Networks for LIFE

Ecological Network Analysis for Cheshire County (UK)

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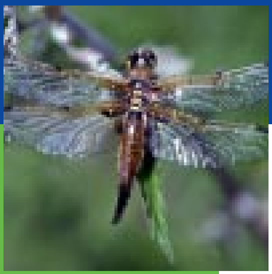

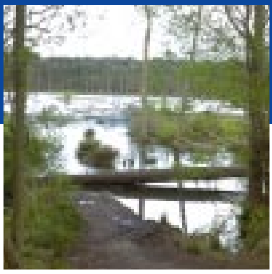

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ABSTRACT

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Drawings: R.G.H. Bunce. Pictures: T. van der Sluis

This report gives the result of an analysis of the ecological network, designed for the agricultural plains of Cheshire. Five ecosystem types were selected: meres and mosses, heathland, wetland and rivers, woodland, and grassland,. Species were selected which can be considered representative for these ecosystems. The model LARCH was used to assess whether these ecosystems still function as an ecological network.
An ecological network, a 'scenario' was designed, which should be seen as a minimum scenario. It was tested with LARCH in how far the situation would improve for the selected indicator species.
Through the implementation of the scenario good opportunities are created, especially for long-range species. Habitat is most limiting for meres and mosses and heathland. Species most vulnerable due to fragmentation, even after implementation of the scenario, are the less mobile species, such as *Water vole, Common lizard, Green hairstreak* and *Common blue*. Specific de-fragmentation measures are important for those species.
The approach used here, based on an analysis with OS MasterMap, can be applied elsewhere in the UK.

Keywords: corridor, ecological network, landscape ecology, LARCH, metapopulation model, nature rehabilitation, spatial planning

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Preface

Cheshire County Council and English Nature have commissioned a study, to analyse the ecological network for Cheshire County, UK.

The set-up of the research follows the outline, as given in the project proposal and inception report, which was discussed with the Steering Committee.

The Steering Committee consists of:

Ian Marshall	Cheshire County Council
Steve Clarke	Cheshire County Council
Mandy North	Cheshire County Council
Keith Porter	English Nature
Stephen Preston	English Nature
Bryan Roberts	British Butterfly Conservation Society
Brian Martin	Cheshire and Wirral Ornithological Society
David Kitching	Dragonflies
Gail Butterill	Cheshire Wildlife Trust
John Boothby	Liverpool John Moores University

We would like to thank the Steering Committee, which has greatly helped to finish this study. Especially thanks to Project Leader Ian Marshall, and Steve Clarke, who was the direct contact person and assisted with the maps and preparations for the study. Furthermore, we wish to thank all other experts that contributed to the meetings and in particular Bryan and Gail, who gave much valuable information.

In addition, we are grateful to Sue Tatman, Chris Green and Richard Storey from Cheshire Wildlife Trust for their constructive comments on the species descriptions and parameters. Thanks to John Boothby for his maps of ponds and pond networks. Jim Foster from English Nature advised on the *Great crested newt* model, David Kitching on modelling dragonflies.

Finally we thank our ALTERRA colleagues Freek Niewold, who assisted in the preparation of the ecological profiles for the watervole, and Wim Nieuwenhuizen who advised on modelling of the *Dormouse*.
Thanks also to Sabine van Rooij who discussed and applied the results of this study.

Picture 1: Teggs Nose, the Pennines in Eastern Cheshire

Picture 2: Brook valley near Kingston (control area 1)

Summary

Biological diversity is highly dependent on the quality, quantity and spatial cohesion of natural areas. Fragmentation of natural habitats severely affects the abundance of species. An answer to this problem is the development of ecological networks, linking core areas for nature by means of corridors and small habitat patches.

The development of ecological networks is part of European policy (Bern Convention, Habitat Directive, Natura, 2000) and has resulted in the development of the Pan European Ecological Network PEEN.

This report presents the results of an analysis of the ecological networks of Cheshire County. The county of Cheshire lies in the north west region of the United Kingdom. It is a county of contrasting landscapes - wooded river valleys and sandstone hills, meres and mosses, estuaries and heaths - which in turn support a variety of wildlife habitats, some of which are of international importance.
Extensive discussions are being held with all stakeholders to raise awareness of the concept of ecological networks, and to seek their support and active participation. The project recognises the importance of people's views and perceptions and these will be actively sought.

In a separate study a scenario has been developed, detailing targets for different ambition levels (Van Rooij *et al.,* 2003a). This report should be seen in relation with that separate study, on which it builds forth the analysis.

The ecological network is assessed to see whether available (fragments of) habitat are large enough for species to survive. So far the work on the Cheshire Ecological Network has concentrated on areas of priority habitat and their spatial relationships (Clarke, 2002). It is now necessary to examine these habitats as the home for species, in particular key animal species considering functioning of ecosystems.

The aim of the analysis is (1) to identify the functional ecological network at present for different ecosystems and wildlife populations and (2) to assess whether a designed ecological network (scenario) would improve the situation for the selected species and ecosystems.
This is done through an assessment of the habitat requirements of specific selected species and the connectivity of the landscape with LARCH. The proposed habitat types to be analysed are woodlands, wetlands and rivers, grasslands, heathland and meres and mosses. The situation is assessed for a number of relevant species for each ecosystem. The selected species include some short-range species, e.g. reptiles, amphibians, mammals, which are all vulnerable for fragmentation. In addition, some bird species are included in the analysis.
To be able to assess the reliability of results, a check on the accuracy of the map was carried out. Overall is shown that differences between observed area and mapped area are almost neglectable, at this scale it won’t bear any effects on the results. More serious

might be that small landscape elements such as woodrows, hedges, ditches and so on are not included. This gives an underestimate of the real situation in the field, both for potential biodiversity and habitat present as well as for dispersal of migrating species.
The study in Cheshire presents ideas and might form a good basis for further development of the ecological network. The scenario drafted (van Rooij *et al.,* 2003a) which is tested in this study, results in an improvement for all ecosystems. It should be seen as a minimum scenario. It is therefore recommended to implement the scenario (if possible the scenario with the high ambition level) as soon as possible.
Through the implementation of the scenario good opportunities are created, especially for long-range species. After improvement of corridors the situation for species with a short home-range might also improve.

