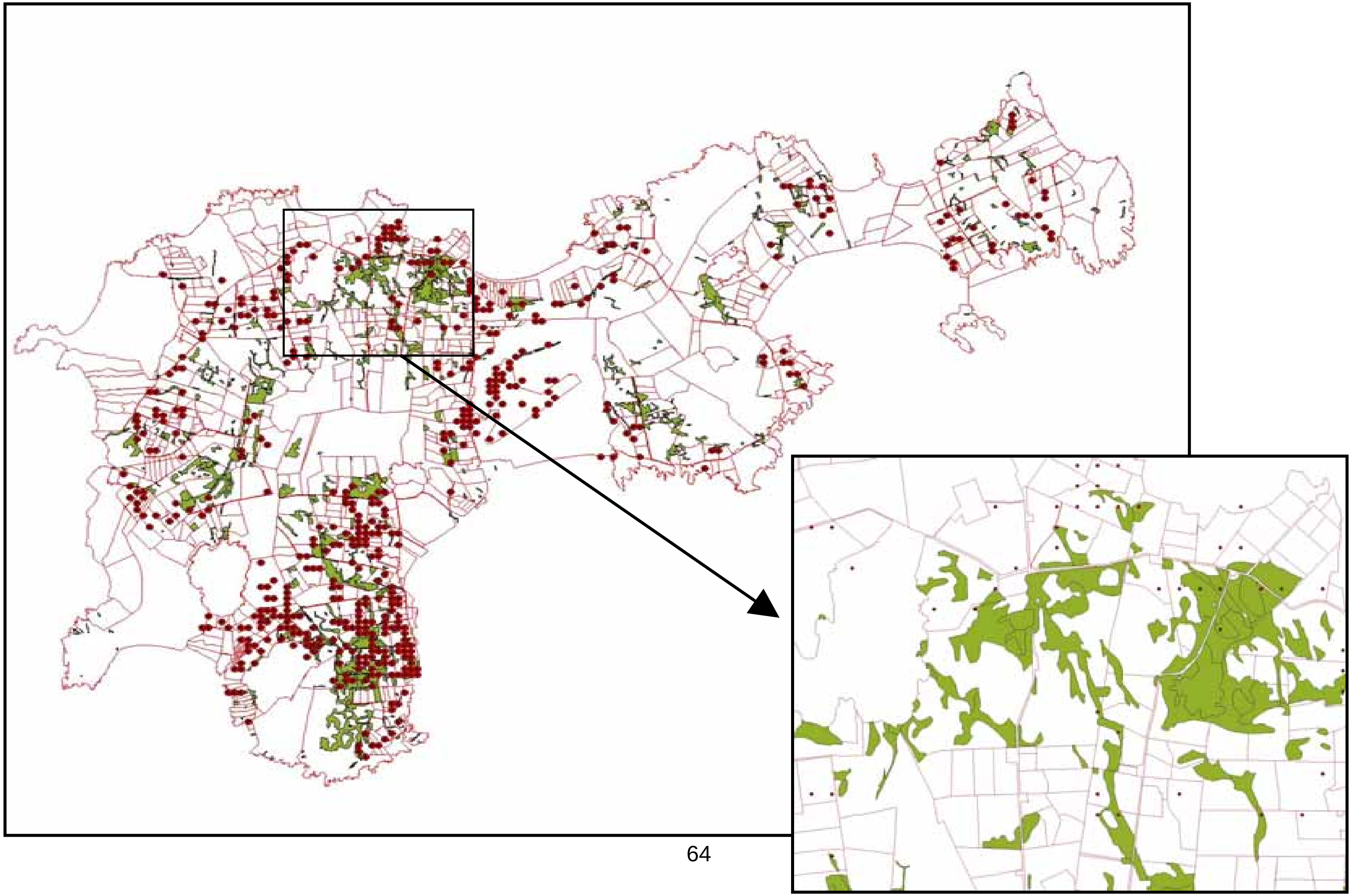
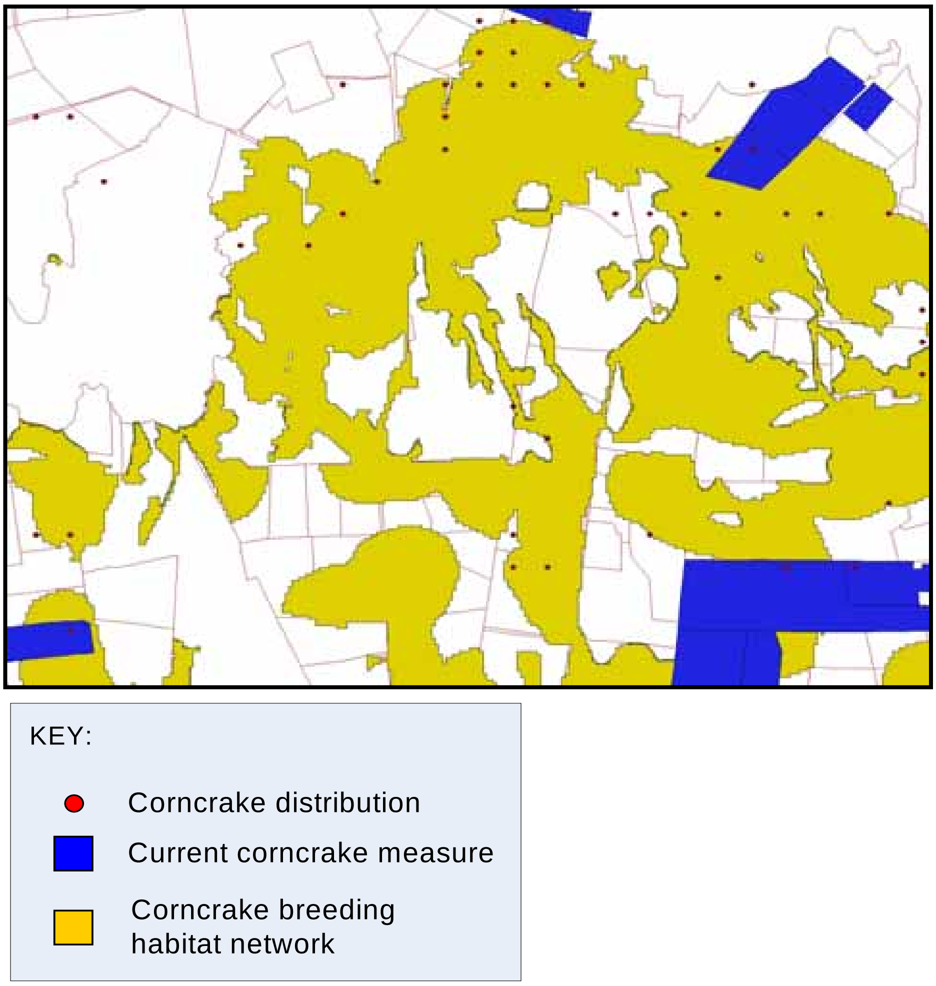


Figure 41 – Corncrake breeding habitat network within the example study area and location of fields with current measures for corncrakes



However, the implementation of agri-environment measures for Corncrake has been at the cost of other arable bird species most notable the Corn Bunting which is now extinct on the island as a result of the decline in cropping schemes. A good example of this process is illustrated by changes in land use over the last 40 years within the township of Barrapoll in the south west of the island (Figure 39). The township covers an area of approximately 750 ha and changes in land use here reflect those over the whole island.

Figure 42 – Random allocation of Corn Bunting measures to fields (green) within existing corncrake networks. Detailed study area shown in the nested square

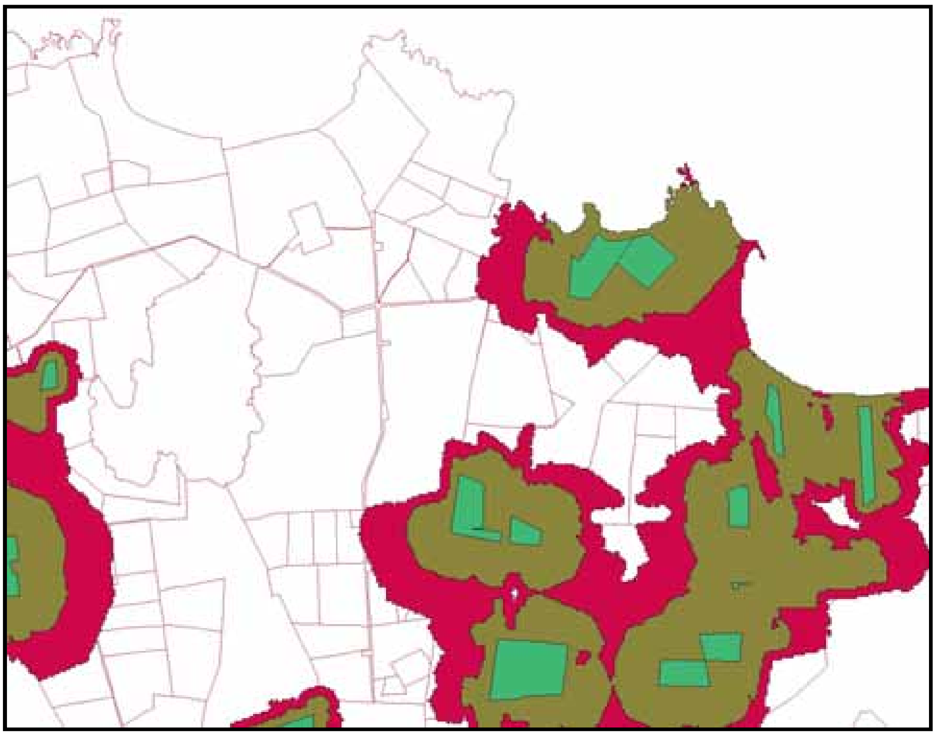
Over 50% of the 342 ha of present day permanent grassland in Barrapoll is in agri-environmental schemes, 85% of which is late cute silage the rest as early cover for birds. Under agri-environmental schemes for Corncrake, 42 ha of former cropping fields (10 out of 14 fields) have being converted to late cut silage, the remainder now being other forms of permanent grassland. Since 1962, 20% of the 447 ha common grazings within this township have been apportioned to individual crofts. This practice has gained momentum over the last 25 years where crofters enclosed the area of common land they had the grazing rights to. These apportioned areas have remained as Machair but the change in grazing regime results in less extensive grazing over smaller areas and a subsequent decline in habitat quality.

Corncrakes and Corn Bunting are both declining across much of Europe and where there are populations or potential populations, the habitats that support them should be safeguarded. By using Corn Buntings as well as Corncrakes as focal species it is possible to explore the development of integrated habitat networks and assess whether a balance can be struck between maintaining the Corncrake population but also allowing for the return of the corn bunting. The essential ingredient in encouraging Corn Buntings is to return to cropping. If this took the form of targeted spring sown crops the networks for Corncrake may not be adversely affected and indeed it may be possible to create networks for the presently extinct Corn Bunting that could facilitate their hopeful return.

In order to test this hypothesis, 50 fields totalling 220 ha were selected to be ascribed Corn Bunting measures (following the East Neuk of Fife method). These fields were allocated randomly across the Island, but within the existing Corncrake networks (Figure 42). Fields that already had measures for Corncrakes were not allocated a Corn Bunting measure. The land cover (dunes, wet heath etc) outside the Corncrake networks is not suitable as Corn Bunting habitat. As in the East Neuk case study the Corn Bunting summer networks were found to be more restricted in extent than the winter networks (Figure 43).

These is a large amount of overlap between the Corncrake and Corn Bunting habitat networks as only a proportion of the area of Tiree is able to support their preferred habitats (Figure 44). However, with judicious targeting of measures to specific fields, there appears to be good potential for integrated Corncrake and Corn Bunting networks on the island to the benefit of both species.

Figure 43 – Corn Bunting habitat networks within the example study area

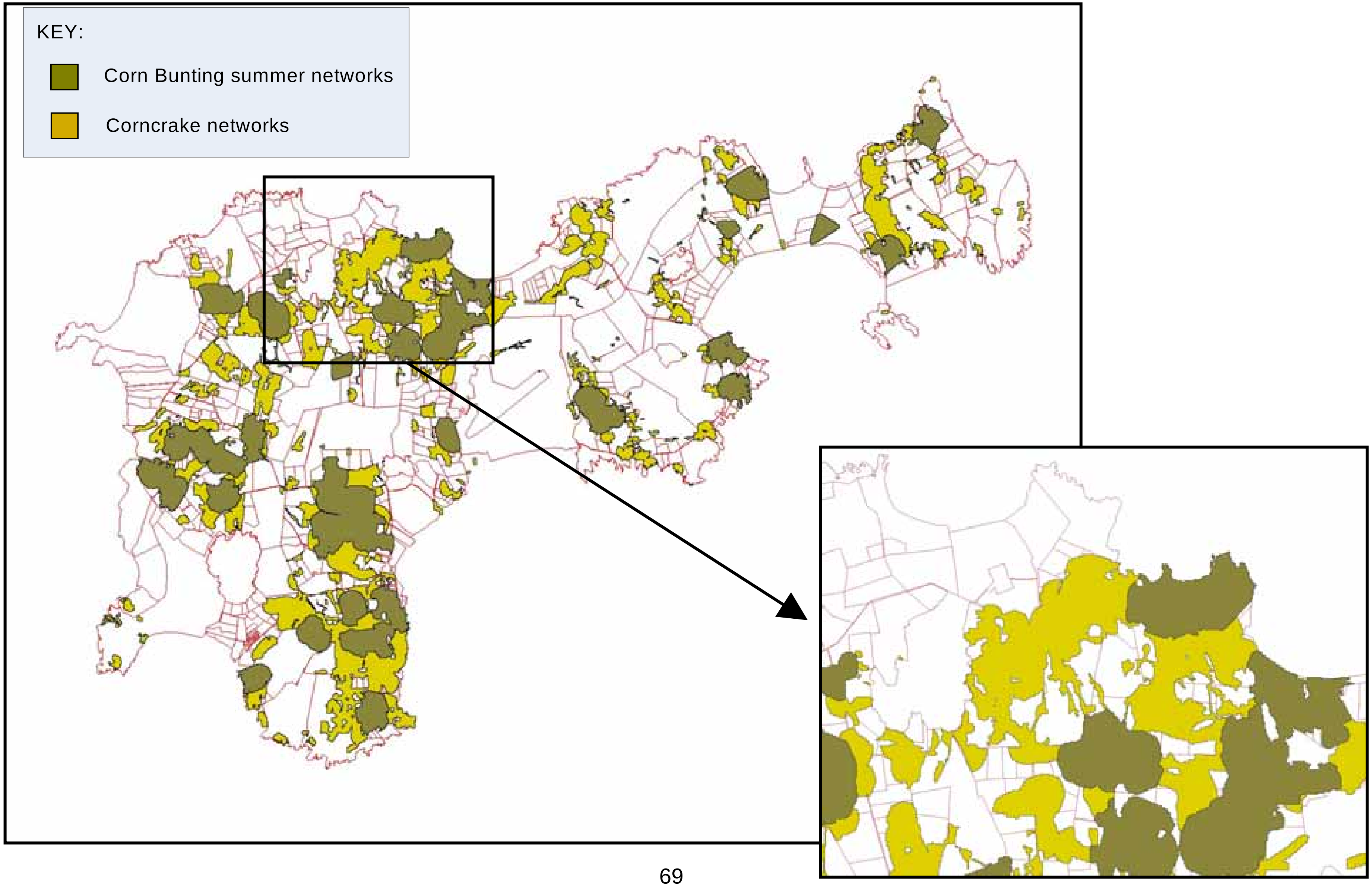


KEY:

- Fields with Corn Bunting measures
- Corn Bunting summer networks
- Corn Bunting winter networks

The re-introduction of cropping to Tiree would also have knock on effects for other habitats and species through the impacts on grazing. Currently a large proportion of cattle feed is imported to the island at considerable cost which restricts the use of grazing. If more feed was produced on-farm this would reduce costs and improve the viability of grazing. This would have a knock-on effect on other habitats that would benefit from extensive grazing such as the Machair and the areas of wet heathland. Machair quality for species such as the bee *Colletes floralis* (the third focal species used in this case study) is closely linked to grazing levels; habitat quality declines if dune grassland is allowed to become to rank.

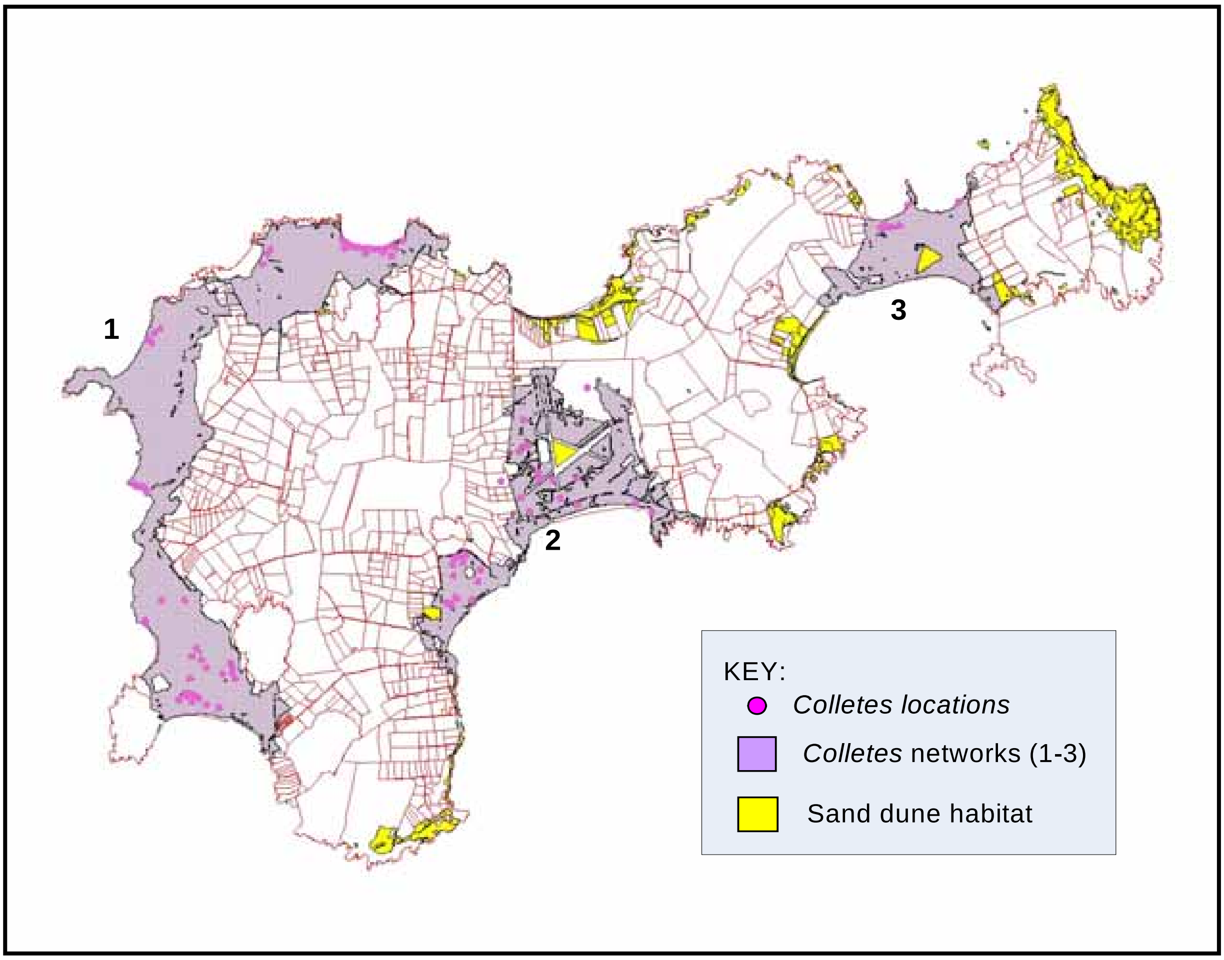
Figure 44 – Corn Bunting and Corncrake networks within Tiree and in the example study area



4.3.6 Modelling habitat networks for Colletes floralis

Coast sand dunes form the habitat for the Northern Colletes bee *Colletes floralis*. Currently the vast majority of the sand dune habitat on Tiree is in three networks (Figure 45) as defined by the location of *Colletes* records and its maximum dispersal distance (Table 9).

Figure 45 – Colletes floralis habitat networks on Tiree



The distribution of the sand dune habitat is governed by the coastal topography and soil conditions, and so is naturally fragmented. The remaining unoccupied sand dune habitat is unlikely to be colonised by *Colletes* given the distance to the existing networks, but more research is needed on population dynamics and dispersal to confirm this. All the existing populations of *Colletes* (within the three networks) are thought to be genetically similar because dispersal is not limited within the network. The NVC mapping did not distinguish between areas of high and low quality habitat, so it is not possible to examine the distribution of the species further within each of the networks. Because it is not possible from the current data to determine the causal link between habitat quality and distribution, it is also not possible to determine other possible effects on population distribution such as habitat patch size.