Measures for the meres and mosses and heathland are most difficult to realise, due to a limited potential of the area. The aims in current conservation policy are too low to improve significantly the situation for those species with higher demands. For these ecosystems habitat is most limiting, and therefore it is essential that measures are taken to increase habitat and improve connectivity of the landscape for those species. Species most vulnerable, even after implementation of the scenario, are the less mobile species, such as *Water vole, Common lizard, Green hairstreak* and *Common blue.* Specific de-fragmentation measures are important for those species.

The spatial analysis with LARCH has yielded useful results. For quantification and calibration of the results, the scenario should still be tested better though.
The approach used here, based on an analysis with OS MasterMap, can be applied elsewhere in the UK. In fact, as long as the same maps are used, and the same target species are selected, the ecoprofiles that were developed in this study can be applied, which will allow for easier and faster analysis results.

1 Introduction

1.1 Concept of ecological networks

Biological diversity is highly dependent on the quality, quantity and spatial cohesion of natural areas. Fragmentation severely affects the abundance of species.

If wildlife is spread over large areas, in low numbers, and if these remaining areas are too small, wildlife species will disappear sooner or later. To allow for repopulating or restocking of small areas and habitats, the areas need to be connected to the remaining core areas for wildlife in the vicinity (Romano, 2000). For birds, this means that the distance from source areas to their habitat is less than the normal distance they might cover when flying. For non-flying animals it might mean that often a physical connection is required, e.g. woodlands, streams, rivers, natural grasslands and so forth.

An answer to this problem is the development of an ecological network, linking nature areas by means of corridors and small habitat patches (Vos *et al.,* 2002). An ecological network is constituted of habitat patches, for a population of a particular species that exchanges individuals by dispersal.

The development of ecological networks is part of European policy (Bern habitat directive, Natura 2000), and has resulted in the development of the Pan European Ecological Network PEEN. European ecological networks especially can be beneficial for large herbivores like red deer, or top predators like wolves, bear, lynx and otter. However, in the first instance many small organisms will benefit from improvements in spatial cohesion and expansion of natural habitats.

Many European countries are attempting to realise ecological networks at a national or regional scale (Rientjes & Roumelioti, 2003). The LIFE-ECOnet Project is a practical example of this approach at the regional scale. This four-year demonstration project is supported by the EU LIFE-Environment Programme, and aims to integrate environmental considerations in land use planning through the use of ecological networks. The project is the joint initiative of local authorities, private industry and research centres from the UK, Italy and the Netherlands.

1.2 Study area: Cheshire County

In 1996, Cheshire County Council began a project to develop an ecological network for Cheshire - the Cheshire ECOnet - in collaboration with the University of Salford and with the support and advice of English Nature locally and nationally. Advice was also forthcoming from The Pond *Life* Project at Liverpool John Moores University.

The '*Life* ECOnet Project' is a joint initiative between the County Council and local authorities, private industry and research centres from the UK, Italy and the

Netherlands. The project will run for 4 years from September 1999 until September 2003. Project Partners will develop an ecological network in Cheshire and in study areas in the two Italian regions of Emilia-Romagna and Abruzzo. Spatial analysis and network development studies were undertaken and several reports were produced within the project (Clarke, 2002, Van der Sluis *et al.,* 2001a, 2003, Van Rooij *et al.,* 2003a, Van der Grift & Van der Sluis, 2003).

Box 1: Cheshire (LIFE internet site, http://www.lifeeconet.com/study_areas.htm)
The county of Cheshire lies in the north west region of the United Kingdom. It occupies the 'Midland Gap', a low lying plain between the Pennines in the east and the Welsh uplands in the south. The Rivers Dee and Mersey and their wide, level-bottomed valleys delimit the county's western and northern boundaries, eventually draining into large estuarine inlets. Rising from the plain to 200 metres, the mid-Cheshire sandstone ridge effectively divides the county into an eastern and western lowland.

Cheshire has been a main line of communication between the south and north-west of England since prehistoric times, and has proved attractive for settlement. Despite considerable post-war development and infrastructure construction, the major conurbations are still comparatively widely dispersed and surrounded by a rural hinterland, the majority of which is intensively farmed.

Cheshire covers 2107 sq. km, and has a population of 670,200. It is a county of contrasting landscapes - wooded river valleys and sandstone hills, meres and mosses, estuaries and heaths - which in turn support a variety of wildlife habitats, some of which are of international importance. In common with most lowland English counties, however, agricultural and economic development has had a substantial impact on Cheshire's biodiversity. All of the county's principal semi-natural habitats have suffered appreciable losses. Surviving habitats are strongly fragmented and isolated from each other, and vulnerable to external and internal change.

Extensive discussions are being held with all stakeholders to raise awareness of the concept of ecological networks, and to seek their support and active participation. The project recognises the importance of people's views and perceptions and these will be actively sought. The realisation of the network and its integration into policy sectors such as agriculture, forestry, fisheries, land-use planning, regional development, transport and tourism will only be possible with political and public support and co-operation.

The project is using the latest information technology (Geographical Information Systems - GIS), digital aerial photography and landscape ecology to analyse the Cheshire landscape. This has identified concentrations of habitats of high value for wildlife as well as areas that have the potential for the creation of new habitats and corridors for the movement of wildlife (Clarke, 2002).

The areas were visited by ALTERRA in April 2002 as part of this research project.

1.3 Problem definition

Due to fragmentation and environmental pressure biodiversity decreases: we are rapidly losing species that cannot survive anymore in the present landscape. The development of ecological networks is a strategy to curb this development, to spread risks, to support smaller wildlife populations and to integrate conservation with other functions.