4.3.7 Conclusions

The provision of good quality species and habitat data for Tiree has enabled accurate modelling of the requirements of the three focal species in terms of habitat networks. There was a departure from the standard approach to focal species modelling where the focal species are selected as "unbrellas" of wider biodiversity (see section 3.6.). Here all three species are of high conservation value in their own right. Nevertheless in showing how networks for two of the species (Corncrakes and Corn Bunting) could be sustained in the same landscape through judicious targeting of incentives, the modelling also prompts exploration of linked ecological and socio-economic issues. One issue in particular is the use of cattle grazing to maintain the habitat quality of Machair (of importance to the Northern Colletes) and wet heath. The economic viability of cattle grazing is linked to agri-environment incentives, and introducing measures for Corn Bunting could make cattle grazing more economically viable without compromising Corncrakes.

5 LANDSCAPE AND VISUAL ASSESSMENT

5.1 Introduction

The development of a habitat network will have an effect on the landscape of the candidate area. The significance of that effect on the character of that landscape, and peoples' visual perception of the area's scenic qualities will depend on what is proposed and how that proposal will interact with what is already there.

To help determine those effects and to inform changes to the proposal there should be an informed appreciation of the existing landscape. There should be an understanding of the physical, human influenced and aesthetic attributes of the landscape, all in the context of the cultural and historic time depth that influenced its development.

To that end and for this study, the following tools were applied:

- Landscape Character Assessment (LCA)
- Historic Land use Assessment (HLA)
- ArcView Geographical Information System (GIS)
- Envision 'Brendan' computer generated visualisations

Although each tool has been developed to increase our appreciation of the Scottish landscape, each has appreciable limitations to their contribution to our level of understanding.

5.2 Landscape Character Assessment (LCA)

5.2.1 Description of LCA

In 1994 Scottish Natural Heritage initiated a National programme of LCA. During the period 1994 – 1999, 30 LCA reports were completed, providing complete coverage of Scotland. Although the brief and methodology of the studies were influenced by the local requirements of the steering groups managing individual LCAs, the consultants were generally all working towards the achievement of six primary objectives for the programme (Martin and Swanwick, 2004):

- to establish an inventory of all the landscapes of Scotland;

- to raise awareness of Scotland's landscapes;
- to identify the main forces for change in Scotland's landscapes;
- to provide information to support various kinds of casework, including development control and other proposals for land use change;
- to provide information to help SNH, local authorities and others to input into development plans and other land use strategies; and
- to help inform national policy on issues relating to landscape interests.

5.2.2 Application and limitations of LCA

It was envisaged that the LCA suite would help to inform a wide range of environmental decision making. Those practical applications broadly fell into two categories; planning and landscape conservation/management (Martin and Swanwick, 2004). In the sphere of landscape conservation/management, applications of the LCA programme have been used to varying degrees in relation to forestry, agriculture and other land use change studies (Martin and Swanwick, 2004).

In Scotland it has been acknowledged that there is a relatively high level of awareness and respect for the SNH programme of LCA. It has also been recognised though that besides their inherent inconsistency (by virtue of both the capabilities of the consultants and local requirements of the steering groups) the major constraints on the use of LCA is thought to be the scale of the work and lack of prescription. The scale applied throughout the programme was 1:50,000 (HLA has been carried out at 1:25,000 because this is the largest scale that field boundaries are shown, a scale that more recent LCA, such as Loch Lomond and the Trossachs, have adopted).

Generally, the descriptions of landscape character are thought to be particularly helpful, the guidelines are generally considered less so and the pressures for change reflect the influences at the time of writing (Tyldesley, 1999). In concert with others, FCS has suggested that the entire programme of LCAs should be reviewed and updated, following the LCA Guidance for England and Scotland (2002).

5.2.3 Application of LCA in the LHN project

The entire programme of LCA is available on GIS as a seamless mosaic of shapefiles for each landscape character type. This database was accessed as part of the general information search for designated sites and constraints information for the East Neuk of Fife, the case study area chosen for the landscape analysis.

Although the GIS theme 'Identify' window contains a schedule of the LCA attributes, the relevant LCA report was also consulted for the associated – and essential – text description, pressures for change, guidelines and illustrations. All this LCA information was used to inform the research team of the landscape character of the study areas prior to visiting the sites.

5.3 Historic Land-use Assessment (HLA)

5.3.1 Description of HLA

HLA is an ongoing project, jointly sponsored by Historic Scotland (HS) and the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS).

An HLA is a complementary study to LCA, interpreting the material remains of the past and providing perceptions and interpretations that allow us to understand the present day landscape. It focuses on the effect of human activity on the landscape. Its purpose is to both inform and facilitate the management of change to the historic environment, primarily at the landscape scale (Fairclough and Macinnes, undated).

The developed methods and approaches are similar to LCA, particularly the spatial map based use of information in a GIS environment. This facilitates the incorporation of HLA into LCA.

The HLA contribution to landscape understanding lies in the following:

- a concern with successive layers in the land – “time depth”;
- an interpretation of the whole modern landscape and its predominant historic character;
- a particular concern for defining and explaining landscape character in historic terms;
- the ability to identify the patterns and historic significance of major land use such as woodland, moorland, designed landscapes etc
- the ability to describe some of the character of previous episodes of landscape, and in other ways to define time depth
- the ability to measure more recent change in landscape character

5.3.2 Application and limitations of HLA

HLA can play a role in land management, informing, for example, agri-environment and forestry schemes, both strategically and at the level of land-units. When achieving wider coverage, it will be able to provide national or regional overviews, and help to define local characteristics as a basis for prioritising actions from national to local level.

HLA provides an overview of cultural sites and landscapes, and can combine with LCA to define key landscape characteristics for protection, management and interpretation. It can assist in monitoring landscape change by providing baseline information against which change can be measured. Alongside LCA, it can also facilitate an integrated approach to countryside management, relating land-use change to existing character in a way which is better informed about the origins of that character (Fairclough and Macinnes, undated).

As an ongoing project, at writing only about half of Scotland has been analysed, with completion not anticipated until 2011. Besides budget constraints the main reason for the length of the delivery programme is that the promoting organisations wanted to avoid the inconsistencies inherent in the LCA project approach.

Rather than commission numerous consultant teams covering areas of the country, a dedicated HLA team has been built up to cover the entire country in a rolling programme. Also – and again learning from the LCA project – the HLA has been carried out at 1:25,000 so that information can be shown at the individual field level. The HLA Steering Group oversees the running of the project. Besides managing the project, the Group is currently considering potential applications and use of HLA, and development of associated guidance.

As the data is compiled though, it is available free to all through the RCAHMS HLAMAP web-site: (http://jura.rcahms.gov.uk/HLA/start.jsp). HLAMAP is a web-based presentation of HLA data that allows the user to view the data by Historic Land-use Type, Period or Category as well as by Relict Land-use, Period or Category, and to print out a report of any selected area.

5.3.3 Application of HLA in LHN project

For the East Neuk study area, only a patch to the west and south of the north-east corner of Tentsmuir Forest is currently available for interrogation on the HLAMAP web-site. For this area, the analysis of past and present land-use was appraised through all the levels of assessment:

- **Historic land-use Categories** Historic Land-use Categories comprise the fourteen major national patterns of historic land-use (refer to HLAMAP).

- **Historic land-use Types** There are 55 Historic Land-use Types (RCAHMS, 2005) that have been defined which form the basic building blocks of the map. Each type is characterised by its period of origin, as well as its form and function. By far the greater number of types are 18th century, or later, in date. As the attributes reflect this characterisation, analysis may be carried out by category, type or period.

- **Historic land-use Period** The period of each Historic Land-use Type is applied as an indication of its period of currency. This is based upon the current archaeological and historical understanding of the particular Land-use Type. For Historic Types dating from before the modern era it is defined by historical age such, e.g. Medieval; for those of more recent centuries, a century to century span, or part thereof, is applied which matches as closely as possible the currency of use. This means that there are types, which have overlapping periods of currency, because of the diachronic historical processes involved.

- **Relict Categories** The Relict Types have also been grouped into Categories. Like the Historic Land-use Categories, Relict Categories reflect the survival of major national patterns of past land-use in the landscape, either as Relict Historic Land-use Types or as Relict Archaeological Types. These Categories may comprise one or more Relict Type. There are sixteen Relict Categories (refer to HLAMAP).

- **Relict Type** Some Historic Land-use Types, or parts of types, are no longer maintained for their original purpose, but have left a visible trace in the landscape. These are Relict Historic Land-use Types. There are 26 at present and they are indicated in the glossary for Historic Land-use Types by the letter R. In addition there are 40 Relict Archaeological Types that are archaeological features no longer used for their original function. Like the Historic Types these are defined by their period of origin and by their form and function.

  The complexity of past land-use means that, on occasion, there are up to three relict types (see data structure) in the same area. Where there is such a palimpsest, the relict types are ordered from most recent to oldest in the data structure. As with all areas within the HLA, Relict Types have to be sufficiently extensive (1 ha). Many archaeological sites are, therefore, too small to be mapped by HLA.

- **Relict Period** This is organised on the same basis as Historic Land-use Period (see above), but ranges back as far as the Mesolithic.

All this HLA information was used to inform the research team of the historic land-use of the study area prior to visiting the site.

5.4 Application of ArcView 3.2 GIS

GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analysing, and displaying all forms of geographically referenced information. GIS can integrate and relate any data with a spatial component, regardless of the source of the data.

ArcView 3.2 is a desktop geographic information system. ArcView 3.2 can create intelligent, dynamic maps using data from virtually any source and across most popular computing platforms. ArcView 3.2 provides the tools that facilitate working with maps, database tables, charts, and graphics all at once. ArcView 3.2 can also use multimedia links to add pictures, sound, and video to maps.

The GIS system has been used as the platform for reviewing and analysing relevant and available datasets, including national and local designations, LCA landscape character type areas, and imported data from the Forest Research BEETLE programme.

All this information was used to inform the research team of the historic, landscape and land-use of the study areas, and their potential for habitat expansion for selected focal species. For the assessment of landscape and visual effects, the selected focal species datasets (corn bunting and red squirrel in the Fife case study area) and associated BEETLE model outputs, the following process was followed:

- Focal species datasets and models were viewed on plan and analysed in relation to Ordnance Survey map information at different scales, and relevant landscape, natural and historic environment datasets
- Theme tables of individual focal species datasets and models were edited, adding a selected colour, and for woodland, an appropriate tree style and height value.
- Amended focal species datasets and models shapefiles were then imported into the Brendan three dimensional modelling tool for visual analysis (see below)

5.5 Envision 'Brendan' computer generated visualisations

5.5.1 Envision 'Brendan' software

Brendan is part of the Envision 3D Limited TRETOP suite of programs. TRETOP has its origins in a group of computer programs developed during the mid 1980s for the UK Forestry Commission. Since that time the software has been enhanced and greatly extended in its capabilities. It remains the visualisation tool of choice for all Forestry Commission landscape architects. Brendan is an interactive, Windows-based program designed for the exploration and viewing of 3-dimensional data sets constructed or imported using other programs in the TRETOP package.

Brendan takes various data files and controls the way they are presented in perspective. The aim of Brendan is to facilitate the exploration of data interactively in 3 dimensions, and the creation of rendered perspective views from any position.
Brendan incorporates the following features:

- Load data from DTM files, treeblock files, building files
- Load style information from colour table files.
- Choose a viewpoint either by typing in perspective parameters or by 'flying' through the data interactively with mouse or joystick.
- Choose single frame or panoramic perspective views.
- Choose lighting parameters and shadowing based on direction of light or on time, date and location.
- Output to screen, printer or to image file.
- Store scene and viewpoint parameters for future use.

5.5.2 Digital Terrain Models (DTM) in Brendan

A Digital Terrain Model (DTM) is the numerical representation of the ground surface used in all programs in the TRETOP package, including Brendan.

The DTM is a 2-dimensional grid of spot-heights. This grid consists of equal-sized square cells; the cells are all square, but the whole DTM can be rectangular. The edges of the DTM are always parallel to the easting and northing axes of the co-ordinate system in use. The parameters that define a DTM are as follows:

- Number of columns. This is the number of *points* across the whole grid from west to east limits inclusive. Note that it is not the number of *cells,* which will be one less.
- Number of rows. This is similarly the number of points from south to north limits.
- Grid interval. This is the mesh size of the grid in metres (i.e. the distance between two adjacent points on the grid).
- Grid origin: this is the easting and northing of the south-west corner of the DTM.

FCS has access to both the OS 1:50000 and 1:10000 DTMs (meaning the interval of *points* across the grid is 50 and 10 metres respectively). The 1:10000 DTM provides a finer grid than the 1:50000, and is therefore preferable as a visualisation terrain model since it will reveal the subtleties of the landform more than the coarser 1:50000 DTM. However, the computer memory for a 1:10000 DTM of a significant area of landscape is prohibitive.

Fortunately, TRETOP also has a programme package called Mosaic, which can not only assemble a bespoke DTM from a sequence of OS tiles but also has the facility for reducing the interval of points on the grid, thus saving computer memory. For the Fife case study area the 1:10000 DTM interval was reduced to 25 metres.

5.5.3 Co-ordinates in 'Brendan'

Underlying all of the programs in the TRETOP package, including Brendan, is a 3-dimensional co-ordinate system. Any point in space can be defined as a triplet of numerical values; the co-ordinates of the point. These co-ordinates represent the easting, northing and height of the point relative to some agreed origin and datum level.

In general, for work in the mainland UK, it is sensible to use the Ordnance Survey (OS) National Grid system, as used on all maps published by OS and also by some other companies.

OS grid references define locations relative to an origin (with zero easting and northing) which lies somewhat south-west of the Scilly Islands, thereby giving positive co-ordinates to all of mainland Britain and the majority of offshore islands.

All TRETOP programs expect co-ordinates to be in metres, so in general six-figure eastings and northings result from the use of the OS origin. The full co-ordinates appear in the corners of all OS sheets at all scales.

5.5.4 Application and limitations of 'Brendan'

As a visualisation software package, Brendan is relatively straightforward to use. With the prepared DTM file, GIS shapefiles and selected colour table loaded all that is needed to create landscape visualisations are OS co-ordinates for both the viewpoints and viewing target. Once entered the programme will produce in just a few minutes rendered perspective views. The programme also includes the facility of free navigation through the landscape.

The strength of the model is that it provides spatially correct representation of the landscape as the terrain and selected features would be seen from selected viewpoints. Spatially, all the selected elements are a 3D model of the 2D GIS information. Reducing the landscape to simple single colour rendered shapes facilitates speed of processing and utility of changes of scene when navigating through the landscape.

The obvious limitation of Brendan is that single colour rendered shapes have none of the subtleties of a landscape, especially the colours and textures that compose a landscape, not to mention seasonal variety.

5.5.5 Application of 'Brendan' in LHN project

Brendan was used to help the research team with their assessment of potential landscape and visual effects that could be a consequence of implementing the BEETLE programme focal species expansion models. Specifically, Brendan was used in the analyses of calculated habitat expansion for corn bunting and red squirrel in the Fife case study area.

5.5.6 Site visit and viewpoint selection

An important aspect of visualisation selection was the identification of appropriate viewpoints. This was carried out as part of a general site visit so that the research team could become familiar with the landscape character and visual qualities of the case study area.

The criteria for viewpoint selection was that they:

- Were publicly accessible
- Had an existing open and panoramic view of the core subject area
- Ranged from close proximity to the core subject area out to the margin of the study area
- Were representative of each landscape character type area within the study area

5.6 Red Squirrel habitat networks

5.6.1 Background and area selection

The research team selected the north-east corner of Fife (Figure 5) to investigate the potential for a red squirrel reserve in the area primarily because of Tentsmuir Forest. Tentsmuir is a predominantly conifer woodland, providing a habitat appropriate for Red Squirrels.

Although there is an established habitat network of broadleaved trees favoured by Grey Squirrels throughout Fife, an initial study of the north-east corner showed that there are relatively few patches of broadleaved woodand in this area. The assumption was that there is potential for a Red Squirrel reserve in Tentsmuir. It was considered that this could be secured by converting the broadleaved woodland to conifer within the Red Squirrel habitat area, and the control of any Grey Squirrels that utilised the increased Red Squirrel network.

The BEETLE programme was used to simulate conversion of broadleaved woodland to conifer. The expansion of the conifer woodland habitat network raised issues of the potential consequences of such land-use change. Besides the effects on the natural environment, of interest here was an assessment of the effects on the established landscape character, historic environment, and on the amenity value of the visual landscape.

5.6.2 Landscape Character Assessment

The Fife landscape can be characterised as generally of lowlands and hills. To this north-east corner the sea is an important visual element and has a significant influence on the landscape. St Andrews Bay forms the large sweeping coastline from Tentsmuir Forest in the north down to the promontory of Fife Ness in the south. The town of St Andrews marks a distinct change in the coastal landform of St Andrews Bay. To the north the flat sandy beaches and flats of the Eden estuary, and to the south, narrow rocky shores with cliffs.

The study area of north-east Fife, to west and south of Tentsmuir Forest (Figure 5) includes the following recognisable landscape character types (after Tyldesley, 1999):

- **Coastal Flats**

These areas are very flat, low-lying coastal landscapes, developed on blown sands and old dune systems. They are covered by a variety of land uses; the afforestation at Tentsmuir forest, the airfield at Leuchars and golf courses at St Andrews. These land uses donate a diversity of landscape character, but their association with the sea is ever present in these very flat, low-lying, horizontal, open, large-scale, exposed coastal landscapes.

These landscapes typically contain intensively cultivated, geometrically laid out, large to medium-scale, predominantly arable fields or forestry plantations with rectilinear, fenced enclosures; straight ditches, sea walls and flood banks with small bridges; slightly sinuous or angular roads raised above the fields with stone dykes or open sides and isolated, scattered or regularly spaced farmsteads, conspicuous due to their lack of screening, in contrast to the designed landscapes which are well screened by policy planting and shelterbelts. (refer map, Vpt 5)

- **Coastal Terraces**

Bordering the landward edge of the Coastal Flats are the more gently sloping Coastal Terraces. These Terraces are either extensively built upon or relatively undeveloped, comprising large, open, undulating arable fields with infrequent or more regular steadings.

They have little vegetation cover except policy planting and shelterbelts around the large houses and designed landscapes, or on the steeper slopes often above burns. There are few field boundaries, limited to some hedgerows, or stone dykes or post and wire fencing primarily around the larger houses and farmsteads. These are coastal landscapes where the character is influenced by the sea and typically they are a simple, undulating, balanced landscape with muted colours and varied textures. (refer map, Vpt 4)

- **Coastal Hills**

Bordering the Coastal Terraces to the south are the Coastal Hills, which slope gradually towards the sea offering panoramic views of St Andrews Bay. They are characterised by their strong association with the coast and usually comprise large, undulating, regular, open arable landscapes with few hedges but some linear shelterbelts and policy woodlands. Settlements are infrequent, small, often exposed and conspicuous, built of stone or white or pale colourwashed render and grey roofs and single or two storey houses with small windows to the sea.

These are medium to large-scale, often open or exposed coastal landscapes where the character is always influenced by the sea and can be particularly affected by the weather conditions and views of the sky and the sea. Generally a simple, sloping, balanced, active, organised, tended farming landscape with regular or geometric patterns. These hills mark the transition between coastal and landward areas of Fife, sharing the characteristics of both. (refer map, Vpt 6)

- **Lowland Dens**

Between the low hill landscapes of Fife are the deeply incised sometimes narrow gorges or valleys of the Lowland Dens. These have been cut by fast flowing burns across the gently rolling Coastal Hills and Terraces. Often they have extensive semi-natural woodland with primarily broadleaved trees, and few buildings other than occasional steadings or large houses with policies. These are confined, small-scale, intimate, sheltered, textured, colourful and balanced landscapes. (refer map, Vpt 6a)

- **Lowland Hills and Valleys**

The visual boundary to views of the low-lying landscape of north-east Fife is created by the Lowland Hills and Valleys. These have a varied and subtle landform covered by open, regular farmland patterns of medium-scale fields of arable or pasture.

There are extensive areas of plantations, shelter planting, roadside planting and policies linked to large estates with a regular, often linear, pattern of steadings and larger settlements and towns, all of which are generally well related to the landscape. Similarly well related to the landscape, is the network of minor roads and other linear or point features including plantations and tree groups, individual trees and local buildings. This is a lowland, settled, farming landscape with variety, continuity, maturity and subtlety and a long history of settlement. (refer map, Vpt 7).

5.6.3 Historic Land Use Assessment

There is prolific evidence of early settlement throughout the entire area. Fife has an outstanding heritage of historic landscapes, with a record of change over thousands of years.

The archaeological landscape is potentially rich, although many of the former sites may have been disturbed or lost through urban development and mineral extraction. There are sites, buildings and features of national importance, from pre-history through early historical times and into the industrial history of the 18^{th}, 19^{th} and 20^{th} centuries.

The Historic Land-use Assessment (Historic Scotland (HS) and the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS)) was consulted for an analysis of past and present land-use. Although for Fife only one HLAMAP area has been completed and made available on the RCAHMS web-site, the research team were fortunate that this area predominantly covers this north-east Fife study area.

For this area, the analysis of past and present land-use was appraised through all the levels of assessment:

- **Historic land-use Categories**

Although the categories were predominantly as observed (in descending order of extent; fields and farming, woodland and forestry, recreation and built up areas) the map highlighted one area of crofting to the north of the community of Balmullo, on the east facing slopes of Lucklaw Hill.

- **Historic land-use Types**

This layer illustrated a predominance of rectilinear fields throughout the field and farming category, but with significant areas of amalgamated fields especially to the west of Tentsmuir Forest and west through south-west of St Andrews. Balmullo was also confirmed as a crofting township.

- **Historic land-use Period**

The fields and farming category has predominantly been identified of18th –19th century period of origin, with the amalgamated fields of 19th century, and conifer forest of 20th century origin.

- **Relict Categories**

Relict Categories reflect the survival of major national patterns of past land-use in the landscape. To the west of Tentsmuir Forest is a significant cluster of cropmark sites. The single crofting area of Balmullo and the designed landscapes (not included in the HS Inventory of Gardens and Designed Landscapes) to St Fort Home Farm south of Newport-on-Tay, and the now ancient woodland site to the immediate north of St Michaels.

To the south of Tentsmuir Forest, with the exception of a handful of relatively small cropmark sites and designed landscapes (non-Inventory) the only other significant relict category areas are the designed landscapes of Strathtyrum House and what is now Craigtoun Country Park, both to the west of St Andrews.

- **Relict Type**

This layer provided no more information than the Relict Categories above.

- **Relict Period**

Approximately half of the relict category cropmark sites have been identified of prehistoric origin, the remainder of medieval/post-medieval origin. As would be expected, the designed landscapes are of 17th-19th century origin.

When read with the available map data on the location and extent of Scheduled Ancient Monuments, this review of the Historic Land-Use Assessment study of north-east Fife clearly shows the historic importance and sensitivity of the area to the west of Tentsmuir Forest. South of Balmullo and Leuchars and across the River Eden estuary there is significantly less evidence of relict land-use, save for the 17th-19th century designed landscapes west of St Andrews.

5.6.4 Site visit

Two site visits were made. The first was with all the Scottish members of the research team on 27th November 2006, the second was solely by the FCS Landscape and Culture Adviser on 31st January 2007.

The first site visit initially focussed on Tentsmuir Forest, looking at the structure and species composition of the forest (**Vpt 1a**). The team especially noted the regenerating area to the southern edge of the conifer forest (**Vpt 2a**) and link with the patch of broadleaved woodland between Tentsmuir Forest and Reres Wood (**Vpt 3a**).

Vpt 1a – Tentsmuir forest


Vpt 2a – Regenerating woodland Tentsmuir forest


Vpt 3a – young broadleaved woodland Tentsmuir

Following this appraisal the research team travelled around and away from the forest looking for vantage points that could represent review locations of the LHN models to be generated by the BEETLE programme.

Within the Coastal Flats landscape character type (LCT) a viewpoint was located to the north edge of Leuchars Airfield, with the benefit of a view of the southern margin of Tentsmuir Forest, including the aforementioned patch of broadleaved woodland (**Vpt 4a**).


Vpt 4a – southern boundary of Tentsmuir forest

Within the Coastal Terraces LCT some 4kms to the west of Tentsmuir Forest an elevated viewpoint was located on the shoulder of Lucklaw Hill. This vantage point provided a view of the southern margin of Tentsmuir Forest, the aforementioned patch of broadleaved woodland through to Reres Wood and the River Eden estuary, with the enclosing hills to the south (**Vpt 5a**).


Vpt 5a – Coastal Flats and Tentsmuir

Some 9kms distance to the south of Tentsmuir Forest the hills of Kinninmonth, Ladeddie and Drumcarrow Craig in the Lowland Hills & Valleys LCT are the highest ground and visual watershed for views north over St Andrews Bay and Tentsmuir Forest. At Drumcarrow Craig a viewpoint was located that looked down into the Lowland Dens, over the Coastal Hills to the Coastal Terraces and Coastal Flats LCTs beyond (**Vpt 6a**).


Vpt 6a – Coastal Hills, Terraces and Flats

The second site visit was primarily an appreciation of all the LCTs throughout Fife, subsequent to a desk study of the SNH Landscape Character Assessment. During this visit additional viewpoints were also located, intermediate to those identified in the first site visit.

South of Tayport and to the west of Tentsmuir Forest a vantage point was located looking west, providing a representative viewpoint of the Coastal Terraces LCT (**Vpt 4**).


Vpt 4 – Coastal Terraces

To the westerly access road to Tentsmuir Forest a viewpoint was located near Craigie Farm that captures the open, amalgamated fields of this Coastal Flats LCT and spatial interlock with the west margin of the conifer forest (**Vpt 5**).


Vpt 5 - Coastal Flats

Between the hills of Kinninmonth, Ladeddie and Drumcarrow Craig are the less pronounced Coastal Hills LCT and high ground of Knock Hill. Straddling this ridge is the community of Strathkinness, from where a vantage point has been obtained over the Coastal Terraces LCT below, across the Eden River estuary and into the Coastal Flats LCT beyond (**Vpt 6**).


Vpt 6 – Coastal Terraces

5.6.5 Viewpoint selection and perspective photographs

All the above viewpoints have been selected for inclusion in the appraisal of the LHN models to be generated by the BEETLE programme. Perspective photographs were obtained of all these locations during the described site visits.

In addition, one oblique aerial photograph has also been selected. The viewpoint has been judged to be from above the southern edge of Newport-on-Tay, looking east towards the centre of Tentsmuir Forest (Pat MacDonald aerial photo 0570-04-29).


Oblique aerial - Tentsmuir

5.6.6 'Brendan' computer generated visualisations

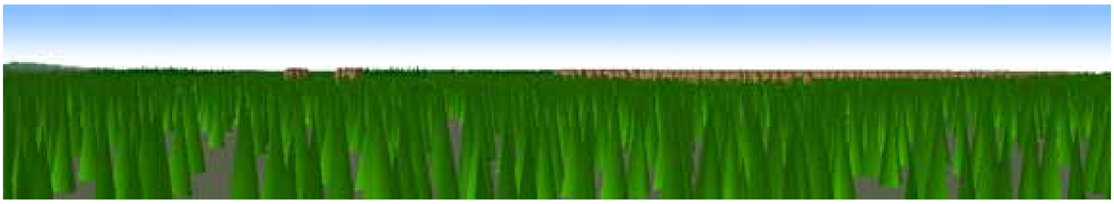
For all the above viewpoints, computer generated visualisations were generated including based on the datasets listed in Table 10.

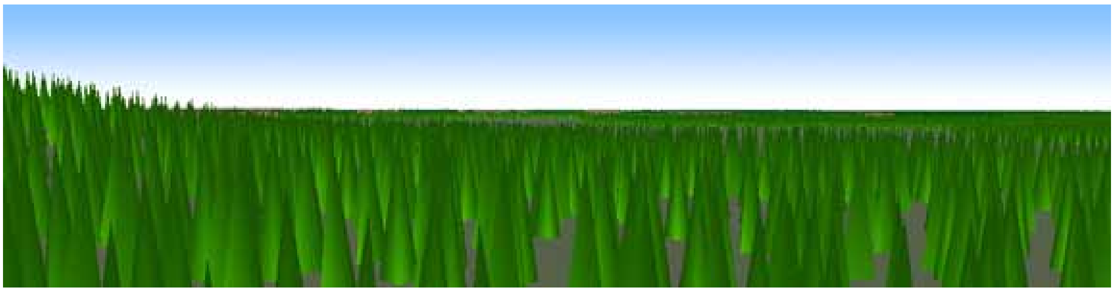
Table 10 – GIS datasets uses in the visualisation analysis

Dataset description	Shapefile	Style / colour	Height
Existing red squirrel habitat	rshabitat	Conifer / dark green	18m
Existing grey squirrel habitat	grey5khab	BL tree / light brown	18m
Projected red squirrel habitat generated (BEETLE)	rsnetwork	Conifer / light green	10m
All roads		Line / purple	
All watercourses		Line / dark blue	

All computer perspectives were generated using OS co-ordinates recorded when the viewpoints were located and perspective photographs taken. However, because of the extent of the projected red squirrel habitat, encircling all viewpoints, to show the landscape view all computer generated visualisations have been generated from 12 metres above the DTM.

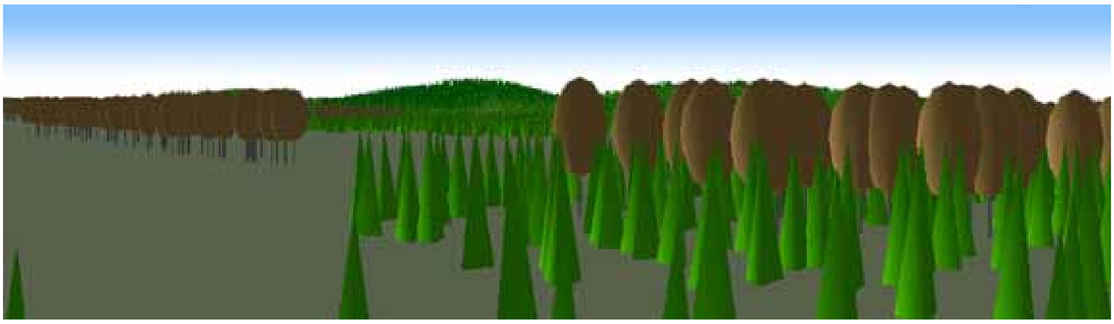
<u>Viewpoints 4a and 5</u>
The computer generated visualisations clearly show that the Coastal Flats LCT have the potential for significant expansion of red squirrel habitat. **Vpt 4a** illustrates habitat expansion southwards, linking Tentsmuir Forest with Reres Wood. **Vpt 5** illustrates expansion westwards from Tentsmuir Forest onto the amalgamated fields, with a significant reduction of open ground between the B945 and the Forest. Because the terrain is low-lying and relatively flat, however, the remaining open ground will only be visible from vantage points within or to the edge of them.


Vpt 4a – Expansion of conifer (Red Squirrel) networks south of Tentsmuir


Vpt 5 - Expansion of conifer networks (Red Squirrel) west of Tentsmuir

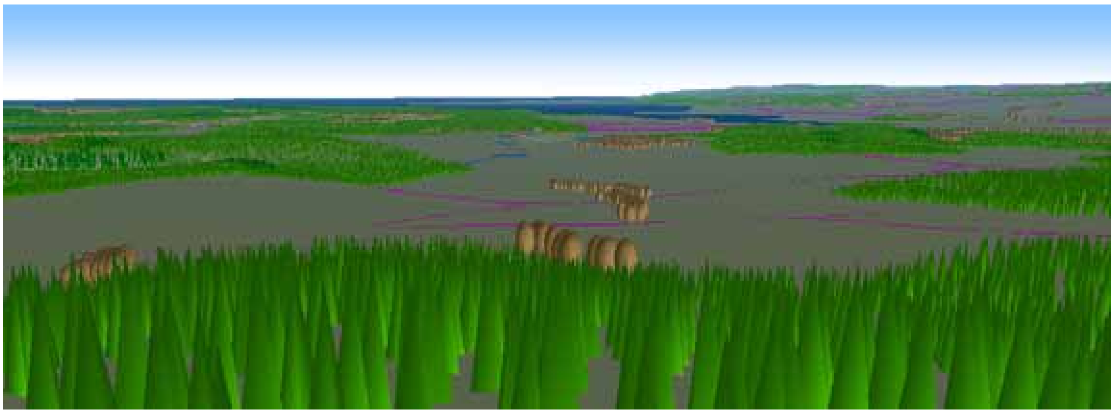
<u>Viewpoint 4</u>
The computer generated visualisation illustrates potential red squirrel habitat expansion off the hill and onto the lower farmland, significantly reducing the area of open ground. A

significant proportion of this expansion would potentially be on those farmland areas identified of prehistoric and medieval/post-medieval relict land-use. Views of the remaining open ground will be obtained from vantage points within, to the edge or from viewpoints on higher ground.

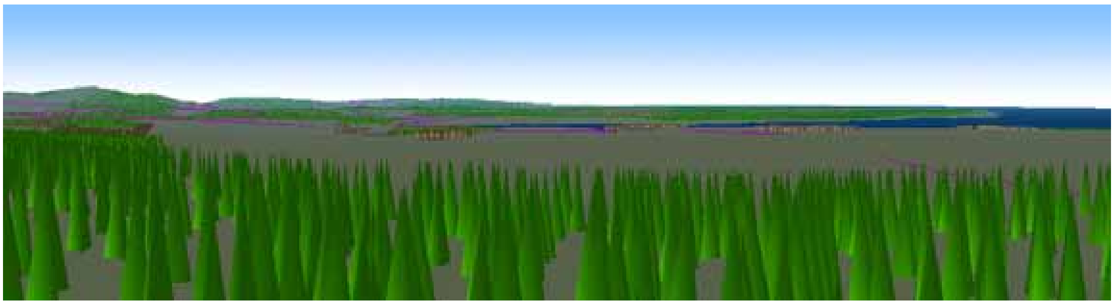

Vpt 4 - Expansion of conifer (Red Squirrel) networks onto farmland

Viewpoint 5a
The computer generated visualisation illustrates that open views of the Eden estuary and middle ground Coastal Terraces and Coastal Flats LCT will be maintained. Red squirrel habitat expansion though will extend south and west from Tentsmuir Forest and Reres Wood, and north-west along the Eden River tributary of Motray Water. A consequence of this expansion will be to further potentially affect those farmland areas identified of prehistoric and medieval/post-medieval relict land-use.

From this viewpoint, although the effect of this expansion will be to significantly reduce the area of open ground, visually the scene retains a spatial balance. The scale of the expanded habitat and the retained open ground appears in balance, with appropriate interlock between the two.


Vpt 5a – Expansion of conifer networks Tentsmuir and river Eden

Viewpoint 6
For the community of Strathkinness their immediate views north would be obscured by the projected red squirrel habitat expansion. From mid-slope, however, the landscape remains open with unimpeded views down to the River Eden estuary.

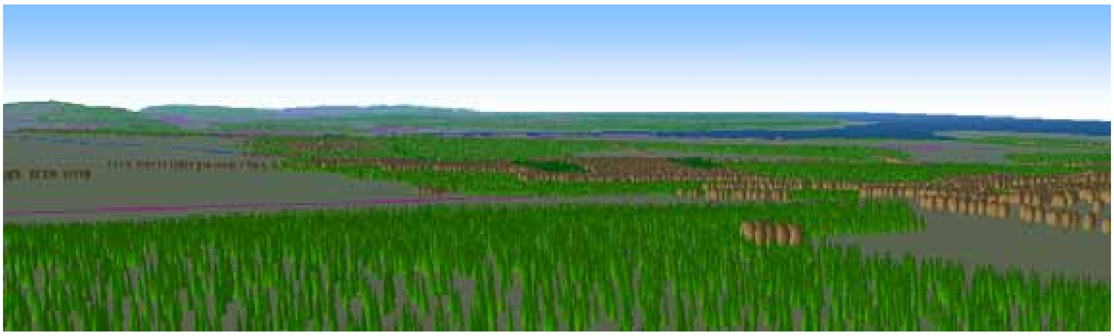


Vpt 6 – Expansion of conifer networks Strathkinness

Viewpoint 6a

From this viewpoint south of Strathkinness, the land-use balance would potentially change considerably. Red Squirrel habitat expansion would extend the woodlands of Craigtoun Country Park, Magus Muir and on the lower slopes of Drumcarrow Craig (below this viewpoint) coalescing to create a predominantly wooded landscape.

Although woodland would become the dominant landscape element there remains a visually appropriate scale and interlock with the remaining farmland open ground.

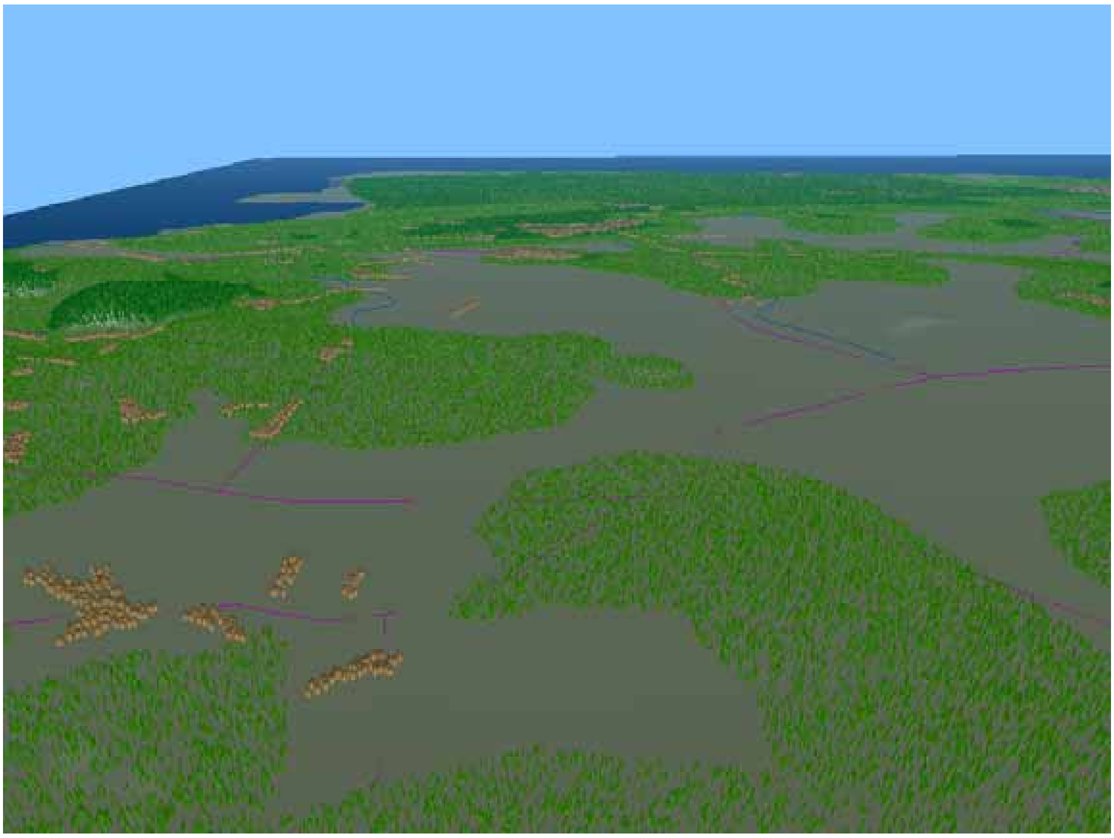


Vpt 6a – Expansion of conifer networks south of Strathkinness

Oblique aerial photograph

This aerial view clearly shows the potential expansion of red squirrel habitat to the west of Tentsmuir Forest. Of particular note from the computer generated visualisation is the relative even visual balance between the expanded red squirrel habitat and the remaining farmland and other open ground. Again visually, there is an appropriate scale and interlock between the two.

That relationship though reflects the organic expansion of the red squirrel habitat areas. This contrasts with the established irregular geometric field pattern. Also, as noted above, such projected habitat expansion would potentially be on those farmland areas identified of prehistoric and medieval/post-medieval relict land-use.



Oblique aerial – expansion of conifer networks Tentsmuir

5.6.7 Discussion

This case study is looking at the potential for extending the habitat of the Red Squirrel. The BEETLE programme has been used to generate an ecological model of those areas that would be both ecologically appropriate and viable for expanding Red Squirrel habitat, specifically conifer woodland.

It has been acknowledged though in our previous report that existing landscapes are valued by society, with even highly modified systems being highly prized in both ecological and cultural terms.

<u>Ecological effects</u>
Ecologically, those existing landscapes may be made up of a number of habitats, interdependent and creating a unity which is itself to be valued. To satisfy the requirements of one focal species would imply not only expansion of the appropriate habitat but also the spatial location of those features in the landscape and the overall relationship of one patch to another to influence the biodiversity value associated with the habitat for the selected species.

Clearly, the implications of considering the development and expansion of a conifer woodland habitat network for red squirrel will have a potentially significant effect on the landscape. The above computer visualisations of the BEETLE model of that expanded habitat network illustrate both the potential extent and spatial implications of an expanded woodland cover. Also, an implicit consequence of such a significant shift in land-use balance between woodland and open ground is the potential implications for existing lowland habitat networks established throughout the farmland and other open ground areas.

Cultural effects
Culturally, this is a long established agricultural area. There is prolific evidence of early settlement throughout the entire area, and Fife has an outstanding heritage of historic landscapes with a record of change over thousands of years. There are sites, buildings and features of national importance, from pre-history through early historical times and into the industrial history of the 18th, 19th and 20th centuries. Also, within the farmed landscape there remains evidence of relict land-use as far back as medieval times. Of especial sensitivity to land-use change is the area to the west of Tentsmuir Forest, an important relict landscape rich in archaeological features.

Clearly, there will be potentially significant cultural implications of considering the development and expansion of a conifer woodland habitat network for Red Squirrel throughout this study area. Not only would an expanded woodland habitat potentially jeopardise the integrity of archaeological features where trees were established over them, but also potentially disrupt the appreciation of their relevance and context in the wider landscape.

Landscape effects
Although the human activity has almost eradicated the natural habitats and landscapes of the landward area of Fife, the pattern of land-use today continues to reflect the important natural influences of geology, climate, landform , drainage and soils. On the coasts near-natural landscapes remain in the intertidal areas, rocks and coastal cliffs and braes.

With the exception of Tentsmuir Forest, the study area is an organised but essentially open farmland landscape. The field enclosure pattern dominates this gently rolling to flat landscape, with woodlands contributing incident, reinforcing and interlocking with the field pattern, and providing elements of enclosure and framing of views. Woodlands and trees are an integral and essential structural component of this pastoral landscape.