The questions are:
- How should an ecological network for Cheshire be designed?
- Is the present situation limiting for species?
- Are the natural habitats for priority ecosystems of the required size, or do they need to be expanded?
- Are present habitats too far apart, or are they fragmented and if that is the case, where are linkages or stepping stones required?
- How should these corridors or stepping stones best be designed?

In other words: how does the present landscape function for species relevant for biodiversity, and how should the landscape be improved to meet the requirements of the species?

The ecological network needs to be assessed to diagnose the current situation for biodiversity. If a new situation is compared with the present situation, a kind of 'scenario', it is possible to assess the improvement in regard of the present situation. During the process it was decided for various reasons that a separate project should be formulated to develop the scenario, to reach a far more detailed scenario design, and detailing targets for different ambition levels. This scenario development was also done by ALTERRA (Van Rooij *et al.,* 2003a). This report should therefore be seen in relation with that separate study, on which it builds forth the analysis.

The final aim of this study was finally limited to the following questions:
- what is the ecological network for different ecosystems and wildlife populations, and
- in which way would the designed ecological network improve the situation for the selected species and ecosystems.

The aim of this study is to address these questions, so that the ecological network can be defined both at strategic level (for county policy) as well as for practical planning purposes.
It is necessary to study the landscape to see whether it functions as an effective network for certain key species. These key species are indicative for other species, information for the species selected can be extrapolated for the group of species. It is also important to compare the current situation with a designed improved network as a test of its likely effectiveness.
So far the work on the Cheshire Ecological Network has concentrated on areas of priority habitat and their spatial relationships (Clarke, 2002). It is now necessary to examine these habitats as the home for species, in particular key animal species considering functioning of ecosystems.

The ecological network is assessed to see whether available (fragments of) habitat are large enough for species to survive. This is done through an assessment of the

habitat requirements of specific selected species and the connectivity of the landscape with LARCH (the connectivity defines how easily species can move to other habitat patches, and is defined by the spatial configuration of habitat patches). The proposed habitat types to be analysed are woodlands, wetlands and rivers, grasslands, heathland and meres and mosses. The situation is assessed for a number of relevant species for each ecosystem. The selected species include some short-range species, e.g. reptiles, amphibians, mammals, which are all vulnerable for fragmentation. In addition, some bird species are included in the analysis. LARCH-SCAN is used to assess where the functional corridors are.
Based on the results it is possible to define areas where corridors should be developed to optimise the landscape configuration for wildlife. Roads are taken into account as barriers, to assess implications of fragmentation. LARCH is used with ecological profiles, developed for this purpose at ALTERRA.

In this report we present the results of a spatial analysis of the ecological network, and recommendations based on these results.

Chapter 2 describes the method that has been applied, more specifically the model LARCH, and all choices that were made, especially regarding the selected species, in discussion with the Steering Committee and the land use map which is very important for the final results. The analysed species are described, as well as parameters used for the model. The results are presented in Chapter 3, this is followed by discussion in Chapter 4, and recommendations and conclusions in Chapter 5. An explanation of frequently used terms in the Report is found below in par. 1.4.

1.4 Definitions of terms

connectivity: measure which defines how easily species can move to other habitat patches (spatial configuration of habitat patches).
carrying capacity: the maximum population of a species that a specific ecosystem can support indefinitely without deterioration of the character and quality of the resource, i.e., vegetation or soil
dispersal capacity: capacity of most individuals of a species (80%) to bridge distances to new, potential habitat
ecological network: network constituted of physically separated habitat patches, for a population of a particular species or a set of species with similar requirements, that exchanges individuals by dispersal.
habitat: an area which can support living organisms for at least part of its life cycle
habitat patch: spatially defined area of habitat for a species
key patch: a patch with a carrying capacity large enough to sustain a key population, and close enough to other patches to receive, on average, one immigrant per generation
key population: a relatively large, local population in a network, which is persistent under the condition of one immigrant per generation

LARCH: a landscape-ecological model (acronym for: Landscape ecological Analysis and Rules for the Configuration of Habitat), to visualise the viability of meta-populations in a fragmented environment.
LARCH-**SCAN**: (=Spatial Cohesion Analysis of Networks) assesses the spatial cohesion of each habitat patch, using habitat features and dispersal characteristics
local population: small population of at least one pair, in one habitat patch, or more habitat patches within the home range of a species. A local population on its own is not large enough to be sustainable. In this report a local population is usually meant to define an area large enough (sufficient habitat) to support a local population.
metapopulation: a set of local populations in an ecological network, connected by inter-patch dispersal.
Minimum Viable Population (MVP): a population with a probability of exactly 95% to survive 100 years under the assumption of zero immigration
patch species: a species for which the area is not so important, but a larger number of habitat species. Especially species vulnerable to stochastic processes and with low area requirements (like the *Great crested newt* or *Black darter*). These were analysed in a different way, in which viability is defined based on the number of patches.
persistent or viable population: a population with a probability of at least 95% to survive 100 years.
RU, Reproductive Unit: breeding pair, couple; often half of the potential population size, provided the sex ratio is equal.
scenario: image of a desirable and possible future situation.
spatial cohesion: a relative measure that can visualise the weakest parts in the ecological network for a certain species
viable population: see persistent population

Picture 3: North of Delamere forest, valley with Gorse near Norley village (control area 2)

Picture 4: Bob Bunce and Harald Kuipers, during fieldwork spring 2002

2 Analysis Method

2.1 Background: metapopulation theory

To define the ecological network function an analysis method has been developed based on the theory of metapopulations and ecological networks (see Box 2). The metapopulation theory states that in fragmented landscapes populations of animal species do not live in a continuous habitat but in a network of habitat patches, which are mutually connected by dispersal movements (Levins 1970, Andrén, 1994, Hanski & Gilpin, 1997, Opdam, 2002). Whether an ecological network can sustain a persistent population or not, depends on:

- characteristics of a species: habitat preference, home range, dispersal capacity
- the amount, shape and area of habitat patches in a landscape
- connectivity of the landscape, which defines how easily species can move to other habitat patches (spatial configuration of habitat patches).

The network function of a landscape can be tested on the basis of a number of species, which can be related to an ecosystem type. The ecosystems that are evaluated combine, in fact, to form the landscape. Specific terms used are explained in paragraph 1.4.

Box 2: Concept of metapopulations and ecological networks

When natural habitat becomes fragmented as a result of landscape changes, small isolated patches are often too small to sustain viable populations. These small, local populations are always at risk from extinction, due to local 'disasters' or stochastic processes, e.g. fire, pollution, or storms. Occasionally breeding may also fail, with disastrous consequences for small populations of few individuals. So the small populations regularly become extinct. When these local populations are connected in an ecological network, the total area of habitat patches can offer possibilities for persistent populations of species.

Large populations with a very low probability of extinction, the so-called 'key populations', constitute the strong parts in a metapopulation occupying an ecological network (Verboom *et al.,* 2001). From these 'key patches' a net flow of individuals to other habitat patches in an ecological network takes place. In this way immigration occurs from key patches to local populations that became extinct. If there are many patches this process can increase overall sustainability. We consider this a metapopulation (Levins 1970, Andrén 1994). A metapopulation is sustainable if the chance of extinction is less than 5% in 100 years (Shaffer 1981, Verboom *et al.,* 2001).

Standards used to decide whether a metapopulation is sustainable or not are specific for each species. Small, short living species (for example, insects) are more vulnerable and require more individuals for a persistent population than larger, long living species (like the beaver). For less mobile species habitat patches should be situated closer together to form part of a coherent ecological network. On the other hand, the area demands of e.g. insects for habitat are smaller.

2.2 LARCH Model

The landscape-ecological model LARCH (Landscape ecological Analysis and Rules for the Configuration of Habitat), developed at ALTERRA, is a tool to visualise the viability of metapopulations in a fragmented environment.

LARCH provides information on the metapopulation structure and population viability in relation to habitat distribution and carrying capacity. LARCH-SCAN assesses spatial cohesion of potential habitat, and provides information on the best ecological corridors in the landscape.
The model LARCH is run with a land use map or vegetation map as input.
In the following paragraphs the functioning of LARCH is explained in more detail.

It should be kept in mind that the results from LARCH present the potential distribution of a species, i.e. disregarding the quality of an area.

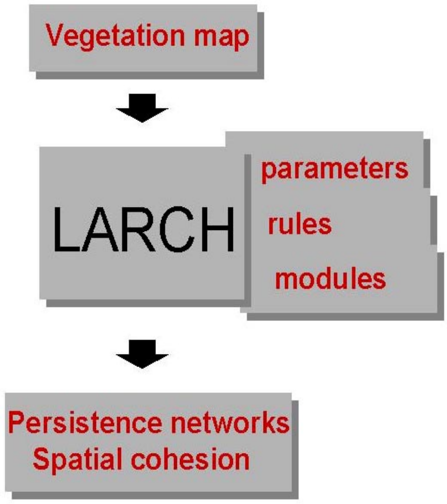


Figure 1: set-up of model LARCH

2.2.1 LARCH

LARCH is designed as an expert system, used for scenario analysis and policy evaluation. The model has been fully described elsewhere (Pouwels *et al.,* 2002a, Groot Bruinderink *et al.,* 2003, Chardon *et al.,* 2000, Van der Sluis & Chardon, 2001, Verboom *et al.,* 2001, Van der Sluis *et al.,* 2001a, 2001b, 2003, Van Rooij *et al.,* 2000, 2003b) and will only be discussed briefly here.

The principles of LARCH are simple: a species is selected, relevant for nature conservation or an indicator species representing a suite of species, to assess the natural areas. The size of a natural area (habitat patch) determines the potential number of individuals of a specific species it can contain. The distance to neighbouring areas determines whether it belongs to a network for the species. The carrying capacity of the network determines whether it can contain a viable population. If that is the case, the network population is viable or sustainable for the species.

LARCH requires input in the form of habitat data (e.g. a vegetation or land use map) and ecological parameters (e.g. home range, dispersal distance, carrying capacity for all habitat types): LARCH parameters are based on literature and empirical studies. Simulations with the dynamic population model METAPHOR have been carried out over the past twelve years to validate parameters and standards for the model (Foppen *et al.,* 1999, Verboom *et al.,* 1993, 2001, Vos *et al.,* 2001, 2002, Chardon, 2001). Actual species distribution or abundance data are not required for LARCH since the assessment is based on the potential for an ecological network of a species. The following steps describe how LARCH models the habitat, and evaluates the network population, the viability of the network population and spatial cohesion (fig. 2).

- Habitat modelling

The Ordnance Survey MasterMap (fig. 2a) is used as the basis to define the relevant habitats for the selected species. The habitat suitability for each vegetation type is rated as optimal, sub-optimal or marginal. The carrying capacity for each habitat type is defined (fig. 2b), based on population densities which is derived from literature, and in some cases expert knowledge and the LARCH database information. The number of individuals that can be supported by the habitat patch are calculated on the basis of the carrying capacity, suitability rating and the size of the area.
Further criteria are possible, e.g. altitude. From literature it is usually known which altitude range is acceptable for a species, and all habitat outside that range can be excluded in the analysis.

- Defining local populations

Suitable patches that are located near to each other allow for movement of individuals on a daily basis, the so-called home-range. The home-range can be estimated from literature. The patches within the home range of a species form part of the local network or territory of the species. Such habitat patches are fused into a cluster and considered to represent a local population (fig. 2c). In the event that species are vulnerable for barriers, roads or other features are taken into account. Barriers, such as busy roads and waterways with sheet-piled banks, may hinder the fusion of habitat sites into a local population, even though they are located within the network distance. This is particularly the case for less mobile species like small mammals, reptiles and amphibians. However, this requires more parameters for the model, e.g. traffic density of specific roads or railway lines, and sensitivity of the species to traffic, etc. A total number of Reproductive units RU (Fahrig, 2001) is defined for the local population. Areas which are too small to support one Reproductive Unit are further disregarded in the analysis.