Clearly, the impact on landscape character and the visual landscape from the development and expansion of a conifer woodland habitat network for Red Squirrel throughout this study area will be significant. The expanded habitat network, as projected by the BEETLE model and reviewed in the computer generated visualisations from the selected viewpoints, will potentially impose a new and dominant spatial element on the field pattern. The new woodlands will have the effect of reorganising the spatial experience of the landscape, and disrupt existing views of the area and its associations with the sea.

As stated (para 4.1.6) because of the extent of the projected Red Squirrel habitat, encircling all viewpoints, to show the landscape view all computer generated visualisations have been generated from 12 metres above the DTM. The implication is that from these representative selected viewpoints, views from settlements, individual dwellings, travel routes and vantage points would be potentially be affected by the habitat expansion proposals. With views of the landscape obscured, filtered or reduced in extent, the inevitable consequence will be an appreciable loss of visual amenity. For people – be they residents, visitors or travellers – accustomed to the relatively open pastoral landscape of this area of Fife, there would be an appreciable reduction in their experience and enjoyment of the landscape.

5.7 Corn Bunting habitat networks

5.7.1 Landscape Character Assessment

The Fife landscape can be characterised as generally of lowlands and hills. To this southern area the sloping and gently rolling Coastal Terraces LCT extends almost the length of this south-facing coast. Behind them are the more discrete sometimes hidden landscapes of Lowland Dens LCT to the west, the distinctive profiles of Pronounced Volcanic Hills and Craigs LCT behind Elie and St Monans, and to the east the rolling Lowland Open Sloping Farmland LCT.

The corn bunting study area of south Fife, essentially between Elie and Anstruther (Figure 5, includes the following recognisable landscape character types:

- **Coastal Terraces**

Coastal Terraces are mostly flat or gently sloping towards the coast, either extensively built upon or relatively undeveloped, comprising large, open, undulating arable fields with infrequent or more regular steadings.

They have little woodland cover except policy planting and shelterbelts around the large houses and designed landscapes, or on the steeper slopes often above burns. There are few field boundaries, limited to some hedgerows, or stone dykes or post and wire fencing primarily around the larger houses and farmsteads. These are coastal landscapes where the sea influences their character. Typically, they are simple, undulating, balanced landscapes with muted colours and varied textures. (refer map, **Vpt 12**)

Vpt 12 – Coastal Terraces south-east Fife

- **Lowland Dens**

Between the low hill landscapes of Fife are the deeply incised sometimes narrow gorges or valleys of the Lowland Dens. Fast flowing burns have cut across the gently rolling Coastal Hills and Terraces. Often they have extensive semi-natural woodland with primarily broadleaved trees, and few buildings other than occasional steadings or large houses with policies. These are confined, small-scale, intimate, sheltered, textured, colourful and balanced landscapes.

- **Pronounced Volcanic Hills and Craigs**

These hills form conspicuous, pronounced, often distinctive and recognisable hills or hill ranges. Sometimes they protrude high above the lowlands or extending the uplands or foothills. They form important backdrops to the lowlands. Their distinctive shapes, silhouettes and skylines, with recognisable shapes, peaks and slopes give Fife a strong sense of place and direction.

There is evidence of ancient human settlement with historical and archaeological features often visible, but there is a lack of villages or larger settlements. The farmsteadings and woodlands are well related to landform and there is a variety of other individual buildings and structures, sometimes associated with the burns and contributing to the identity of the area. There are numerous small quarries, most now disused and well screened but some large, exposed quarries which adversely affect the landscape character.

The upper slopes of these Hills and Craigs can be steeply sided, rugged and open, contrasting with the shallower, smoother, more vegetated and more intensively used lower slopes. These are medium to large-scale, open, simple, sloping, curved, quiet and balanced landscapes with smooth or varied textures and muted colours. (refer map, **Vpt 11**)


Vpt 11 – Volcanic Hills and Crags

- **Lowland Open Sloping Farmland**

This extensive area of farmland in eastern Fife comprises predominantly large, open, sloping, arable fields, often with no field boundaries or with mainly wire fences. Field enclosure is by low hedges or some stone dykes. There is little woodland cover, with relatively few plantations and shelterbelts.

There are isolated but regular farmsteadings, often with modern agricultural buildings but only a few, generally very small and conspicuous settlements with a variety of building materials. This is a large-scale, open or exposed landscape where the character is strongly influenced by the weather conditions and views of the sky. It is a simple, sloping, balanced, active, organised, tended, farmed landscape with regular or geometric patterns. (refer map, **Vpt 9**)


Vpt 9 – Lowland Open Sloping Farmland

5.7.2 Historic Land Use Assessment

There is no HLA covering this study area. Map evidence of the core study area shows that the few designated Scheduled Ancient Monuments in this area are all related to the coastal strip.

5.7.3 Landscape effects

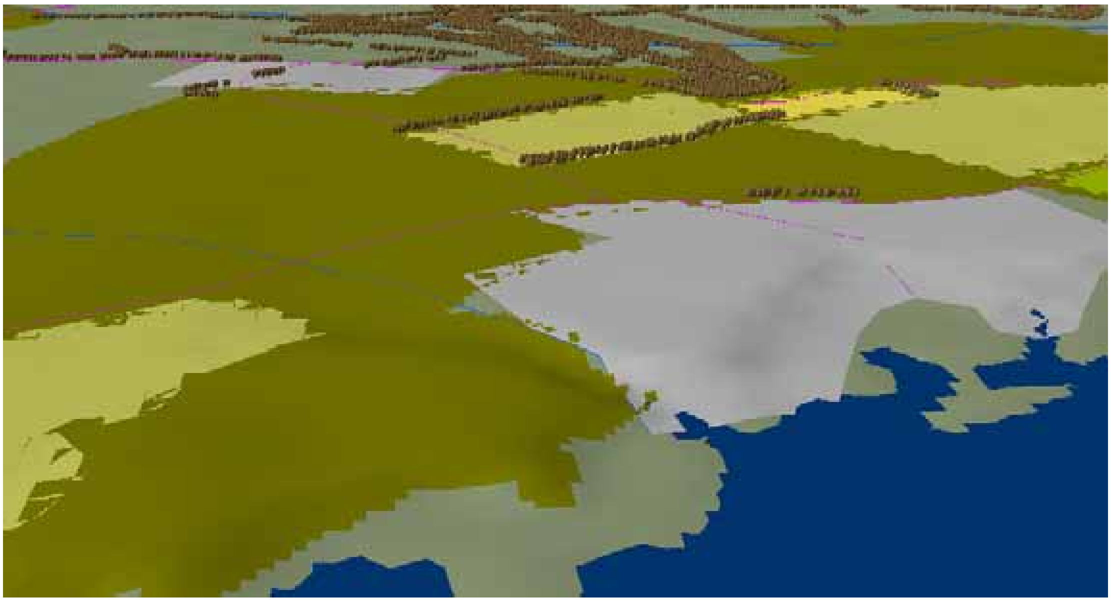
The corn bunting study area is primarily an organised but essentially open farmland landscape. With the exception of the distinct volcanic hills, the field enclosure pattern dominates this gently rolling to flat landscape. Woodlands, especially the policy woodlands associated with Balcarres and Balcaskie designed landscapes, contribute incident, reinforcing and interlocking with the field pattern, and providing elements of enclosure and framing of views. Woodlands and trees are an integral and essential structural component of this pastoral landscape.

The oblique aerial (Pat MacDonald 0563-02-23 & 24) has been taken off the south coast, looking north to St Monans with the Balcaskie House and policy woodlands of the designed landscape in the background. The picture, taken during August 2006, clearly shows the mosaic of field pattern and other land-use. Further, the variety of farmland use and field management is also revealed in the colours and textures of within the agricultural mosaic.

Oblique aerial to St Monans

Implementing measures to further encourage the expansion of corn bunting habitat and consolidate a habitat network, will require farmers to follow a relatively prescriptive crop selection and management regime. The potential impact, however, of such measures on landscape character and the visual landscape will be minimal for the following reasons:

- Spatially, there will be no change between the relationship of the field pattern with the woodland, tree belt and enclosure framework
- Considering the current variety of colours and textures in the farmed landscape, proposed changes to that regime will see but a marginal increase in that diversity
- General public views of the terrain tend to be from the lower levels, limiting the viewers experience of the diverse farmed landscape mosaic
- The exception is obviously from the hills, but these views tend to be from less populated areas and at a greater distance from the lowland farmed areas, therefore the detail of different management regimes will be less distinct



Computer generated oblique aerial to St Monans

6 HABITAT NETWORKS AND RECREATION AND ACCESS

6.1 Introduction

Ecological networks are though to deliver wider environmental and social benefits by providing increased opportunities for recreational access to the countryside (Dover, 2000; Humphrey et al., 2005). For example, developing linear features as part of ecological networks such as riparian zones, buffer strips along field margins will also in theory encourage access, especially if farmers also apply for Tier 2 subsidies for improving access (Table 3). Current legislation (Land Reform (Scotland) Act 2003 – www.scotlandlegislation.hmso.gov.uk) provides rights of access to farmland and this is likely to be focused in wildlife rich areas both by accident and design as economic crops are excluded from rights of access. Humphrey et al. (2005) concluded that integrating biodiversity and people should be possible given adherence to a few basic rules, and there may be just as many positive benefits (i.e. greater access for viewing wildlife) as negative (increased risk of disturbance to wildlife). In this phase of the project, we tested the impact of ecological development on access and recreation in the East Neuk study area by treating people as a "focal species" and relating people networks to species networks. The aim was to reveal potential areas of conflict between the two and discuss possible mitigation strategies.

6.2 People as a focal species

Here three different user categories (sedentary, intermediate and active) were used to define people focal species. The potential density of visitors is directly proportional to the presence, distribution and dimension of 'attractions' with recreational interest (e.g. facilities, viewpoints with attractive scenery, paths, archaeology, historic sites, wildlife, native woodlands etc). Each user categories will have a specific preference (interest) to visit certain sites with various recreational attractions, and differing abilities to travel to and from these attractions (Figure 46).

Figure 46 - visitors of the countryside; user-categories classification

Visitor 1: SEDENTARY, Low Dispersal Ability

This class of visitors describes those people that are manly interested in accessing recreational areas with facilities in the countryside such as picnics and play areas with toilets and car parks. The class encompasses a wide age spectrum of social users that take days out to the countryside to relax with friends and family. They represent the major percentage of the user category (Table 11). The ability of the sedentary visitor to move within the countryside was assumed to equate to a1 km dispersal ability.

Visitor 2: INTERMEDIATE, Intermediate Dispersal Ability.
People within this class of user represent the 20% of visitors (Table 11), they are the daily or weekly visitor who use the countryside for a short walk to get fresh air or dog-walkers. They are convenience users with very regular/routine habits, they often live locally, likely to be visiting to walk dog or other spontaneous visit, and cover a wide age spectrum. Intermediate visitors were assumed to have the ability to move up to 5 km within the countryside.

Visitor 3: ACTIVE, High Dispersal Ability
These active visitors (very small percentage of visitor population, Table 11) enjoy wildlife and natural heritage aspects of the countryside. They are motivated to visit sites where conservation is preserved with specific habitats and species of interest are to be seen. The ability of the Active visitor to move within the countryside was assumed to be a distance of 10 km.

Table 11 - Visitor types and visitors potential densities (results based on fieldwork study).

Visitor type	Dispersal Distance (km)	Percentage of visitors number
Sedentary	1	75%
Intermediate	5	20%
Active	10	5%

As with the non-people focal species, it was assumed that the dispersal ability of the three people focal species would be affected by the permeability of the matrix, with certain land cover types being highly impermeable (e.g. wetland) and others being more permeable or attractive for recreation such as nicely grazed semi-natural grassland, roads and paths. Cost values for the different land cover types for the people focal species are included in Appendix 5.

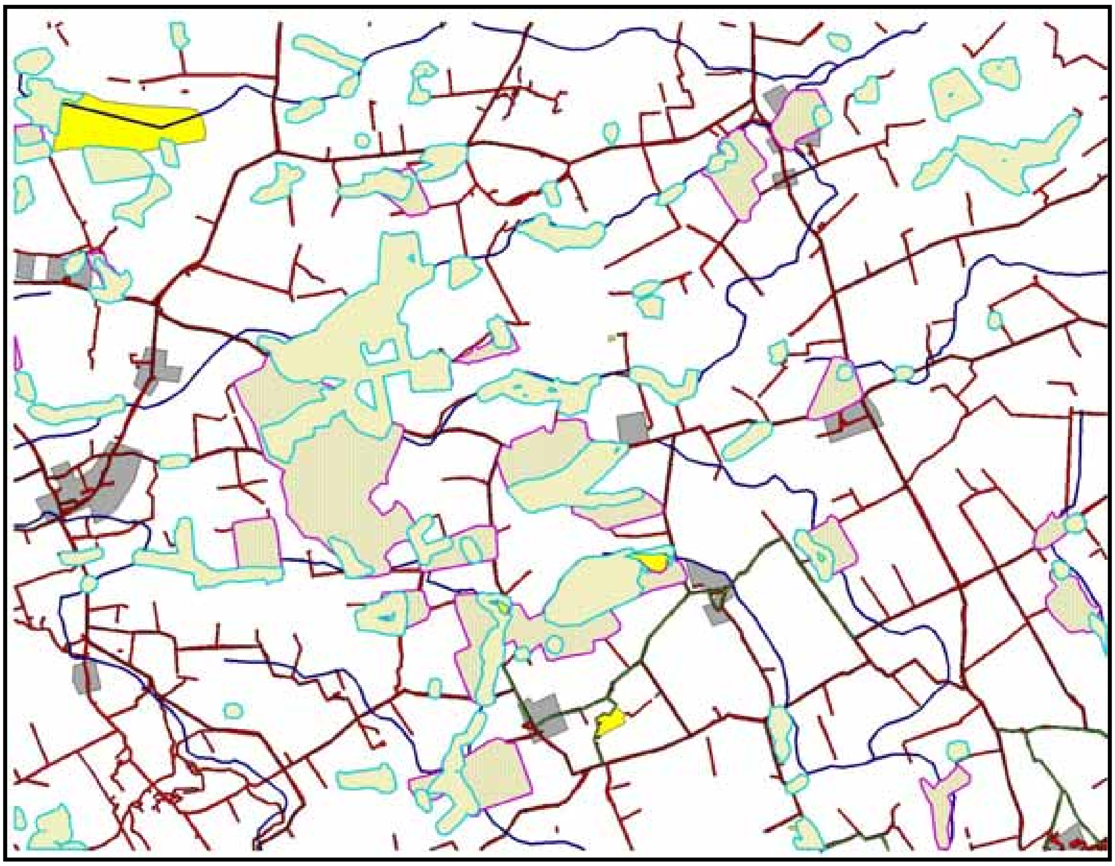
To explore the relationship between people and habitat networks, a sub-section of the East Neuk study area was selected where modelling of semi-natural grassland networks had been undertaken previously (Figure 47). People habitat was defined as visitor attractions, and dispersal distances calibrated by land cover type calculated outward from these attractions (Figure 47).

6.3 Interaction between people and semi-natural grassland networks

Figure 48-51 provide illustrations of the impact of the different types of people focal species networks on the existing and enhanced grassland networks. The evidence suggests that the majority of visitors (“sedentary” category) would not greatly impact on the grassland networks. The overlap between the two is less than 5% of grassland network area for both the existing and enhanced grassland networks (Figure 48; Table 12). For the “intermediate” visitors there is a 15% overlap between the two grassland networks (Figure 49; Table 12) and these visitors potentially will have the greatest impact on species and habitats in the network areas. These are likely to be regular visitors and make up a fairly large proportion of the potential total visitors. The fact that they may be dog walkers further increases their impact.

While the “active” people group has the largest overlap between networks at over 20% (Figure 50; Table 12) their impact is likely to be less. They are less likely to be regular visitors and make up a small proportion of the potential visitor numbers. These visitors are also likely to be actively interested in conservation issues and would be sensitive to the needs of habitats and species.

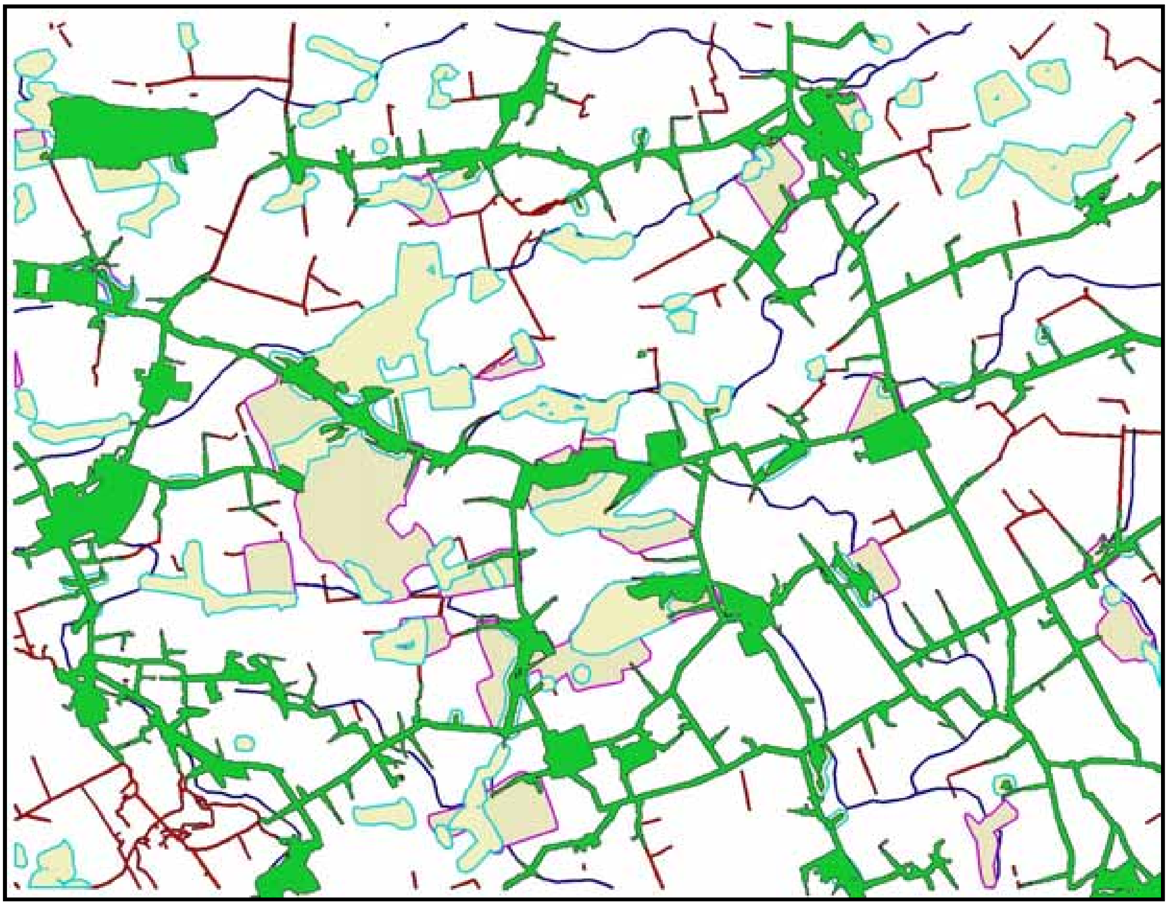
Figure 47 – Sub-section of the East Neuk study area showing roads, rivers, paths, existing visitor attractions and grassland networks



KEY:

- Core path network
- Roads, tracks and Paths
- Rivers
- Built- up areas
- ‘Attractions’
- 1km grassland network
- Enhanced grassland habitat network (see section 4.1.5)

Figure 48 - Sub-section of the East Neuk study area showing networks for "sedentary" people focal species in relation to existing and enhanced grassland networks



KEY:

- Core path network
- Roads, tracks and Paths
- Rivers
- Built- up areas
- 1km people network
- 'Attractions'
- 1km grassland network
- Enhanced grassland habitat network (see section 4.1.5)

Figure 49 - Sub-section of the East Neuk study area showing networks for “intermediate” people focal species in relation to existing and enhanced grassland networks

KEY:

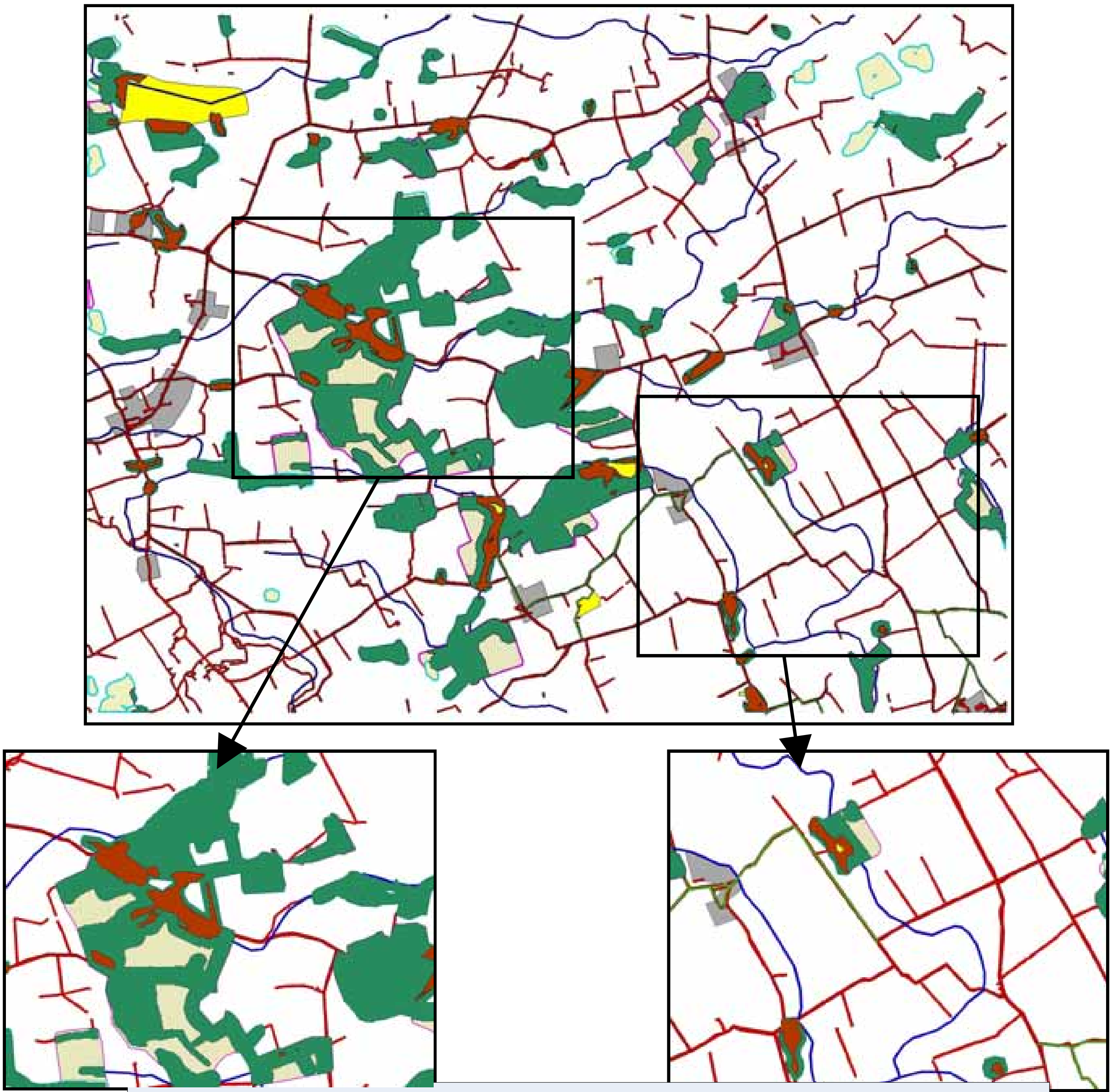
- Core path network
- Roads, tracks and Paths
- Rivers
- Built- up areas
- 5k people network
- ‘Attractions’
- 1km grassland network
- Enhanced grassland habitat network (see section 4.1.5)

Figure 50 - Sub-section of the East Neuk study area showing networks for "active" people focal species in relation to existing and enhanced grassland networks

KEY:

- Core path network
- Roads, tracks and Paths
- Rivers
- Built- up areas
- 10km people networks
- 'Attractions'
- 1km grassland network
- Enhanced grassland habitat network (see section XX)

Figure 51 - Sub-section of the East Neuk study area showing examples of interactions between people networks and grassland networks



KEY:

- Core path network
- Roads, tracks and Paths
- Rivers
- Built- up areas
- 'Attractions'
- 1km grassland network
- Enhanced grassland habitat network (see section XX)
- Interaction between 1km grassland network and 1km people network
- Interaction between enhanced grassland network and 10km people network

Table 12 - Areas of overlap between people and grassland networks

	1km people network (1267 ha)		5km people network (3916 ha)		10km people network (6437 ha)	
	Area overlap	% overlap	Area overlap	% overlap	Area overlap	% overlap
1km grassland network (3736ha)	145	3.8	577	15.4	765	20.4
Enhanced Habitat network (5151ha)	222	4.3	806	15.6	1127	21.8

The interesting feature of the overlap between the people and grassland networks is that percent area of overlap remains very similar for the existing (1 km) grassland and enhanced habitat networks regardless of the people network type (Table 12). This indicates that if recreation levels were to remain unchanged, grassland network expansion should be possible without incurring an increase in negative impacts on recreation potential, or vice versa incurring an increase in the impact of recreation on wildlife.

However, the network maps do illustrate potential pressure points particularly where sedentary visitors may have detrimental impacts on existing grassland habitats (Figure 51). Similar modelling work in Scottish Borders forests (Smith et al., 2007) has shown that by siting recreational “attractants” in specific areas and improving the path network, dispersal routes and land-cover permeability can help reduce impacts on habitat networks.

7 DESCRIPTION OF BEETLE SNH/SEERAD TOOL

7.1 Purpose

The SNH/SEERAD Tool is designed to automate the creation of habitat networks, thereby allowing users with limited GIS experience to make full use of ArcGIS functionality and reducing the potential for errors in processing.

7.2 Overview

The program has been developed using ArcObjects technology, which is based on Visual Basic and the Microsoft Component Object Model (COM) interface. Programming in ArcObjects allows access to methods defined within the software thus allowing the reduction of complex manual tasks to simple automated procedures with a few predefined inputs. The tool is therefore more about widening accessibility and reducing user intervention than a radical development of GIS software and algorithms.

At the core of the tool is the Cost Distance algorithm included within the Spatial Analyst extension. The first few processing steps convert the land cover files from vector to a raster format that the Cost Distance method can use to calculate the maximum dispersal distance for the species under investigation. Once the algorithm is completed the output raster is processed to determine functional network groups and then compared to the original home habitats to create a link between the two outputs. The final stage is conversion back to a vector formatted file and display in ArcMap.

7.3 Using the SNH/SEERAD Tool

7.3.1 Pre-requisites

To run the tool ESRI ArcMap 9.0 GIS software and higher with Spatial Analyst extension are required. As ArcGIS version 8.0 also uses ArcObjects as the native programming language, the tool may work within this version, but this has yet to be verified through our end user testing.

7.3.2 Installation

The SNH/SEERAD tool is distributed as an ActiveX DLL, this can be added to ArcMap by taking the following steps:

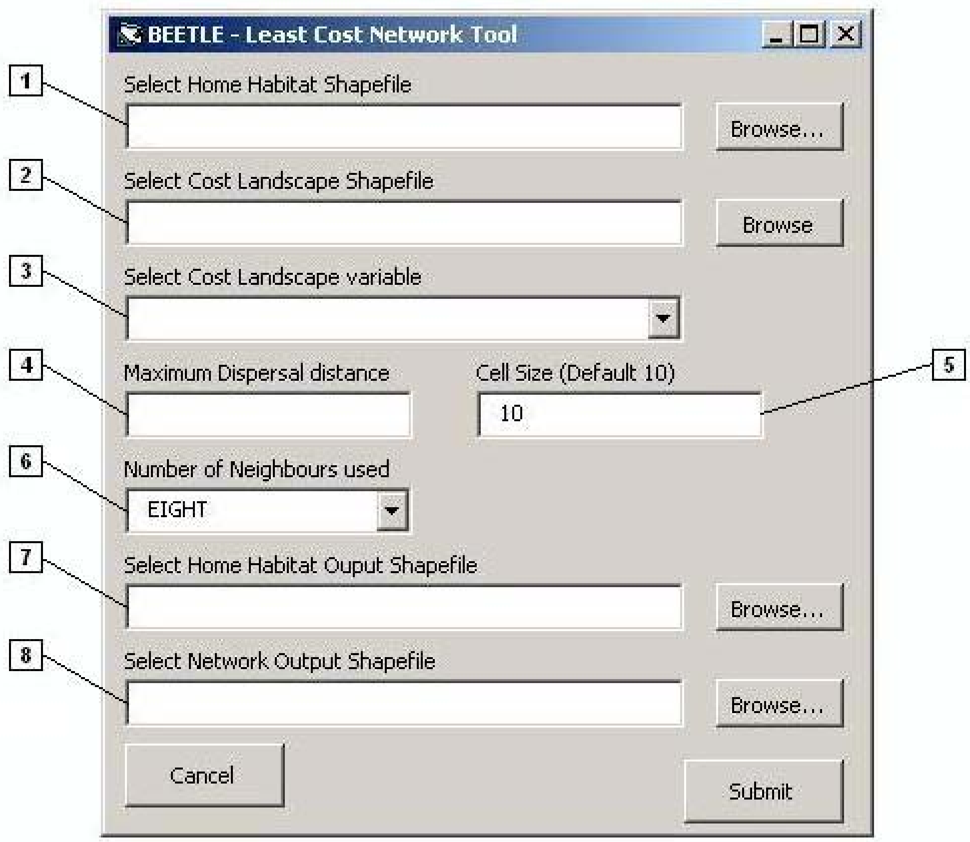
1. Click the Tools menu and click Customize.
2. Click Add from file.
3. Navigate to the file containing the *SNHBEETLE.dll*.
4. Click the file and click Open.
5. The Added Objects dialog box appears, it should report that *BEETLE_SN* has been registered with ArcMap.
6. Click OK.
7. Click on the *SNH - BEETLE* category in the Categories list.
8. Click and drag the *Habitat Networks Tool* command from the Commands list and drop it on the toolbar.
9. Click Close.

7.3.3 Inputs

There are eight inputs into the SNH/SEERAD Tool, these are described below and illustrated in Figure 52.

1. **Home Habitat Input File**. An ESRI shapefile containing only polygons which represent the native habitat of the species under investigation. Due to the internal workings of the tool it must also have an 'FID' field within the attribute table.
2. **Cost Landscape Input File**. An ESRI polygon shapefile with complete coverage for the study area. Within the attribute table a cost variable, i.e. the associated cost for species moving through 1 unit of the habitat, must already have been added.
3. **Cost Variable.** A list is generated, when a Cost landscape shapefile is selected, of all numeric fields contained within its attribute table. The user must then select the appropriate field.
4. **Maximum Dispersal Distance**. Free input, numeric variable, this is the maximum distance the species can travel through a landscape assuming no associated cost.
5. **Cell Size**. Free input, numeric variable, controls the resolution at which processing occurs. Higher values decrease processing time, but decrease accuracy and are a less realistic representation of the study area.
6. **Number of Neighbours**. The user can select eight or four, choosing eight will allow patches linked diagonally to be included in the same network group. If four is chosen only those patches adjacent to each other will be included within the same network group.
7. **Home Habitats Output File**. Controls destination of the final Home Habitats shapefile. Temporary files created during the processing will be stored in the directory specified by this input; files are deleted once the Tool has finished processing.
8. **Networks Output File**. Controls destination of the final Networks shapefile.

Figure 52 – The user interface showing inputs to the SNH/SEERAD Tool



7.3.4 Outputs

The SNH Tool produces three outputs:

1. Home Habitat Output File

This represents the original home habitats (describe in the Inputs section), grouped according to the functional network within which they exist (Figure 53).

2. Networks Output File

An ESRI shapefile containing the functional networks for the study species as defined by the maximum dispersal distance. Each network should have a separate ID that links to the home habitats contained within the network and stored in the first output file (Figure 54).

3. Area Table

This lists each network, the total area contained within a network and the sum of home habitats area contained within that network (all figures stated in m^2). The table is temporary and needs to be saved/exported if the area information needs to be kept permanently (Figure 55).

Figure 53 – Example of Home Habitat Output file showing home habitat patches linked to "parent" networks – habitats are coloured in line with their links to individual networks

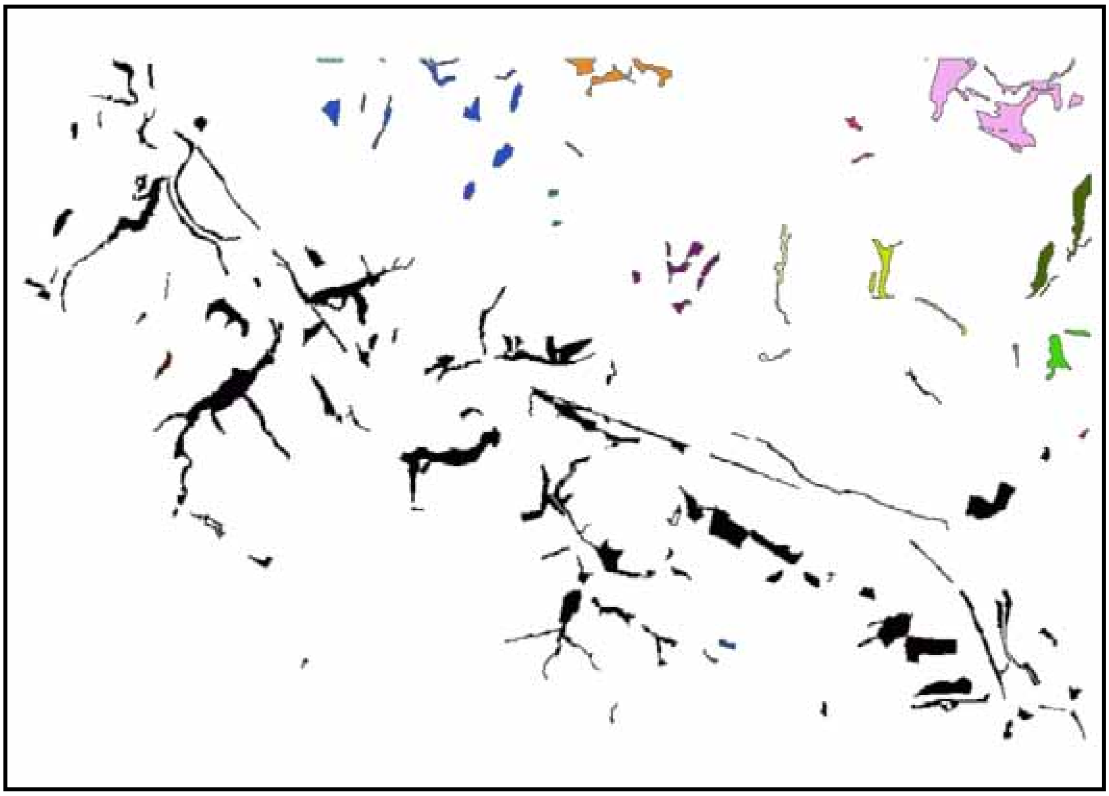


Figure 54 – Example of Networks Output file showing different habitat networks (denoted by different colours

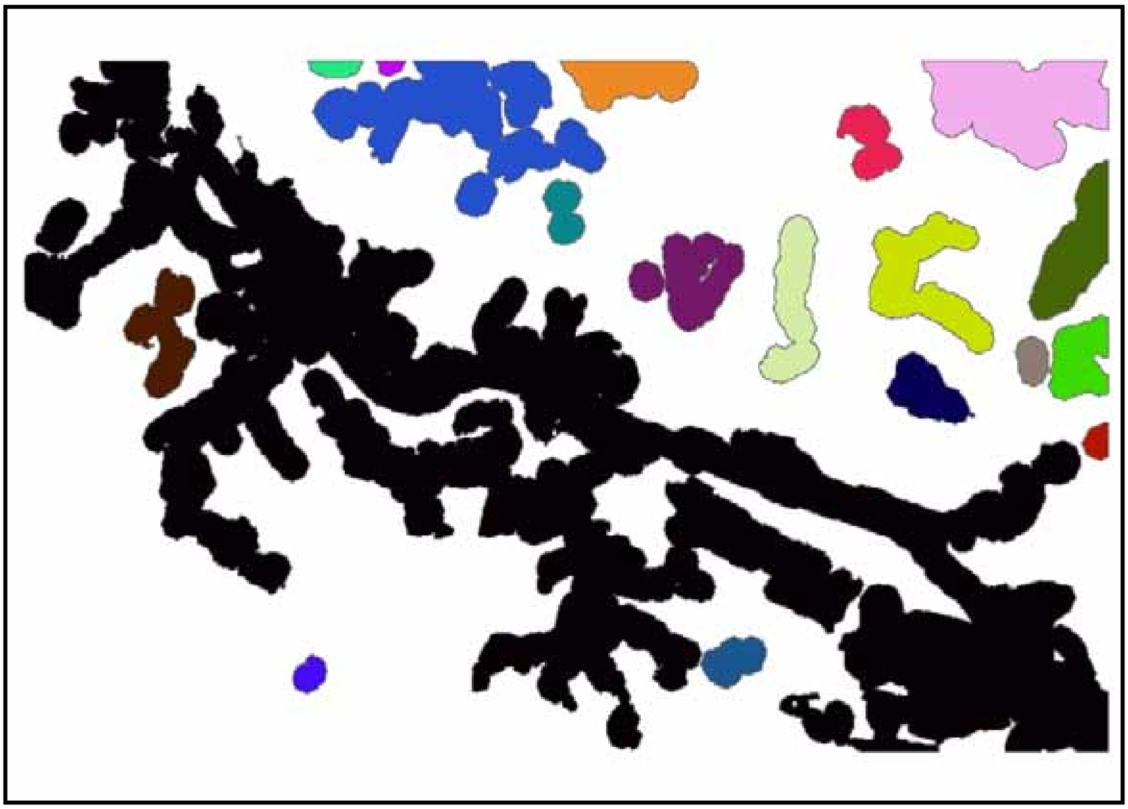


Figure 55 – Example of Area Table listing network statistics

Network_Number	Home_Area	Network_Area
1	2125500	17444500
2	4500	61600
3	600	27000
4	72800	384700
5	305500	1131800
6	136700	1591000
7	11900	233600
8	106400	535100
9	7300	153400
10	53400	666100
11	36400	465500
12	59300	544000
13	15600	410900
14	45400	313200
15	3800	102000
16	8600	285700
17	3300	61000
18	9400	184600
19	2100	72000

8 DISCUSSION AND LESSONS LEARNED

8.1 Engagement with stakeholder groups

Engagement with stakeholders in each of the case-study areas was vital to identifying priorities and securing buy-in to the concept. Feedback from the stakeholders on the approach was positive in all three areas. Unfortunately, there were no opportunities to engage with stakeholders in the Cessnock/Irvine area. An initial meeting was held with staff at SAC Ayr to discuss the diffuse pollution mitigation measures project funded by SEERAD, the development of SEPA's diffuse pollution Priority Catchment Initiative and the content and progress with the revision of the Ayrshire LBAP. Although there has been some progress in trying to re-start the LBAP process in Ayrshire, there was no opportunity for us to engage with this process during the time period of the project. Projects, such as our one which look at real life examples are unfortunately constrained by the availability of opportunities to engage with local situations.

As a consequence of the lack of engagement in the Cessnock study area we were unable to explore the links on the ground between Water Framework Directive measures for diffuse pollution and those for habitat enhancement and connectivity. On the positive side we were able to devote more time to addressing priorities in the remaining three study areas, and we were able to expand the Strathspey case study work to include floodplain restoration issues.

In the East Neuk, Strathspey and Tiree study areas we were successful in engaging with pre-existing processes and groups such as the LBAPs, FWAGs and planning authorities. With busy schedules and a crowded agenda of existing initiatives, it was clearly a priority not to add an additional layer of meetings and bureaucracy to work programmes. Engagement with pre-existing processes allowed us to quickly identify key priorities for habitat network modelling. Stakeholders understood the focal species concept when it was applied to actual species, particularly when those species were of conservation concern as well as being surrogates for wider biodiversity.

8.2 Applicability of the BEETLE cost-distance modelling approach

The three case studies provided a suitable range of "real life" tests of the BEETLE accumulated cost-distance (ACBT).modelling approach. Focal species were selected in consultation with stakeholders (see above), but were also chosen to help explore the applicability of the network concept in the different situations. In particular we were interested to know whether the spatial arrangement of habitats (i.e. the degree of connectivity) is always of key importance for maintaining biodiversity. Conceptually (Figure 4) improving habitat connectivity is of most relevance to those species with moderate powers of dispersal.

Species with very restricted dispersal abilities often have life history characteristics which enable them to persist at small population densities in small habitat patches (e.g. woodland herbs). The characteristics might include the ability to reproduce clonally or to tolerate environmental stress (Grime et al., 1988) and so there is in theory less of a requirement for movement between habitat patches and exchange of genetic material. In these circumstances the priority is to secure and enhance the extent and quality of existing habitat patches. An example of this is the situation of *Collettes floralis* on Tiree. A species of limited dispersal it is wholly restricted to three large patches of sand dune habitat which are naturally isolated from each other. The habitat network is essentially the habitat patch and there appears to be little movement between these habitat patches. Here the priority is to secure and maintain the quality of the existing habitat rather than create new habitat to improve linkage. In any case improving linkage is not a feasible option because the sand dune habitat is naturally fragmented being restricted to flatter coast topography.

At this scale the BEETLE cost accumulation approach and the identification of habitat networks is not particularly relevant to defining conservation priorities. Habitat quality appears to be a key determinant of the location of *Colletes* nests, and is connected with grazing levels. The NVC dataset used to map the sand dune habitat was not detailed enough to include information on habitat quality. However, if this information were collected on a spatial basis within habitat patches, then the BEETLE modelling would be applicable as a tool for guiding conservation management priorities (e.g. identifying key areas of good quality habitat). This example highlights the key inter-linkage between management priorities, scale and data availability. If the land cover data are not available at the scale required to address management priorities or possible land use change scenarios then the modelling will not hold much relevance.