- Determining reproductive units (territories/families) in an area and key populations

The areas that meet the threshold are habitat patches where, potentially, a population may be able to exist. However, one reproductive unit is not enough to maintain a viable population. A population is only large enough to cope with normal fluctuations in the population (see Box 2) if the population is sufficiently large. This is called a 'Minimal Viable Population' (MVP). In many fragmented landscapes, this is no longer a realistic option and we speak instead of key populations. The number of breeding pairs (RUs) for a key population should be large enough to survive the majority of normal number fluctuations a population is faced with. The probability of extinction for a key population within a network is less than 5% in 100 years, assuming there is an immigration of 1 or more individuals per year from other local populations in the same network (Verboom *et al.,* 2001). If present, key populations can form the core of a network (Groot Bruinderink *et al.,* 2003).

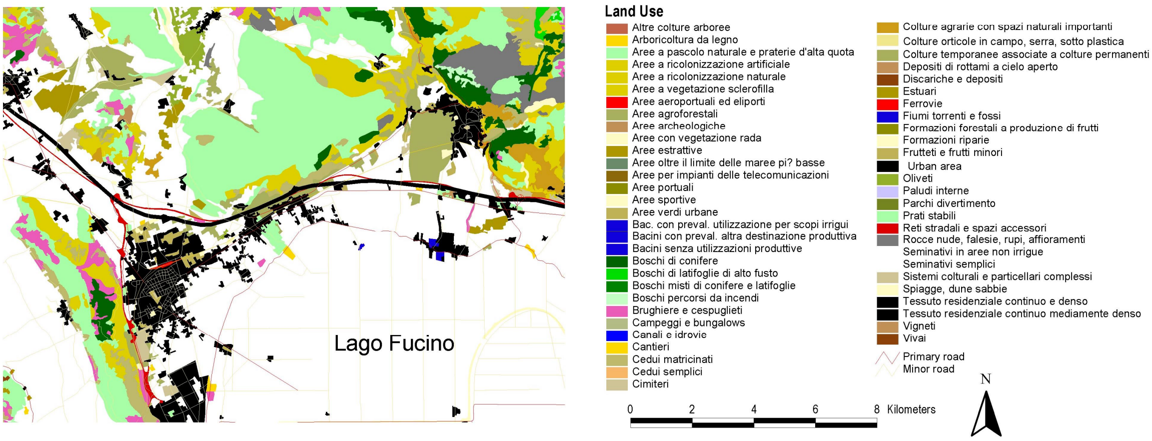
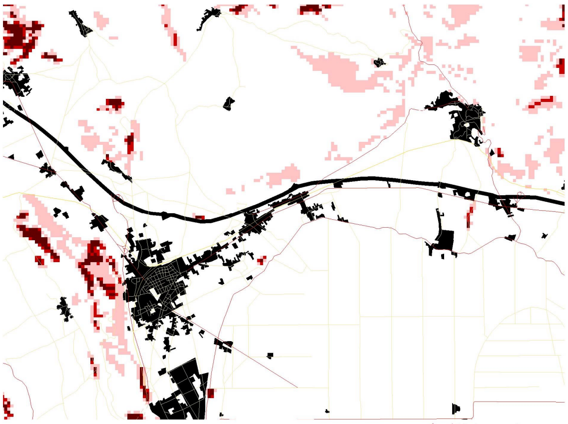


fig. 2A: Input for LARCH *is Land Use map (in this example from Abruzzo)*



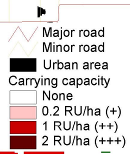


fig. 2B: Assessment carrying capacity

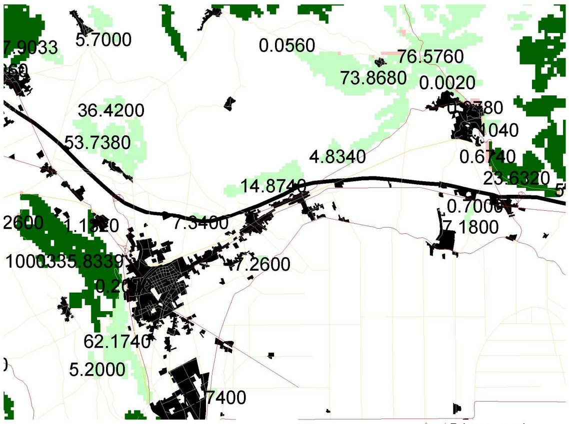


fig. 2C: Identification of local populations and key-patches based on carrying capacity

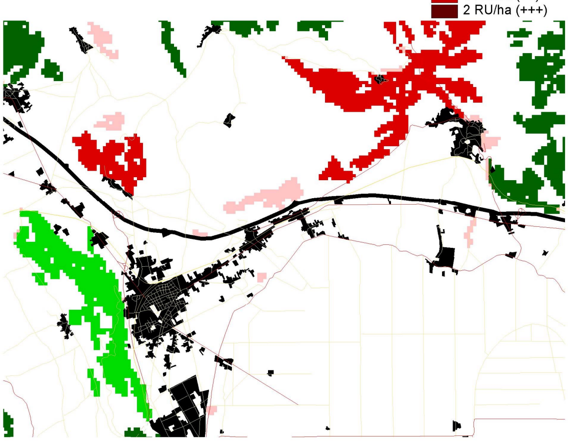
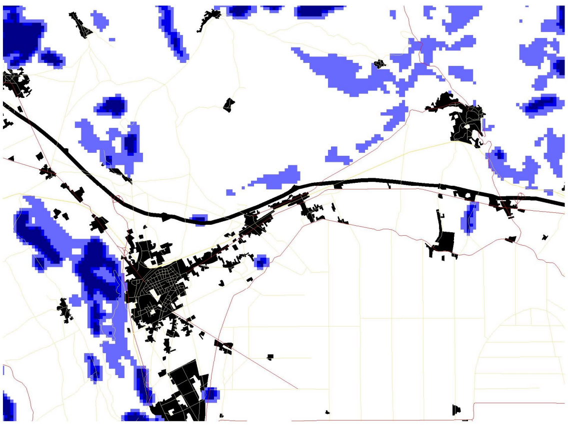


fig. 2D: Identification of network populations and sustainability of network



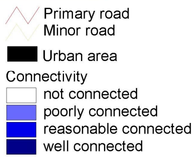


fig. 2E: LARCH-*SCAN, analysis of spatial cohesion*

Figure 2: LARCH *analysis procedure: fig. 2A to 2D indicate the steps taken in* LARCH *to come to a viability assessment on the basis of the habitat map. Fig. 2E illustrates the spatial cohesion. See text for further explanation.*

- Determining the boundaries of the network

Sites located within dispersal distance of a species can be considered to belong to one network. A network is formed by local populations that are connected to each other, because the animals can move from one site to another when searching for a new habitat site (dispersal). So in most cases, a set of local populations will form a population network, which may render it viable or sustainable (fig. 2D).
This is dependent on the total number of animals present, but also on the rate of fragmentation: is it a network population with a key-population, or does the network consist of only small local populations?
In delineating networks, the effects of barriers (like roads) can also be included. In addition, altitude can in some cases limit network formation.

- Determining the viability of the network

In the final step the viability of the network is determined: the viability (or otherwise) of each population is indicated, and whether it meets the size requirements of a MVP or key population (fig. 2D). The criterion used is the chance of a (network) population still existing after 100 years are greater than 95% (Shaffer 1981, Verboom *et al.,* 2001). Here it is assumed that the area does not undergo any changes, or only slight changes, during this period of time.
To define the viability of networks, either with or without key population, standards have been established in the form of the minimum required number RUs for a network. This information is derived from a standard for the minimum number of reproducing individuals required. The exact standard depends upon the species group and whether or not a key population exists within the network (Verboom *et al.,* 2001). A Marsh heron in a network with at least a key population, for example, requires a total of 60 reproducing females for a sustainable (meta-) population.

2.2.2 LARCH-SCAN

Besides surface area, the connectivity or spatial cohesion is also important (Verboom *et al.,* 1993, Hanski & Gilpin, 1997). The surface area determines the expected number of individuals in an area, while the connectivity primarily depends upon the carrying capacity of a patch and dispersal capacity of a species. The dispersal distance of a Smooth newt is much smaller than that of a large mammal, such as the Red deer. In effect, this dispersal distance defines whether or not habitat patches will form part of a network for a species. A Red deer might utilise forest areas within a radius of 50 km, whereas a Smooth newt only utilises habitat within a radius of 300 m from its breeding site.

LARCH-SCAN (=Spatial Cohesion Analysis of Networks) assesses the spatial cohesion of each habitat patch, using habitat features and dispersal characteristics (Vos *et al.,* 2001, Groot Bruinderink *et al.,* 2003, Sluis & Chardon, 2001). The dispersal range of a species in a landscape can be described by a function in which alpha is the key parameter (Box 2), describing the distance over which potential source patches can still deliver immigrating individuals (Hanski & Gilpin, 1997). The extent of potential habitat surrounding a cell that contributes to this measure of

connectivity is determined for each grid cell. Here, the value of the potential habitat for a grid cell depends upon the carrying capacity (or the size) of the habitat. Because the method examines each individual grid cell, the degree of connection between habitats is considered in this measure as well as the surface areas of the habitats themselves. After all, a grid located in the middle of a very large habitat patch will have a high connectivity value. The spatial cohesion (fig. 2E) provides an insight into the degree that areas are connected and the potential of an area to function as a corridor for species.
In defining spatial cohesion, roads have also been taken into account for some species.

2.3 Basemaps

Several available maps were assessed on its suitability for habitat modelling. The Land Cover Map 2000 (CEH) became available soon after the onset of the project. LCM2000 is derived from a computer classification of satellite scenes, obtained mainly from Landsat satellites. It also incorporates information derived from other datasets. LCM2000 is a vector database, and shows areas of land as 'parcels' or polygons (further specifications are found on: http://www.ceh.ac.uk/data/lcm/LCM2000.shtm). The advantage of LCM2000 is the legend, which resembles very much natural vegetation types. However, for the purpose of this project the map data was too course, and included too many mis classifications at this stage.
For that reason a choice was made for the Ordnance Survey MasterMap, which became available soon thereafter. The typology of the OS MasterMap is based on the topographical information of the Ordnance Survey map. For habitat modelling it has some limitations because peatlands (meres and mosses) are not well defined within this legend type, neither are natural grassland and rivers and streams well defined. For that reason additional maps were used: maps from the Cheshire Peatland inventory, Grassland Inventory and Heathland inventory, Rivers and streams, the Ancient Woodland map and a Pond map (Pond-Life Project).

2.3.1 OS MasterMap in Cheshire County

The Ordnance Survey MasterMap forms the basis for the LARCH analysis. OS MasterMap is supplied as very accurately digitised vector data. and with so many landcover types and individual polygons it is a very large dataset for the whole of Cheshire. Ordnance Survey mapping data has an absolute positional accuracy in rural areas at 1:2500 scale (Absolute positional accuracy is a measure that indicates how closely the coordinates of a point in Ordnance Survey map data agree with the true National Grid coordinates of the same point on the ground). Further specifications are found on: http://www.ordnancesurvey.co.uk/downloads/mm/OS_MasterMap_user_guide_v2.1.pdf.
Because of the volume of data, the map has been converted to both a 5 and 10 m grid. In doing so, a wider area of approximately 25 km was converted.