In terms of the other focal species, the cost accumulation modelling worked extremely effectively in producing network maps and helping to identify priorities. One issue that could be progressed further is the inclusion of habitat condition/quality in the modelling process. Quality influences the carrying capacity of the habitat patch and hence population size and density. This would have a knock on effect on the permeability of the matrix, as in theory with more individuals available to disperse, there is greater likelihood of successful dispersal between patches. However, this theory would need to be tested further empirically.

8.3 Data availability

Data availability varied between case study areas. Tiree had NVC level data which can help determine habitat suitability in that in some communities are species-rich others species poor (e.g. unimproved grassland communities MG6 and MG5). Depending on the relative contribution of different NVC types, networks can be scored in terms of quality (even though they may cover the same area) and management could be targeted to move a low quality network towards a high quality network.

The IACS data proved enormously useful in identifying existing and potential agricultural habitats. It also allowed us to develop realistic land-use change scenarios, such as in Fife and Tiree where we simulated the addition of agri-environment measures to specific fields in targeted and untargeted ways. The power of the IACS database is that it is available for the whole of Scotland and allows for potential modelling in any location or region. The inclusion of IACS data would seem to be a minimum requirement for this type of project. The data need to be regularly updated and ideally include records of all LMC Tier 3 measures. Ideally availability of Phase 1 habitat information should also be a minimum requirement for the focal species modelling work (Humphrey et al., 2005). Phase 1 surveys provide information on the location and extent of semi-natural habitat not generally recorded within IACS. Without Phase 1 information, modelling can still be carried out but is more likely to generate spurious accuracy since by necessity it will be based on remote sensed surveys such as LCS88 and LCM2000. LCS88 in now well out of date, and there are problems of interpretation with LCM2000 (Humphrey et al., 2005). Good quality aerial photography is now available for Scotland and efforts should be made to translate this into an updated land cover map.

By focusing on case study areas and engaging with local stakeholders, the project benefited from availability of species data collected by various organisations. Data on location, population dynamics and dispersal ecology were available for a range of species and were of huge value in helping to make the modelling process more realistic and grounded in real conservation issues in each of the study areas. A further sophistication that is beyond the scope of this project, may be to develop some form of probability of occupancy model (Mörtberg et al., 2007) to intelligently model the presence of species in habitat patches. This might be applicable where more further more specific targeting of management action is desirable.

8.4 Link between LHN modelling and targeting of agri-environment incentives

The work in the three case study areas has clearly demonstrated the value of the modelling approach in informing the spatial targeting of agri-environment incentives. As mentioned above, the use of IACS data allowed investigation of the current distribution of incentives and how this relates to networks for different focal species. The lack of correlation between Corn Bunting distribution/habitat networks and current wild bird measures is remarkable (see section 3.5 for a description of the LMC scheme). When measures are targeted to fields within the existing network, the increase in network area and the area of networked habitat is greater than if measures are allocated randomly to the landscape.

The current network maps could therefore be used by local SEERAD, FWAG, SAC and other conservation advisors as a strategic tool to guide the targeting of bird measures. This could be done pro-actively by inviting applications from farmers whose landholdings fell within the network areas or by carrying out a re-active analysis as and when applications were received. In the latter case, each individual application could be scored in terms of the amount of networked habitat it would add to the landscape. This approach was used in the Highland Locational Premium Scheme (HLPS) where grants for new woodland creation were awarded on the basis of how much they would contribute to improving woodland connectivity (Forestry Commission, 2006). This is a more sophisticated, but arguably more cost-effective way of targeting resources. There is no reason why LMC agricultural measures (both Tier 2 and Tier 3) could not be targeted on the same basis as the HLPS. The BEETLE cost-accumulation tool is being made available to stake holders as part of this project and landuse advisors could be trained in the use of the tool enabling them to evaluate individual applications on a case by case basis.

The LBAP process appears to be a good way of identifying habitat and species priorities in local authority (or National Park) areas. This would take account of regional habitat priorities and make best use of local expert knowledge. This ‘bottom up’ approach would also ensure that the development of integrated habitat networks would support ongoing conservation activities. However local authority boundaries do not always reflect biogeographical realities, and there is a strong case for also relating conservation priorities to biogeographical zones such as SNHs Natural Heritage Futures (Chapman, 2006). With the development of new LMC Tier 3 measures in 2007, there is an exciting opportunity to develop an integrated approach which ties together regional/biogeographic, LBAP and landscape spatial targeting through BEETLE modelling into one transparent system that will facilitate the cost effective disbursement of financial support for species and habitats.

The development of habitat networks can foster a commonality of approach between organisations when addressing conservation, land use and planning issues spatially at a regional level. In terms of the Water Framework Directive (WFD) it would be possible to link River Basin Management Plans (SEPA, 2006) with habitat networks so any land use changes as a result of WFD would be fully integrated with potential habitat networks developed at the local level. LMCs should deal with WFD issues in a spatially targeted way.

Adopting a regional and spatial targeting approach will impact significantly on the current LMC philosophy. Currently the LMC guidelines describe the menu of options (Tier 2) as being

> *“designed to provide a range of measures suited to the diversity of agricultural activity and land types throughout Scotland. Farmers and crofters can choose which activities they wish to carry out from the menu, depending on what suits*

their individual circumstances, their plans for future business development and the eligibility requirements of individual measures".

A move to targeting will undoubtedly have an impact on the freedom of individuals to choose what measures best suit there circumstances and there may be a case for retaining the menu system for the Tier 2 measures and adopting the targeting approach for Tier 3 measures. In addition to the current Tier 3 measures (in the Rural Stewardship Scheme) there may be a need to add further measures for habitats that are currently not covered adequately (Chapman, 2006).

8.5 Consolidation of designated sites

The current set of designated sites in Scotland (SSSIs and Natura 2000 sites) were not selected on the basis of landscape ecology principles and therefore could not be classed as forming an "ecological network", as such. Nevertheless, conservation agencies have responsibilities under the EC Habitats & Species Directive Article 10 (European Community, 1992) to improve the improve the ecological coherence of the Natura 2000 network by encouraging positive management of landscape features of importance for wild fauna and flora. These essentially cover connectivity elements such as linear features/stepping stones etc.

The grassland modelling work carried out in Fife provided a demonstration of a procedure for spatially targeting new habitat to consolidate designated sites. Again the IACS data were essential in identifying the potential contribution of individual fields ("nodes") to enhancing network development. Additional data on habitat quality indicators (species records) and "restorability" (from the 1st Edition OS) maps proved valuable in identifying priority fields for creation of, or restoration, to semi-natural grassland. Where species information is not available, the OS 1st Edition maps on their own can help identify areas with restoration potential.

A three stage approach to consolidating designated sites is proposed: a) protecting and enhancing the sites themselves; b) creating/restoring semi-natural grassland in fields that coincide with "nodes" (Figure 12); c) creating/restoring semi-natural grassland in fields that are part of, or adjoin, existing networks. SNH Natural Care Grants (which will be included as LMC tier 3 measures in the future) for consolidating designated sites could be spatially targeted using this three stage approach.

8.6 Balancing priorities – integrated habitat networks

Integrated networks for range of habitats and focal species that reflect local landscapes can be used to prioritise conservation effort. The networks that are derived using the BEETLE ACBT can highlight where there are interactions between different networks. However the model does not indicate the relative importance of these in terms of conservation priorities. It would be possible to develop rule based multi-criteria analysis to help with this prioritisation based on political priorities at different levels, e.g. local (LBAP) v regional (SBS) v national (UK BAP) and using the expert knowledge that exists at these different levels.

The development of habitat networks is seen as an important mechanism for reversing the effects of fragmentation on biodiversity while delivering a range of other environmental benefits such as flood control. This was investigated in more detail in the Strathspey floodplain. The analysis showed how it may be possible to develop more sustainable methods of flood control that are also ecologically functional. Specifically, ecologically targeted habitat restoration that increases the retentive properties of the floodplain would generate multiple benefits. There are four main ways that wetland habitats could assist flood control: delayed floodplain flows; delayed channel flows, delayed soil runoff and increased water use (Thomas and Nisbet, 2007).

In developing functional flood plains and targeting actions for LBAP species, wetland successional processes also need to be considered (although beyond the scope of this project). For example the development of temporal networks of ponds, fens and wet woodland to represent the full range of successional development of wetland habitats.

8.7 Landscape and visual assessment

Earlier in the project, there was discussion about using aerial photographs to give a visual characterisation of habitat networks. This would involve morphing existing photos to show changes in the extent of different networks reflected in changes in field colour and texture. The approach has been used before to illustrate Forest Habitat Networks (Fowler and Stiven, 2003). However, there was not time in the existing project to explore this option further and we focused instead on evaluating the usefulness of computer visualisation software in assessing the impacts on landscape character on habitat network development.

Computer visualisation proved to be extremely useful in the case of the Red Squirrel networks in Fife in helping to identify broad impacts on the visual characteristics of key landscape character areas. The availability of a GIS layer for Historic Land Use Assessment also helped to pinpoint the impacts of network development on historically valued elements of the landscape. In contrast the technique was not of such obvious value in assessing the visual impact of an increase in Corn Bunting networks.

3D visualisations are more effective as a communication tool when there are significant changes in network elements that have an influence on the spatial structure of a landscape, e.g. the insertion of conifers in the landscape for Red Squirrels. In addition, even in the Red Squirrel case study the appreciation of landscape change has not been helped by the selected visualisation package. Although the software has proven benefits of accuracy and user utility, it does not give a particularly detailed reflection of reality, so there are questions over its applicability in real planning situations involving the general public. However, it should be appreciated that the availability of a 3D visualisation software with the capability of utilising readily adapted GIS shape files make it relatively easy for visualisations to be generated for the exploration of the landscape and visual implications of habitat network options. The outputs are also readily interpretable by those professionals - such as land-use planners - accustomed to reading computer models that represent the spatial elements of a landscape. To them such visualisations are helpful in raising conflicts between network development and impacts on landscape character and the visual landscape.

As with the consideration of all new significant developments in our landscape there is no reason why the BEETLE outputs could not be considered against all existing land-uses and constraints, and the proposals refined in appreciation of those recognised sensitivities. Such a refinement strategy could involve:

- Utilisation of GIS and OS map information at 1:25000 (smallest scale map that shows field pattern)
- Review in GIS of all relevant ecological, cultural and landscape sensitivities, with an informed analysis of their sensitivity to change and the relationships of one feature to another in the wider landscape
- Utilising the above developed constraints map, consider the BEETLE model for habitat expansion against the identified sensitivities and their relative capacity for change

- Refine the BEETLE model to show just those areas with the potential for habitat expansion with either no appreciable impact or a considered acceptable effect on identified sensitivities
- Test the potential visual impact of the refined habitat expansion model with computer generated visualisations from the identified viewpoints, and analyse the outputs in terms of landscape character and visual impact
- From the visual assessment, make any final adjustments to the refined habitat expansion model

8.8 Habitat networks and recreation

The interaction between habitat networks and recreation was explored in Section 6 by taking the innovative step of treating people as focal species and assuming different levels of dispersal ability or mobility. This approach seems to have value in highlighting interactions between recreational and habitat networks and is fully automated within Arc9 GIS. Ecological profiles for people can be drawn up in the same as is done for other species. The profiles can also be varied depending on the specific groups of people known to be using a particular landscape.

However, it should be noted that little work has been done to validate our assumptions that human behaviour can be summed in BEETLE relevant classes. In addition, in the East Neuk case study, people profiles were drawn up based on survey information collected for people using forests for recreation. There may be subtle differences in the types of people using mixed farmed landscapes for recreation as opposed to forests (e.g. higher proportion of walkers compared to cyclists). Future studies could look at the effects of varying the ecological profiles on development of recreational networks.

In Fife, there is the possibility that the consolidation of designated grassland sites through targeting incentives may increase the concentration of grassland in particular areas. This may lead to increased people pressure on habitats that may otherwise not have occurred if the habitat had been added randomly to the landscape.   The BEETLE accumulated cost buffering approach appears to have considerable value in identifying priority areas for action to reduce potential conflicts between wildlife and people. By comparing the interaction between grassland and people networks it is obvious that in general there should be little conflict between grassland networks and people apart from particular pressure points around existing facilities. These could be mitigated by creating new facilities away from core network areas and improving the path network to encourage people to use paths rather than disturb habitats. Simple precautions such as siting conservation headlands on the other sides of fields from paths, may be all that is needed to ensure that both recreation and expanded habitat networks can co-exist happily in the same area.

8.9 Accessibility of the BEETLE ACBT for land use planners

As highlighted in section 7, the SNH/SEERAD Tool is designed to automate the creation of habitat networks, thereby allowing users with limited GIS experience to make full use of ArcGIS functionality and reducing the potential for errors in processing. The tool carries out the cost buffering calculations and outputs network maps. However, the acquisition and construction of the land cover and species datasets still needs to be done manually and the data calibrated for local circumstances.

The next stage in the process of rolling out the tool to end-users will involve testing and refinement. A sub-set of potential end-users would need to be identified and some training may be required for those not familiar with the BEETLE approach. There may also be value in holding a workshop to demonstrate the functionality of the tool and identify any further developments. In order to function properly the tool requires the ArcGIS add-in software Spatial Analyst. This software is expensive and may limit the potential take-up of the tool amongst end-users to one or two individuals per organisation.

8.10 Implementing networks

The statutory and policy framework for biodiversity conservation in Scotland (e.g. The UKBAP, the Nature Conservation Scotland Act 2004, and the Natural Environment and Rural Communities Act 2006), places a duty on landowners and public bodies to maintain and restore important semi-natural habitats where practicable, and to implement measures in the wider landscape to enhance biodiversity. Translation of these principles into on the ground action requires synergy between Local Authority Structure Plans, LMCs, the LBAP process, landowners and advisors.

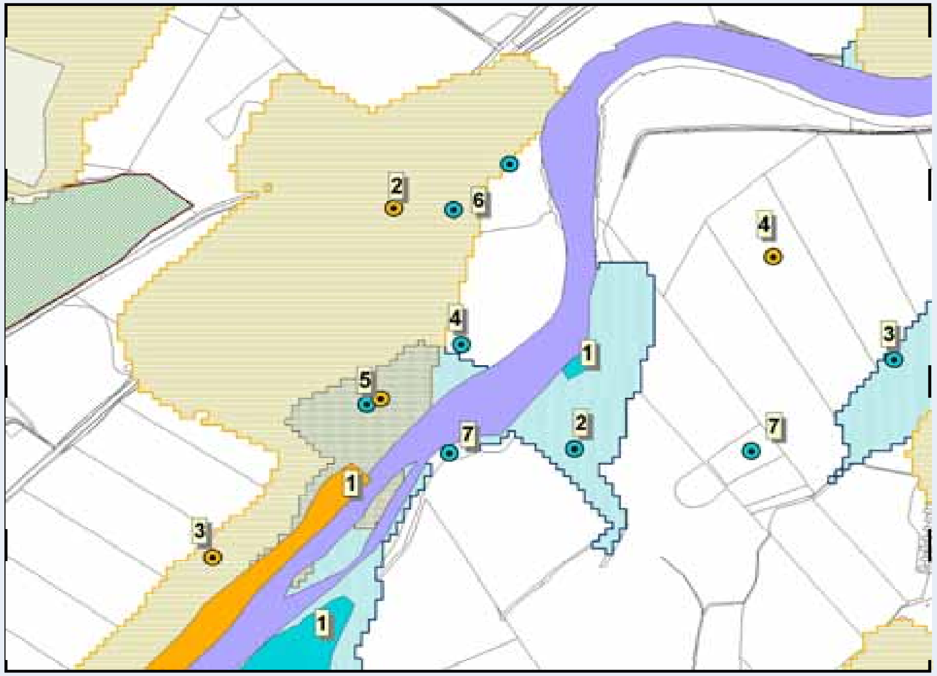
The BEETLE modelling approach has a role in helping to guide the spatial targeting of actions to restore and enhance biodiversity. The availability of the tool to landuse planners and advisors should help with the practical implementation of networks. Procedures are in place to get plans working on the ground. For example, FWAG and SAC are involved in whole farm conservation audits and the provision of advice to farmers as to what prescriptions and habitat management actions would potentially be best to implement on the farms. The recreation and landscape analysis can also help identify constraints and opportunities and are essential elements within the planning process.

What is now needed is the development of guidance outlining how conservation priorities can be translated through the modelling process to implementation. This guidance would cover some of the aspects described above, but would also need to cover elements of the modelling process such as data requirements, acquisition and processing. Specifically, guidance is needed on:

- Conducting habitat and land cover surveys (e.g. particular requirements for Phase 1 and NVC surveys)
- Assessing habitat condition in relation to priority species requirements
- Identifying priority locations (“nodes”) for targeting restoration e.g. remnants of ecological processes or particular habitats (see example in Box 1)
- Methods for gathering species information.
- Monitoring ecosystem development

The guidance would also cover methods for carrying out recreation and landscape impact analysis of proposed networks.

Box 1 - Identifying priorities for restoration using “nodes”



- Grassland networks
- Wetland networks
- Water
- Wetland node
- Grassland node

In order of prioritisation

1. Area of habitat within network area where management should be implemented to achieve or maintain favourable condition, e.g. management of areas of fen within the wetland habitat network
2. Areas where restoration nodes are within their representative network area, i.e. wetland restoration node within wetland network. These should be priority areas for restoration
3. Areas where restoration nodes are within their representative network area but the management unit is only partially within the network area, i.e. grassland restoration nodes are within the grassland network but the field extends out-with the network area. These should also be priority areas for restoration and will also further expand the network area.
4. Areas where restoration nodes are out-with their representative network area, i.e. wetland restoration nodes out-with wetland network. These should be lower priority areas for restoration
5. Areas where more than one restoration nodes are within their representative network area, i.e. wetland and grassland restoration nodes within an area of both grassland and wetland networks. These should be priority areas for restoration, although a decision regarding habitat priority would need to be made. This decision may be influenced by local or regional priorities, i.e. if wetlands have a higher priority within the LBAP, and the views of the land manager.
6. Areas where restoration nodes are out-with their representative network area but within another network area, i.e. wetland restoration nodes within a grassland network. These should be lower priority areas for restoration but there may be possibilities of restoration that may support the network habitat. Restoration of some wetland habitats e.g. rush pastures will increase the connectivity of the landscape for grassland species.
7. Areas where restoration node is out-with its representative network area, i.e. wetland restoration node out-with wetland network. These should be lower priority areas for restoration but could contribute to connecting networks together.

8.11 Monitoring

8.11.1 Approach to monitoring

The success of the BEETLE accumulated cost buffering approach to modelling habitat network development can be judged by monitoring the contribution that habitat networks make to increased connectivity of targeted habitats. The monitoring should be focused so that it can address the objectives of:

- assessing ecosystem development within habitat networks
- assessing the valued conservation features within habitat networks

The results of monitoring can then be used to inform the management of habitat networks and to influence and inform grant support systems for habitat networks. In the simplest terms the monitoring will involve developing protocols for assessing increased population size and distribution of the selected focal species and those species that it represents within the network area. This can be achieved in 3 ways:

1. By measuring the increase in records and extent of distribution of the selected species across the network area. Incidental records that are collected by biological record centres over time will to some extent give an indication of this. It may, however, be more appropriate to study populations of functional species (see below) where there are good known habitat preferences, and change in species composition of these groups will give an indication of habitat change, development and functionality.
2. Rapid assessment of biodiversity. Evidence of the increase in activity of the selected species across the network area.
3. The change in the degree of genetic similarity within the population of the selected species across the study area.

8.11.2 Ecosystem development within habitat networks

The development and concept of habitat networks asks some important fundamental questions: When does a modelled potential habitat network, become a functionally connected landscape, and then more philosophically: What is a functionally connected landscape? It is easy to imagine the answer to these questions but more difficult when they are broken down into their constituent pieces.

The accumulated cost distance modelling approach taken here assumes that the current network areas for a particular habitat are connected and a flow of focal species through them (both actual and genetic) is possible and therefore they are functionally connected.

This brings in the concept of condition and whether or not this is favourable. This is essentially an objective assessment of the range of habitat features. In terms of habitat network this assessment is applicable when these features become present in a new patch of habitat within the network. This is very much value based and each habitat or site will react or behave differently depending on the range of environmental conditions which they face.

The term Ancient Woodland is often used to indicate value or quality in a wood the premise being that because it has been woodland for a long period of time certain structures have developed together with long established and functional ecological processes. For new native woodland it is the establishment of aspects of structural development and ecological process that will give an indication of a site becoming woodland. The same set of principles should therefore be applied to all habitats within an ecological network.

8.11.3 Ecological process and functional species groups

The relationship between biodiversity and ecosystem function (the degree to which an ecosystem is working effectively) has been of interest to ecologists for some time (Shultz et al., 1993). Various indicators for assessing ecosystem function have been proposed such as: indicator species, keystone species, species richness, diversity indices, functional species and functional diversity. There is continuing discussion about the effectiveness of such indicators and the most appropriate method of assessment of ecosystem function but the consensus would appear to fall in favour of the use of what are termed 'functional species groups' (Davic, 2003; Patchley, 2002).

There is no single way of defining what comprises a functional species group. It has been proposed that there should be an evolutionary basis to the groupings (Chapin et al., 1992) so that these have a natural basis rather than a pragmatic one (Baker et al., 2003). Here, attributes such as phenology, physiology and life form would be selected to define the groups, but behavioural environmental responses or trophic criteria (Cohen and Briand, 1984) have also been used. For example, ground beetle species (Coleoptera: Carabidae) in Scottish farmland have been allocated into functional groups by the use of multivariate analysis of their ecological traits (Cole et al., 2002).

It has been suggested that intraspecific competition (Fox and Brown, 1993) could be the basis for groupings so that species that have evolved to exploit a similar niche are aggregated to form a functional group. This allows for species of different taxonomic groupings with similar ecological niche requirements to be allocated to the same functional group as they have evolved to fulfil similar functional roles within an ecosystem. Key niches that represent a range of microhabitats within an ecosystem are identified with species groups representing their functionality. The assumption is that these niches are functioning if the representative species of that niche are present. These species should have known, similar evolutionary and ecological traits (i.e. are in intraspecific competition with each other) and are grouped to form a functional species group.

In many ways the ideal scenario is where the focal species selected for the modelling is also included within the functional species groups. This, however, may not always be practical. Therefore the success of the habitat network should not only be measured by the presence of the focal species used, but also by the presence of species that are indicators of the ecological functioning of the habitats that make up the network.

The monitoring of functionality of habitat networks should assess

- A range of functional species groups representative of habitats within the network
- Temporal changes in these functional species groups
- Functional diversity within the ecosystem (site)

The challenge is to find practical, cost effective, field methodologies that are able to measure this functionality without assessing the complete biodiversity resource within an ecosystem. In terms of direct measurement of the species themselves, criteria for the selection of possible functional species for assessing network development are proposed (based on Speight, 2001):

- The information available for the species (or species group) should be sufficient to characterise their macrohabitat associations and their microhabitat associations
- Less than 5% of the genera should pose significant identification problems and the taxonomic literature should be readily accessible, even if scattered
- Reliable on-site sampling techniques should be available and open to standardisation
- Sampling should be effective within short periods, using generally available equipment that does not require daily site visits or direct involvement of experts in sample collection.
- Processing of samples should be undemanding in terms of labour and facilities.
- The regional distribution of species must reflect selected sites

Based on these criteria, groups such as Hoverflies (Syrphidae) and Snails (Gastropoda) could be selected as possible functional species groups and are currently being tested on a range of new native woodland sites in Scotland (www.scottishforestalliance.org.uk).

8.11.4 Rapid assessments of biodiversity

Rapid assessments of biodiversity (indirect species measures or “smoking gun” measures) could involve the use the evidence of invertebrate activity on micro-habitats in new habitats within a habitat network as a measure of ecosystem function. It is proposed that by measuring the evidence of activity of individual invertebrates or populations of invertebrates on a known unit of habitat (e.g. 1m. of ground flora) it will be possible to calculate an index of diversity for that unit. Changes in this index over time will reflect ecosystem development within a habitat network.

Some background research is required to test methods, justify them scientifically and validate it as a methodology for long-term monitoring. Indirect signs of insects are more easily identified than the species themselves and it has been shown (Oliver and Beattie, 1993) that estimates of species richness, based on recognisable taxonomic groups, can be made by non–experts as readily as by taxonomic experts. This principle of biodiversity assessment has been put forward by Angelstam and Donz-Breuss (2004) for dead wood species. While they recognise that the measure is coarse it does allow for rapid assessment of elements of diversity.

8.11.5 Genetic evidence

The change in the degree of genetic similarity within the population of the selected species across the study area will give an indication of how connected the populations are. Landscape genetics is the combination of landscape ecology and population genetics (Manel et al., 2003) and can provide the tools to quantify population gene flow indices and ecological connectivity indices in real landscapes (Holderegger and Wagner, 2006). The BEETLE accumulated cost distance modelling, which takes account of matrix quality combined with population genetic data of the selected focal species, can be used to quantify actual connectivity across a landscape.

The approach obtains indirect estimates of migration (hence movement through the habitat network) based on the spatial variation of adaptively neutral genetic markers. This provides a time-averaged measure of movement through the landscape. There is no single pattern and level of gene flow which is typical for a given species as dispersal is dependent on the structure of the landscape. This is particularly true where the habitat is fragmented and the landscape is composed of suitable habitat within an inhospitable matrix, factors which are addressed in the BEETLE accumulated cost distance modelling.

Genetic differentiation between samples is generally measured using Weir and Cockerham's (1984) estimator of Wright's (1969) ‘Fst’. If there is isolation by distance, genetic differentiation is expected to increase with spatial distance between samples. Conversely, kinship (Vekemans and Hardy, 2004) is expected to decrease with increasing spatial distance between samples. If a habitat network is functional the distances based on landscape connectivity may improve the relationship between genetic and geographic distance. The 'Sp' statistic is primarily dependent upon the rate of decrease of pairwise kinship coefficients between individuals with the logarithm of the distance in two dimensions. Under certain conditions, this statistic estimates the reciprocal of the neighbourhood size.

9 CONCLUSIONS

- The project has been successful in demonstrating the BEETLE accumulated cost buffer approach to modelling potential habitat networks in a variety of lowland agricultural landscapes with contrasting conservation priorities
- The strength of the approach lies in taking account of local conservation priorities and making best use of local expertise. Engaging with local stakeholder groups is a vital part of this process and enables the networks to relate to local on-going projects
- LBAPs and SNH Natural Futures provide appropriate scales and mechanisms for determining network priorities and for informing the regional targeting of agri-environment incentives
- The case study scenarios have shown that the BEETLE approach can be used to help with the spatial targeting of agri-environmental schemes and incentives within regions while also guiding actions for consolidating designated sites
- The case studies have illustrated the scope for developing robust integrated habitat networks that can be used in local authority planning procedures or in River Basin Management Plans
- The availability of good data on focal species autecology and distributions is vital for the robustness of the modelling and its applicability to real life conservation issues
- There needs to be more development, testing and validation of specific focal species profiles for use in the basic accumulated-cost buffering approach. This should involve developing a library of ecological information for a range of species calibrated by region. This library could be linked to the species management database HaRPPs (Habitats and Rare Protected and Priority Species) currently being developed as a web-based decision support tool for forest managers (Ray and Broome, 2007)
- The availability of good land cover data is also essential for the modelling. IACS field data and Phase 1 survey information on semi-natural habitats are the two main data requirements. It is recommended that Phase 1 be completed for the whole of Scotland, or at the very least an updated land cover map produced from modern aerial photography
- Computer generated visualisations of network development provide a useful tool for evaluating the likely impacts on the visual aspects of landscape character. The availability of GIS data on Landscape Character and Historical Land-Use allows consideration of landscape constraints and subsequent refinement of the BEETLE ACBT outputs
- The manipulation and interpretation of oblique aerial photographs could be of value as a tool for communicating the visual impact of network development to a wider group of stakeholders but needs to be tested further
- The modelling of “people networks” seems to have potential value in highlighting interactions between recreation and habitat networks, but more work is required to validate the assumption that human behaviour can be analysed using a focal species modelling approach

- Procedures for assessing the impact of network development on landscape character and recreation and made accessible to land-use and conservation advisors through ArcGIS by encouraging take up of appropriate software (i.e. 3D visualisation software and Spatial Analyst®)
- The BEETLE ACBT developed in ArcGIS automates some aspects of the modelling of habitat networks needs to be refined further through testing by potential end-users
- The implementation of habitat networks requires the integration of local and national policy conservation priorities and planning mechanisms with network modelling and "on-the-ground" advice and execution. Guidelines which encapsulate this integrative process need to be developed and made accessible to land managers and advisors.
- Methods for monitoring the success of habitat network implementation and development include: assessing habitat condition and ecosystem development, tracking the distribution and dispersal of both focal and functional species, recording evidence of species use of new habitats and undertaking post-hoc genetic analysis to infer patterns of migration

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11 APPENDICES

Appendix 1 - Description of Rural Stewardship Scheme (RSS)/LMC Tier 3 measures

Measure	Aims
Measures for birds relevant to lowland situations	
Extensive management of mown grassland for birds	To encourage the management of hay and silage fields for the protection of ground nesting birds, their eggs and fledglings, e.g. Skylark, Lapwing
Management of open grazed grassland for birds	To encourage the management of grazing land for the protection of ground nesting birds, their eggs and fledglings e.g. Corn Bunting, Skylark
Extensive management of mown grassland for Corncrakes	To encourage corncrakes by delaying cutting and grazing on hay and silage fields in Corncrake areas
Management of early and late cover for Corncrakes	To provide cover (e.g. rushes/tall vegetation for Corncrakes arriving back from wintering grounds early in the year or in the late season
Management of wet grassland for waders	To provide suitable breeding and feeding grounds for wading birds and provide protection for their eggs and fledglings. e.g. Reed Bunting, Snipe etc.
Creation and management of early and late cover for Corncrakes	To create and maintain the conditions (iris beds and tall vegetation) on improved grassland/arable for Corncrakes to breed successfully.
Measures for semi-natural habitats relevant to lowland situations	
Management of species-rich grassland	To encourage the growth and spread of flowering plants and other species in natural grassland, which act as a food supply for insects (e.g. Marsh Fritillary, Northern Brown Argus) and a seed source to ensure the continuation of the species.
Bracken eradication programme for species-rich grassland, coastal or lowland heath	To eradicate bracken from an area of species-rich grassland, coastal or lowland heath and thus allow the species-rich grassland, coastal or lowland heath vegetation to re-establish itself.
Creation and management of species-rich grassland	To convert arable or improved grassland to species-diverse grassland by restricting the agricultural use (to benefit bees, Skylark)
Management of coastal heath	To encourage the regeneration of native heathland plants and small grassland herbs (e.g. Dune Gentian) found on coastal heaths.
Management of lowland heath	To protect native lowland heath and encourage the regeneration of the plants and provide breeding and feeding grounds for the animals found in the area

Management of wetland	To enhance inbye wetland areas, for birdlife and to encourage botanical diversity that will in turn benefit invertebrates and amphibians (e.g. Great Crested Newts)
Management of lowland raised bogs	To enhance areas of lowland raised bog to promote biodiversity and wetland functions.
Creation and management of wetland	To convert arable or improved grassland to wetland by raising water levels. The habitat created will support a range of plants, invertebrates, birds (e.g. Reed Bunting) and mammals and provide both feeding and breeding areas.
Management of water margins	To protect water margins from erosion and permit development of tall waterside vegetation, e.g. tall herbs and other flowering plants, scrub and trees that will help to stabilise the bank and provide a habitat for invertebrates, on which fish can feed.
Management of flood plain	To create and maintain a mosaic of wash lands and dry lands by allowing the watercourse to overflow onto its natural flood plain.
Management of basin and valley mire buffer areas	To conserve and enhance the buffer zone surrounding basin and valley mires by maintaining water levels and preventing enrichment through runoff from fields. The aim is to support the range of plant and animal communities found in these wetland
Management of scrub (including tall herb communities)	To enhance and extend areas of native scrub vegetation, which will also help the survival of associated flora and fauna (e.g. Chequered Skipper, Linnet).
Management of native or semi-natural woodland	To enhance and extend areas of native or semi-natural woodland, which will also help the survival of the associated flora and fauna.
Management of ancient wood pasture	To enhance and extend sites with existing ancient wood pasture by maintaining the veteran trees, introducing or encouraging the regeneration of appropriate trees and managing the open pasture beneath and between those trees, to ensure the continuity of habitats which will support a range of invertebrates, birds, plants and other wildlife

Measures for field margins and boundaries	
Management of grass margin or beetlebank in arable fields	To create strips around or across fields on which insects can over-winter and breed early in the season. This allows them to effect a useful form of biological control by attacking aphid populations in adjacent crops. The strips also provide food and cover for birds (e.g. Corn Bunting).
Management of conservation headlands	To leave the headlands of arable fields free from herbicides or insecticides. This will allow the natural development of a varied flora within the headland, which will become a feeding ground and habitat for insects, birds and small mammals.
Management of extended hedges	To create hedges that are wider and taller than normal which, along with the adjacent undisturbed areas, will support a diverse range of plants as well as habitats for invertebrates, birds (e.g. song thrush and small mammals.
Management of hedgerows	To enhance existing hedgerows, which will in turn provide improved habitats for invertebrates, birds and small mammals.
Measures for arable areas	
Introduction or retention of extensive cropping	To increase the conservation value of arable land within a Less Favoured Areas by supporting traditional cropping rotations that will provide cover and feeding areas for birds (e.g. Corn Bunting)
Spring cropping	To increase the conservation value of arable land outwith the Less Favoured Area by encouraging the growing of spring-sown in place of autumn/winter-sown cereal crops and the practice of leaving areas of stubble over-winter in order to provide feeding and breeding areas for seed-eating birds. (e.g. Yellowharmer; Corn Bunting)
Management of cropped Machair	To encourage the traditional cropping of previously cultivated Machair land, i.e. improved grassland, land in crop or lying fallow after an arable crop. This will provide feeding grounds for birds and following cultivation, will encourage a range of annual plants to grow and flower as the area reverts to natural grassland
Unharvested crops	To encourage the practice of leaving areas of crop unharvested or partially harvested and left in stooks, in order to provide cover and feeding areas for birds.
Measures peripheral to lowland habitat networks	
Moorland management	To encourage changes in management practices to benefit a diverse range of habitats within moorland of conservation interest, including feeding and breeding sites for birds (e.g. black grouse) and animals and a wide range of insects and plants.
Moorland stock disposal	To encourage the regeneration of suppressed heather and/or other moorland vegetation of conservation interest, by the reduction of sheep numbers where it has been identified on a Moorland Management Plan.
Moorland – muirburn	To create blocks of heather at different growth stages through a planned programme of burning or swiping.
Moorland – bracken eradication	To eradicate bracken from an area of moorland and thus allow the moorland vegetation to re-establish itself.

Appendix 2 - Report from East Neuk Case Study Stakeholder workshop

12th January 2006 Lochore Country Park

Attendees contact details and what they-hoped LHN might deliver:

Allan Brown Fife council
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Integrating habitat networks into council planning

Karen Cunningham RSPB.
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The targeting of agri-environmental incentives, regionalisation of priorities

Keith Dalgleish SNH
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Focusing SNH grant money; agri-environment focus on targeting - no mechanism at present; help for local advisors

Suki Finney – RSPB.
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Improving land management advice for birds

Julie Horsburgh LBAP officer
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Strategic tools for focusing environmental benefits

Shelly McCann FERN
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Fife environmental resource targeting

Shirley MacGowan FWAG
shirley.macgowan@fwag.org.uk
Delivery of agri-environment measures and targeting - links with FWAG network project

Dallas Seawright Fife ranger service
'frs.lmcp@ukf.net' Fife Ranger Service
Learn more about project and see how it would relate to the work of the ranger service

Graham Taylor Forestry Commission-
The relevance of project to SFGS targeting

Andy Wight RSPB
andy.wight@ rspb.org.uk
The targeting of agri-environmental incentives, regionalisation of priorities

Aims of workshop

The aim of the workshop was to find out what issues of conservation concern were within the case study area and from these to try to tease out what species and habitats were the most important and could be used for BEETLE modelling

RSPB Corn bunting presentation

Karen Cunningham gave a presentation on the work that RSPB undertaking in the East Neuk. This included the habitat requirements of the corn bunting.

BEETLE modelling using corn bunting data

Mike Smith gave a presentation using RSPB Corn bunting data as the basis of an example of how the beetle model works. One of the objectives of this was to show that basic autecology is likely to be enough to be used as focal species in order to construct networks using the BEETLE model. Also presented some previous work undertaken by FR on core areas for Red Squirrel, which includes Tentsmuir Forest, part of the case study area. This raided the question of conflict between different networks (here Red Squirrel and deciduous broad-leaved woodland) and how prioritisation is an important issue in developing different habitat networks in the lowland situation.

Other GIS tools / remote sensing applications were then looked at to see how to target areas for potential restoration within Network areas. Specifically the OS 1st edition map can be used to highlight areas of past habitat were restoration is likely to be more successful. Also presented was the use of coincidence mapping of species based on information held on Recorder by FERN the environmental record centre.

There then followed a more general discussion on the beetle model and how it is constructed. This proved useful as it allowed those with little knowledge of the model to become more familiar with the concept behind it and its potential applications. It is thought that this is an area that more detail could be included in presentations.

Workshop on developing habitat networks

The group was split into two which were led by Mike Smith and Jonathan Humphrey. Davy McCracken (SAC) moved between the groups. Initially each participant was asked to identify 3 issues of conservation concern, which were then discussed within the workshop group to see if there was relationship between these issues and the development of LHN. Species and habitats that were of thought to be of relevance to LHN were then discussed and whether there was the expert knowledge (and who held this knowledge) on these for use within the BEETLE model.

Each Group had a set of maps

- AO map of East Neuk Case study areas with coast, rivers, roads and urban areas marked for reference
- Maps showing Case Study designated sites
- Maps showing woodlands (conifer, broad-leaved and scrub)
- Maps showing wetland areas (open water, swamp, marshy grasslands etc
- Maps showing unimproved and semi-unimproved grasslands

These maps of areas were used to identify issues and information that would be useful for the development of LHN and also allowed this information to be located geographically. Contact details of relevant experts were also included on this map (Fife LHN contacts database is in the process of being constructed).

Each of the participants were asked to identify 3 areas of conservation concern within the case study area. These could be ordered by strategic level (national, local or habitat network) or by issue but is probably more useful to look at them by issue as the main part of the workshop was to look at these issues and relate them to the concept of lowland habitat networks.

Agri-environment issues

Targeting of Agri environment grants was raised by several of the participants and while it is a broader national issue it is one the modelling will hope to be able the help with and is part of the wider remit of the project. The case studies will investigate how this could be achieved in differing lowland situations related –

- Delivery Easiest ,newest most attractive regardless of their suitability
- Change in agriculture/agri economics will result in changes in land use and habitat change. It will be possible to look at different scenarios in an attempt to predict how this might affect connectivity between different habitats leading to loss of cereals esp. spring barley
- Large companies e.g. supermarkets and their effect on agri economics

Climate change

The BEETLE model can be used to address some of the issues that relate to species and habitats in relation to climate change these could include sea level changes, coastal erosion, and identifying suitable areas for managed retreat. (See Fife Shoreland management plan -protection rather than managed retreat no wetland saltmarsh or intertidal gains for wildfowl or seabirds -copy of report KD)

Species management in relation to climate change can also be addressed using The BEETLE model. There are several issues that relate to this and whether a proactive or reactive approach should be taken to address species change as a result of climate change.

- Species predicted to have an extended northern distribution e.g. nuthatch certain butterflies spp. should we look to be accommodating potential new arrivals
- Species that are southern end of their distribution, lost causes ? they are likely to disappear anyway ?
- Or should we look to creating checks in the system as and when changes are seen to be occurring and react as a result of these.

Bio fuels

There is a proposal for a Biofuel plant in Glenrothes to power a paper mill. This is likely to have an impact on farming within Fife and case study area. The plant require large amounts of short rotation coppice (SRC), which is hoped will be grown within 30Km of Glenrothes and so includes the whole of the case study area. It is thought that more likely to be an issue in West and Central Fife in the short term but changes in agri economics could change this. The growing of SRC requires an EIA though does not require planning permission? It requires 30cm cultivated soil to grow SRC and so identify areas that would be good for SRC production

- Can use BEETLE to address some of the issues red squirrel etc landscape and habitat issues SRC coppice more details of this are requires (MS to follow up)
- Approach to conservation proactive vs. reactive LHN allow for proactive approach while allowing for reaction to situations as they arise –dynamic
- Species and habitat loss in east Neuk reintroductions?? -Not those at the southern end of their range –see climate change what work has been done on this
- Habitat management long term approach with in built monitoring (see below) and quality of advice and ability to under take work

Delivery of Fife Lowland Habitat Network

The continuation of the momentum that has been developed was raised as there has been a demand and expectation created as a result of the LHN project. Questions about how to implement and resource future projects in terms time, management, advice, money, people (e.g. how much did west Lothian cost SNH /council funding and are there lessons to be learned). While this was not as specific objective of the workshop it is very apparent that stakeholders are keen on the LHN and its practical delivery on the ground.