Table 1 lists the distribution and quantity of land use types present in Cheshire. It is clear that the area is intensively used, with General Surface (mainly sowed fields, cultivated area) accounting for 80% of the land use: less than the other study area in Region Emilia-Romagna (Sluis *et al.,* 2001), but much more than Region Abruzzo (Sluis *et al.,* 2003). Urban or similar habitats form some 5%, and natural habitats relevant for this analysis account only for some 13% of the total area.

Some minor areas were not included in the habitat maps, a part of the Wirral (which is not administratively part of Cheshire though) and Stanlow banks and Ince banks, north of Ellesmere.

The contents of the maps were briefly checked during a three-day field visit in Cheshire (par. 2.3.2).

Table 1: Land Use Types most used for habitat classification (generalised)

Habitat	Area (ha)	Percentage
General Surface	204342	80.04
Nonconiferous Trees	10223	4.00
Marsh Reeds or Saltmarsh	1997	0.78
Heath	2003	0.78
Coppice Or Osiers	34.79	0.01
Coniferous Trees	6001.64	2.35
Boulders	448.63	0.18
Landform Slope	637.84	0.25
Landform Cliff	5.05	0.00
Inland Water	3937.21	1.54
Gen. surface Multi Surface (Build-up area)	13618	5.33
Tidal Water	1742	0.68
Roadsides	4032	1.58
Scrub	869	0.34
Rough Grassland	5169	2.02
Rock	28	0.01
Orchard	198	0.08
SUM	255287	100.00

2.3.2 Field check on map data

The quality of the analysis results is especially determined by the quality of the base maps and the parameters used for LARCH. It is important to know for the assessment of the ecological network whether e.g. all woodland patches have been mapped or not. To be able to assess the reliability of results, a check on the accuracy of the map was carried out.

For this check on the map, 3 sample areas were chosen at random, in Kingsley and Delamere - areas with more natural habitat present (sample area 1 and 2) and an agricultural area in Lower Kinnerton (sample area 3; fig. 2).

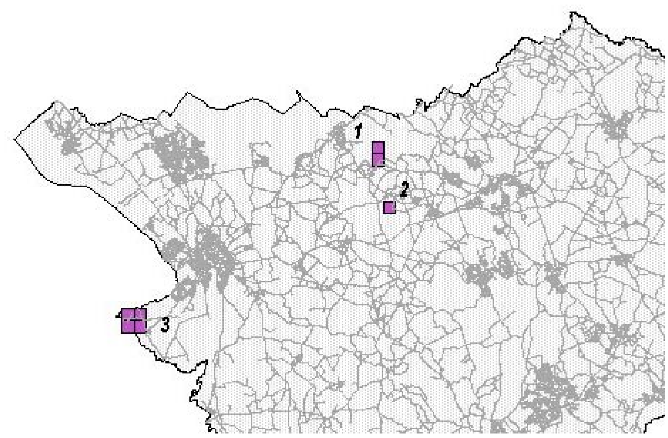


Figure 3: Location of the sample areas

Squares 1 and 2 are 1 by 1 km, i.e. 100 hectares each, at site 3 two squares of 100 ha each were sampled. For each square, land use has been mapped. A percentage sum of land use types was estimated.

Table 2: observed versus mapped area, near Kingston (area 1)

Land use Kingston (area 1)	Land Use OS MasterMap (%)	Observed area (%)
General surface	87.09	76.10
General surface, multi surface	5.80	5.80
Inland water	1.68	1.68
Coniferous trees	1.21	1.21
Marsh reeds	0.71	1.71
Nonconiferous trees	3.50	4.50
Rough grassland	-	9.00

For the Kingston area (a river valley with Ancient woodland) differences are small, the difference is mainly in general surface, part of which is rough grassland, and slightly more marshland and non-coniferous forest (Table 2).
Due to the many hedges present, it was not possible to map these in detail.

Table 3: observed versus mapped area, South of Delamere forest (area 2)

Land use Delamere forest (area 2)	Land use OS MasterMap (%)	Observed area (%)
General surface	85.71	85.69
General surface, multi surface	5.71	5.71
Inland water	1.65	1.65
Coniferous trees	0.72	0.77
Marsh reeds	0.69	0.69
Nonconiferous trees	3.54	3.50
Rough grassland	1.98	1.99

Near Delamere a hilly area was mapped with many small landscape elements (Table 3) Differences are found in coniferous and non-coniferous forests, in some cases these units were exchanged, which can also be a matter of dominance of species in mixed forest, or an interpretation difference.

Table 4: observed versus mapped area Lower-Kinnerton (area 3)

Land use Lower Kinnerton (area 3)	Land use OS MasterMap (%)	Observed area (%)
General surface	88.50	88.52
General surface, multi surface	5.90	5.90
Inland water	1.71	1.71
Coniferous trees	0.00	0.00
Marsh reeds	1.24	1.24
Nonconiferous trees	2.28	2.26
Rough grassland	0.38	0.38

Two squares were mapped at Lower Kinnerton, generally an open landscape with large fields (Table 4). A small difference occurs in non-coniferous trees, of which one area might be wrongly classified or changed. In addition, in the field inventory several ponds were observed, which were not mapped in the MasterMap.

Overall is shown that differences between observed area and mapped area are almost neglectable, at this scale it won't bear any effects on the results. It is obvious that this visual assessment is just an indication of actual land use. No check was carried out afterwards to see whether changes in land use, or errors in the control samples cause large differences.
More serious might be that small landscape elements such as woodrows, hedges, ditches and so on are not included. This gives an underestimate of the real situation in the field, both for potential biodiversity and habitat present as well as for dispersal of migrating species. It might be assumed, therefore, that landscape connectivity is better than the map suggests.

Also specific habitat types, such as Meres and mosses, and ancient forests are not mapped. This was overcome by use of other maps, with a much lower accuracy though, or sometimes with outdated information. Peatlands classified as such were at times remnants of poor quality, the habitat being of little use for the peatland species modeled in this study (control area 2).
In some cases the information on ancient woodland differed from the information on the MasterMap. The boundaries differed slightly, which won't be of much influence on the results. Also pine forest was observed, where the map indicated Ancient woodland (control area 1). This might be based on features present e.g. old forest plants. For the analysis this will result in some errors, e.g. for a species like the *Nuthatch*.