- Relate LHN to existing biodiversity projects (AP find examples Keith Dalgleish/Julie Horseburgh) and use BEETLE modelling as part of these
- Local grant targeting as with capper – e.g. corn bunting within habitat
- Phase 3 -FWAG project likely to be Key to the delivery of LHN in Fife.
- Landowner co-operation /change long term funding

- Stakeholder network: the stakeholder group in its own way is developing a network in that different bodies have a common approach to conservation and land use issues within the case study area.
- In association WFD nitrogen sensitive zone? (all of case study area is in this) Relate to SEPA catchment plans –Ayrshire case study will be addressing this
- Public awareness and recreation -dogs

LNH issues-Habitats and species

From the issues outlined above, specific habitat and species priorities were identified where the BEETLE model could be used to highlight the potential for improved connectivity within the case study area. The emphasis being on the use of BEETLE as an aid to testing scenarios rather than as a proactive tool. Priorities were:

1. Designated sites and LBAP areas as linking in with existing projects.

2. Biodiversity hot spots – link with planning in urban and peri urban – legislation and local plans link in with these on council land

3. Red squirrel - protecting core areas over long time scale; prioritising and decision making

4. Wych elm and Aspen as field boundary tree - maintaining populations of veteran elms; defending existing “resistant” populations; seed collection/inoculation; possible host for elm lichen (RDB species). Also aspen with is suite of specialist associates. Relates to hedgerows field boundaries

5. Raised Bogs restoration of raised bog was highlighted as a priority

6. Unimproved grassland is a key habitat in the case study area and had been in serious decline as a result of agricultural improvement over the last 60 years Some species and issues:

   - Hare
   - Maiden pink
   - Burnet moth
   - Grass margins
   - Small patch size
   - Coincidence mapping list spp.
   - MS2000 report linked with Beetle
   - Core 2nd 3rd level sites within networks and supporting existing sites
   - Green hairstreak
   - Birds foot trefoil

7. Non Natives/riparian issues were highlighted with the following species issues:

   - Japanese knotweed
   - Himalayan Balsam
   - Otter
   - water vole (existing project)
   - mink
   - riparian/ WFD River corridors

8. Fife council land and development planning issues –how can BEETLE work with these issues – West Lothian report fragmentation as a result of green belt etc-development layer could be included in the model. Predictive mapping could be undertaken based on future land use planning

9. Coastal erosion; SSSI loss; dune systems; coastal heath; develop coastal network; Native Scots Pine on dune slack -Baltic dune Scots pine woodland

10. Woodland
    - Barn owls

- Bats
- Orange tip butterfly
- Badger
- Ancient woodland-bats

11. Agricultural - the majority if the case study area is in arable production and modelling in relation to this is going to be key in the development of an East Neuk habitat network. Species and issues

    - Agri grants (see above)
    - IACS data for modelling
    - Agricultural birds
    - Partridge
    - Arable weeds

12. Golf courses - there are a large number of golf courses within the case study area and there are both opportunities and constraints in relation to this recreational activity.

13. Monitoring - monitoring the success of LHN is an issue that was raised as the model is based on theoretical dispersal of species, but will this happen in suitable time frames and deliver the required connectivity between habitats ? There needs to be a suitable monitoring procedure that assess this, possibilities include:

    - Use functional spp approach see SFA monitoring
    - Non-woodland rapid assessment of biodiversity (RAB's)
    - Invertebrate herbivory
    - Lack of agri environment monitoring –could they be linked i.e. success of agri monitoring is functionality using RAB's
    - Freshwater RAB's
    - Agri RAB's
    - Forestry RAB's s part of SFGS?

14. Designated sites specific issues - one of the aims of the project is to look at how LHN can support designated sites by: restoration of habitat; Restoration /creation of supporting sites to maintain meta- populations. Examples

- Cameron Reservoir -Over wintering wildfowl feeding sites within a specific distance from site
- Earlshall Muir - restoration of wetland and heathland for wildfowl vs. conifer for red squirrel
- Tensmuir - forestry on coastal heath vs. dune Scots pine Need for strategic approach as there is pressure from SFGS and the desire to maintain red squirrel populations

Appendix 3 - Strathspey Stakeholder Workshop

Grantown on Spey 22 November 2006

Attendees

Justin Prigmore	LBAP
Mike Smith	FR
David Bale	CNPA
John Parrott	SNW
Adrian Hudson	Dee Fishery Board
Keith Duncan	SNH
Pete Moore	SNH
Matthew Hawkins	CNPA
Ellen Rotheray	Hoverfly researcher
Amanda Calvert	HAG/Laggan Forest Trust
Carl Mitchell	RSPB
Tom Prescott	BCS
Ern Emmett	HAG
Mary Winsch	HAG
Phil Baarda	HB
Ewan Purser (?)	HB
Fiona McPhee	HB
Malcolm Wield	FC
Kenny Taylor	Chair, Cairngorms LBAP
David Hetherington	CNPA
James Davidson	SEPA
Nicola Seal	SEPA
Alan Harrison	FR

Aims of workshop

The aim of the workshop was to find out what issues of conservation concern were within the case study area and from these to try to tease out what species and habitats were the most important and could be used for BEETLE modelling

BEETLE modelling using Aspen data

Mike Smith gave a presentation using aspen data (see appendix 1 assessing Aspen connectivity) as the basis of an example of how the beetle model works. One of the objectives of this was to show that basic autecology is likely to be enough to be used as focal species in order to construct networks using the BEETLE model.

Other GIS tools / remote sensing applications were then looked at to see how to target areas for potential restoration within Network areas. Specifically the OS 1st edition map can be used to highlight areas of past habitat were restoration is likely to be more successful. Also presented was the use of coincidence mapping of species based on information held on Recorder by FERN the environmental record centre based on the work carried out on unimproved grasslands in Fife. This also showed how the Habitat network approach could be used to target Land management contracts and the consolidation of Designated sites

There then followed a more general discussion on the beetle model and how it is constructed. This proved useful as it allowed those with little knowledge of the model to become more familiar with the concept behind it and its potential applications. It is thought that this is an area that more detail could be included in presentations

Workshop on developing habitat networks

The workshop was split into two groups, which were led by Justin Prigmore and, David Heatherington of Cairngorm National Park Authority. Mike Smith moved between the groups. Initially each participant was asked to identify 3 issues of conservation concern, which were then discussed within the workshop group to see if there was relationship between these issues and the development of LHN. Species and habitats that were of thought to be of relevance to LHN were then discussed and whether there was the expert knowledge (and who held this knowledge) on these for use within the BEETLE model.

Each Group had a set of maps
AO map of Case study areas
Maps showing Case Study designated sites
Maps showing wetland areas (open water, swamp, marshy grasslands etc
Maps showing unimproved and semi-unimproved grasslands
Maps showing peatlands (dry/wet heaths and blanket bog

These maps of areas were used to identify issues and information that would be useful for the development of LHN and also allowed this information to be located geographically. Contact details of relevant experts were also included on this map (LHN contacts database is in the process of being constructed) This information was then transposed here and are summarised as follows:

Highlighted Conservation issues of concern.

The first element of the workshop asked each the participants to identify 3 areas of conservation concern within the case study area. These could be ordered by strategic level (national, local or habitat network) or by issue but it is probably more useful to look at them by issue as the main part of the workshop was to look at these issues and relate them to the concept of lowland habitat networks.

Aspen
Fragmentation of the aspen, link-ups and expansion of aspen resource came up as an important theme and this reflects the importance of this tree and its associated species in the Strathspey area. At present the Aspen modelling has gone as far as it can until further arial photographs are taken to identify the full extent of the resource in the case study area. The work that has been carried out clearly shows how the methodology would work (See appendix1) and hopefully this is a project that can be taken forward in the next financial year.

Flood plain management
This is the biggest issue in the Strathspey Case study area and encompasses a wide range of issues that come together under the Floodplain Management banner

Loss/fragmentation/lack of lowland floodplain wetland features.
Loss/fragmentation/lack of riparian woodland in particular but semi-natural woodland in general.
Distribution of ponds in relation to rare Odonata (Northern Damselfly and WF Darter).
Loss of habitat for breeding waders
Potential for further wetland expansion, including increase in forest bogs.
Protection and enhancement of Freshwater Pearl Mussel populations.

These issues are all inter-related through ecological succession in that ponds become wetlands which will eventually become wet woodlands. It is proposed that these successional relationships are investigated both spatially and temporally through using the BEETLE model. This may help with decision making that allows for management of ecologically functional floodplains.

The possibility of using beaver as a focal species was raised as it was thought that this would be a good species to reflect a wide range of floodplain habitat issues. Other potential wetlands focal species were members of the Odonata family, It may be more useful to use Newt species as there is good autoecology for these species and the fact they use a range of wetland habitats at different stages of the year.

Veteran trees/wood pastures.
The wood pasture and veteran tree resource across Scotland in under recorded and this is true also of the Strathspey area BEETLE modelling of this unrecognised and under-valued habitat its often high biodiversity value trees could investigate. Inadequate/discontinuous supply of deadwood for hole-nesters and saprophytes and the continuity of veteran trees

Squirrels
Threat of grey squirrel colonisation (can BEETLE be used to help design a monitoring / trapping sanitation corridor as a last line of defence?)

Invasive species
These are riparian issues in many ways but are being treated separately since the use of the modelling tools may well be able to address these issues but it is thought that this is not within the scope of this project –indeed it is a project all of its own

Invasive non-native plant species in the riparian zone.
Potential for the spread of non-native fish species in the Spey catchment.

Balancing Priorities
It is envisaged that investigation into the relationship between different habitat networks to derive an integrated habitat network. While the BEETLE cannot resolve issues relating to the interaction between these habitats it will highlight where these issues occur. In this way woodland, wetland heathland and other habitat networks can be overlaid to see where the interactions between networks are.

Conclusions
There will not be time to run the BEETLE model on all of the above and so there will need to be a targeting exercise in consultation with stakeholders and steering group to select a reasonable number that can be investigated within the context of the project.

It is suggested that the following be selected for BEETLE modelling

Aspen networks
Floodplain management wetlands using newts as the focal species
That these will be looked at in terms of
Functional connectivity
targeting of agri environmental incentives
In relation to designated sites
Balancing priorities/resolving conservation conflicts

Appendix 4 – Tiree Stakeholder Workshop

Meeting 12th December 2005 SNH offices, Oban

Attendees: Mike Smith (FR), Helen Doherty (SNH), Ross Lilley (SNH), Allan Nichol (SEERAD) Helen Bibby (SAC) Marina Curran-Coltart (LBAP) By Videoconference: John Bowler (RSPB) and Janet Hunter.

- Mike Smith gave a presentation on Lowland Habitat Networks and the scope of the project as background
- There was discussion about the usefulness of the project with respect to conservation issues on Tiree. It was felt that the project would be able to provide the stakeholders with a common approach and give a visualisation of the landscape ecology issues on the island.
- There is the opportunity to put the theoretical and modelled outputs into practice as much of the current island's agri-environment schemes will be changing over from being part of ESA's to entering Land management contracts in 2007.
- Grazing was identified as the single most important conservation management tool and issue for habitats of conservation concern on the island. The habitats that were identified by stakeholders were:

    1. Machair
    2. Carex dominated wet heaths on thin peat
    3. Inbye grasslands
    4. Coastal grasslands
    5. Machair lochs and margins.

- Work will be undertaken to look at developing an approach to incorporating grazing issues into the BEETLE model.
- There was discussion about ecological information on species that were representative of the habitats on the island and how existing data on these species could be used within the BEETLE model. There will be an ongoing task of assembling data-sets on the habitats and species on the island. There is existing digital NVC and Phase 1 survey information available.
- It was emphasised that there is a bottom up approach to this project and the more effort the stakeholders put in the better the outputs are likely to be. Also that most local strategic conservation planning decisions are made by local expert knowledge and that a key part of this project is to bring this knowledge together to put into the BEETLE model which can them be used as a common resource.
- Support for the Tiree case study will be available for the duration of the whole LHN project as new approaches are likely to be developed from other case studies and will need to be incorporated into the Tiree project.

Appendix 5 – Cost values (permeability) ascribed to Phase 1 land cover types for the focal species used in the East Neuk study area

Description	People [1]	Cb_winter	Cb_summer	Squirelred	Squirelgrey	Grassland
A111 Woodland: broadleaved, semi-natural	2	50	50	5	0	2
A112 Woodland: broadleaved, plantation	2	50	50	5	0	5
A121 Woodland: coniferous, semi-natural	2	50	50	0	5	2
A122 Woodland: coniferous, plantation	10	50	50	0	5	10
A132 Woodland: mixed, plantation	10	50	50	1	3	8
A21 Scrub: dense/continuous	50	50	50	5	2	5
A31 Parkland/scattered trees: broad-leaved	1	50	50	5	1	1
A41 Recently felled woodland: broad-leaved	50	50	50	20	5	5
A42 Recently felled woodland: coniferous	50	50	50	10	25	5
B11 Grassland: acid, unimproved	1	10	10	20	20	2
B12 Grassland: acid, semi-improved	1	10	10	10	10	4
B21 Grassland: neutral, unimproved	1	10	10	10	10	0
B21/H84 Grassland: neutral, unimproved/Coastal grassland mosaic	1	10	10	10	10	0
B22 Grassland: neutral, semi-improved	1	10	10	10	10	2
B31 Grassland: calcareous, unimproved	1	10	10	10	10	0
B32 Grassland: calcareous, semi-improved	1	10	10	10	10	2
B4 Grassland: improved	5	10	10	10	10	5
B5 Grassland: marsh/marshy grassland	5	10	10	20	20	5
B6 Grassland: poor semi-improved	5	10	10	20	20	2
C11 Tall herb and fern: Bracken, continuous	20	25	25	20	20	3
C31 Tall herb and fern: other, tall ruderal	20	25	25	20	20	2
D11 Heathland: dry dwarf shrub heath, acid	15	50	50	20	20	5
D2 Heathland: wet dwarf shrub heath	20	50	50	20	20	5
D5 Heathland: dry heath/acid grassland mosaic	10	50	50	20	20	3
D6 Heathland: wet heath/acid grassland mosaic	15	50	50	20	20	3
E11 Mire: blanket bog	40	50	50	50	50	3
E21 Mire: Flush/spring, acid/neutral	40	50	50	50	50	2
E22 Mire: Flush/spring, basic	40	50	50	50	50	2
F1 Swamp	40	50	50	100	100	4
F11 Swamp: single sp. dominant swamp	40	50	50	100	100	4

[1] Low score = low cost (high permeability); high score = high cost (low permeability)

Description	People	Cb_winter	Cb_summer	Squirelred	Squirelgrey	Grassland
F12 Swamp: tall fen vegetation	40	50	50	100	100	4
F21 Marginal/inundation: marginal	40	50	50	50	50	25
F22 Marginal/inundation: inundation	40	50	50	100	100	25
G1 Open water: standing water	50	50	50	100	100	50
G11 Open water: standing, eutrophic	50	50	50	100	100	50
G12 Open water: standing, mesotrophic	50	50	50	100	100	50
G2 Open water: running water	50	50	50	50	50	50
H1 Coastland: intertidal	10	50	50	50	50	50
H11 Coastland: intertidal, mud/sand	10	50	50	50	50	50
H12 Coastland: intertidal, shingle/cobbles	10	50	50	50	50	50
H12/H13 Coastland: intertidal, shingle/cobbles and boulders/rocks mosaic	10	50	50	50	50	50
H13 Coastland: intertidal, boulders/rocks	50	50	50	50	50	50
H21 Coastland: saltmarsh, Spartina dominated	50	50	50	50	50	4
H22 Coastland: saltmarsh, dominated by species other than Spartina	50	50	50	50	50	4
H26 Coastland: Saltmarsh, dense/continuous	50	50	50	50	50	4
H3 Coastland: shingle above high tide mark	1	50	50	50	50	30
H4 Coastland: boulder/rocks above high tide mark	10	50	50	50	50	30
H4/B22	10	50	50	50	50	30
H4/H22	10	50	50	50	50	30
H5 Coastland: strandline vegetation	1	50	50	50	50	5
H6 Coastland: sand dune	1	50	50	50	50	5
H61 Coastland: fore dunes	1	50	50	50	50	5
H62 Coastland: yellow dunes	1	50	50	50	50	5
H63 Coastland: grey dunes	1	50	50	50	50	5
H64 Coastland: dune slack	1	50	50	20	20	5
H64/H65 Coastland: dune slack and grassland mosaic	1	50	50	10	10	5
H64/H65/H66 Coastland: dune slack, grassland and heath mosaic	1	50	50	10	10	5
H65 Coastland: dune grassland	1	50	50	10	10	5
H65/B5 Coastland: dune grassland and marsh/marshy grassland mosaic	5	50	50	20	20	5
H65/H66	5	50	50	20	20	5
H66 Coastland: dune heath	5	50	50	20	20	5
H66/B5 Coastland: dune heath and marsh/marshy grassland mosaic	5	50	50	20	20	5
H67 Coastland: dune scrub	50	50	50	10	10	5
H68 Coastland: open dune	1	50	50	50	50	8

Description	People	Cb_winter	Cb_summer	Squirelred	Squirelgrey	Grassland
H81 Coastland: hard cliff	50	50	50	50	50	10
H81/H4	50	50	50	50	50	10
H82 Coastland: soft cliff	50	50	50	50	50	10
H83 Coastland: maritime cliffs, crevice and ledge vegetation	50	50	50	50	50	10
H84 Coastland: coastal grassland	1	50	50	10	10	10
I111 Rock: Natural exposure, inland cliff, acid/neutral	50	50	50	50	50	10
I112 Rock: Natural exposure, inland cliff, basic	50	50	50	50	50	10
I142 Rock: other natural exposure, basic	50	50	50	50	50	10
I21 Rock & waste: artificial exposure, quarry	50	50	50	50	50	10
I22 Rock & waste: artificial exposure, spoil heap	50	50	50	50	50	10
I22/A21	50	50	50	50	50	10
I24 Rock & waste: artificial exposure, refuse-tip	50	50	50	50	50	10
J11 Cultivated/disturbed land: arable	50	10	10	20	20	10
J12 Cultivated/disturbed land: amenity grassland	50	10	10	10	10	5
J14 Cultivated/disturbed land: introduced shrub	50	50	50	10	10	5
J26 Boundaries, dry ditch	50	50	50	20	20	20
J3 Built up area	0	50	50	5	5	50
J34 Built up area, caravan site	0	50	50	10	10	50
J35 Built up area, sea wall	0	50	50	50	50	50
J36 Built up area, buildings	0	50	50	50	50	50
J4 Bare ground	1	50	50	20	20	30
J5 Other habitat	25	50	50	20	20	30
	25	50	50	50	50	30
J13 Cultivated/disturbed land: ephemeral/short perennial	25	10	10	20	20	15
H64/B5 Coastland: dune slack and marsh/marshy grassland mosaic	5	50	50	20	20	5
Broadleaf	2	50	50	10	0	5
80-90% Broadleaf	2	50	50	10	0	5
Mixed Broadleaf/Conifer	2	50	50	5	5	10
80-90% Conifer	10	50	50	0	10	10
Conifer	10	50	50	0	10	10
Scrub	10	50	50	10	3	2
'Airfield'	50	10	10	10	10	20
'Arable: no rock no farms no trees'	50	5	5	20	20	10
'Arable: no rock no farms trees'	50	10	10	5	5	15
'Arable: rock no farms no trees'	50	10	10	20	20	10

Description	People	Cb_winter	Cb_summer	Squirelred	Squirelgrey	Grassland
'Bings (area)'	50	50	50	50	50	50
'Blanket bog/peatland veg.: no erosion trees'	50	50	50	10	10	5
'Built-up (area)'	0	50	50	5	5	50
'Cararvan parks'	0	50	50	10	10	20
'Cemetries'	0	50	50	15	15	20
'Coniferous (plantation - area)'	10	50	50	0	10	10
'Dry heather moor: rock no burning trees'	20	50	50	20	20	10
'Dune lands: bare dunes'	1	50	50	20	20	2
'Dune lands: links area - grass'	1	50	50	10	10	1
'Dune lands: unstabilized dunes'	1	50	50	50	50	2
'Estuary'	50	50	50	100	100	50
'Factory'	5	50	50	25	25	20
'Golf course'	0	10	10	10	10	15
'Imp. pasture: no rock no farms no trees'	10	10	10	10	10	10
'Imp. pasture: no rock no farms trees'	10	10	10	5	5	15
'Imp. pasture: rock no farms no trees'	10	10	10	20	20	10
'Open canopy (young plantation)'	50	10	10	10	10	5
'Quarries (area)'	50	50	50	50	50	15
'Recent felling'	50	50	50	15	15	5
'Recent ploughing'	50	50	50	20	20	10
'Smooth grass/low scrub: no rock no trees'	2	10	10	10	10	10
'Smooth grass/low scrub: no rock trees'	2	10	10	10	10	15
'Smooth grass/low scrub: rock no trees'	2	10	10	10	10	10
'Smooth grass/low scrub: rock trees'	2	10	10	10	10	15
'Smooth grass/rushes: no rock no trees'	2	10	10	5	5	10
'Smooth grass/rushes: rock trees'	2	10	10	5	5	15
'Undiff. broadleaf (area)'	2	50	50	1	1	5
'Undiff. low scrub'	20	50	50	5	5	2
'Undiff. mixed woodland (area)'	5	50	50	1	1	10
'Undiff. salt marsh: no trees'	2	50	50	50	50	5
'Undiff. smooth grass.: no rock no trees'	2	10	10	10	10	10
'Undiff. smooth grass.: no rock trees'	2	10	10	10	10	15
'Undiff. smooth grass.: rock no trees'	2	10	10	10	10	10
'Undiff. smooth grass.: rock trees'	2	10	10	10	10	15

Description	People	Cb_winter	Cb_summer	Squirelred	Squirelgrey	Grassland
'Water (area)'	50	50	50	100	100	50
'Wetlands: drains no trees'	50	50	50	100	100	2
'Wetlands: drains trees'	50	50	50	20	20	5
'Wetlands: no drains no trees'	50	50	50	100	100	2
'Wetlands: no drains trees'	50	50	50	20	20	5
agrienvironmental schemes for arable birds	2	0	0	20	20	8
Corn bunting winter	5	0	2	20	20	10
Corn bunting summer	2	2	0	20	20	10
Attractions	0	50	50	50	50	50
Paths	0	50	50	50	50	50
Aroads	1	50	50	50	50	50
Broads	0	50	50	50	50	50
Minor roads	0	50	50	50	50	50
Rivers	3	50	50	50	50	50
tracks	0	50	50	50	50	50
urban	0	50	50	50	50	50
roads2	1	50	50	50	50	50
paths4	0	50	50	50	50	50
paths2	0	50	50	50	50	50