2.4 Species selected for analysis

A table was prepared with relevant species for Cheshire, to be analysed with LARCH (Appendix 1).

Based on a number of criteria a further selection of species for analysis was made by the Steering Committee:
- Species should not be too rare, not too common, and ecologically relevant
- Species should preferably have been analysed before with LARCH

- The scale of the species (home-range) should be relevant for the scale of the area
- If possible, species should already have been analysed in one of the other Life-Econet studies, for comparative purposes

Based on these criteria 15 species were selected for analysis with LARCH (Table 5). The selected species form target species for local policy, or are representative for the different ecosystems analysed. It is not necessary that the selected species have a wide distribution in Cheshire, since ecological profiles are used, and the species is representative for a group of species with these characteristics.

Table 5: Selected species for analysis with LARCH; shaded are species sensitive for barriers

Dispersal capacity Priority Habitat Type	Barrier sensitivity	small range (< 5 km)	medium range (5-15 km)	large range (15-50 km)
Meres/mosses	Sensitive			
	Not sensitive		Green hairstreak	Black darter Four-spotted chaser
Heathland	Sensitive	Common lizard		
	Not sensitive		Stonechat Small heath	
Wetlands/rivers	Sensitive	Water vole		
	Not sensitive		Banded demoiselle Sedge warbler	
Woodland	Sensitive	Dormouse		
	Not sensitive	Purple hairstreak	Nuthatch	
Grassland – unimproved and semi-improved	Sensitive	Great crested newt		
	Not sensitive	Common blue		Barn owl

2.5 Spatial profiles

The species selected differ in their habitat requirements and dispersal range (Table 6). Some species have a very limited range, of less than a kilometre, whereas some dragonflies and large birds might have a range of 50 km or more. Similarly for habitat requirements for a key population: dragonflies will persist with a small area, containing few ponds, whereas a *Barn owl* requires extended areas for foraging. In the table the position of the species is indicated. In the following paragraphs the ecoprofiles are described for each ecosystem.

Table 6: Dispersal distance and habitat requirements for Species profiles, and attribution to ecosystems: ***Woodland, Rivers & Streams, Meres and Mosses, Heathland, Grassland***

Ka \ Nd	<1	1-3	3-7	7-15	15-35	>35
0-0.1		**Purple hairstreak**	**Common Blue**	**Banded demoiselle**		**Four-spotted chaser** **Black darter**
0.1-1	**Common lizard** **Great crested newt**	**Dormouse**	**Nuthatch** **Water Vole** **Small heath** **Green hairstreak**			
1-5				**Sedge warbler**		
5-10						
10-50				**Stonechat**		
50-150						**Barn owl**
>150						

KA = key area (km^2)
ND = net distance (km)

2.5.1 Meres and mosses

2.5.1.1 Black darter

The *Black darter (Sympetrum danae)* occurs from the Pennine fringe to the mosses of the Cheshire plain. Its habitat consists of moorlands, peatmoss and raised bogs. The *Black darter* breeds in oligotrophic ponds, drainage ditches and bog pools. Other waters are rarely utilised (Wasscher & Velzen.1998, Askew 1988). Some Sphagnum cover is preferred, but is not essential (ref darters). In the Netherlands the species seems to be expanding its range (Geijskes & van Tol 1983).

The *Black darter* does not move far from its breeding places, but it is reported to have migrated to the Irish Coast (Askew 1988), and also invasions from mainland Europe might have occurred (pers. Comm. B. Roberts). Its home-range is estimated to be 1000 m, with network distance of 50000 m.
http://www.brocross.com/dfly/species/danae.htm
The species has been analysed as a 'patch-species'.

The selected habitat of the *Black darter* consists of:

Table 7: Relevant habitat types in the land use map for Black darter

Habitat type	Importance
Peatland – in combination with water	++
heather – in combination with water	++

2.5.1.2 Green hairstreak

The *Green hairstreak (Callophrys rubi)* occurs mainly on the Pennine foothills, where it is fairly widespread and numbers are fairly stable (Shaw, 1999). In the Cheshire Plain the species has almost disappeared. The foodplants of *Green hairstreak* consist of Bilberry (*Vaccinum myrtillis*) and Cranberry (*V. oxycoccus*), i.e. dry acid woods, moorlands and heathlands (Rose 1981), lowland heaths and mosses (Shaw, 1999).

Green hairstreak is described as a species with poor powers of dispersal (Shaw, 1999). The Millennium Atlas (Asher *et al.,* 2001) says 'Little is known about the mobility of this species, but occasional records from gardens suggest that some dispersal from breeding sites occurs in most years'. The species was observed 2 miles away from the nearest regular colony in Delamere Forest: indicating that the dispersal distance is at least 3000 m.

The home-range is 500 m, network distance 5000 m. Area requirements for a population is at least 64 ha, with species densities ranging from 4/ha up to 64/ha (Bink, 1992). Density is estimated to be on average some 10/ha, minimal required area being 50 ha.
The species might be analysed as a 'patch-species'.
The selected habitat of the *Green hairstreak* consists of (Table 7):

Table 8: Relevant habitat types in the land use map for Green hairstreak

Habitat type	Importance
Coniferous trees	+
Coniferous trees; other	++
Non-coniferous trees	++
Non-coniferous trees (scattered)	++
Rough grassland; heath	+++
Peatland	+++
Heath	++

2.5.1.3 Four-spotted chaser

The *Four-spotted chaser (Libellula quadrimaculata)* occurs in lakes and ponds with abundant marginal vegetation. Its distribution area correlates with the principal acid bogs and associated heathland. Its breeding area is the margin of shallow ponds and lakes, with a moderate growth of emergent vegetation as well as open water. Ponds on mosses and moors are used, but so are water bodies in open woodlands (Askew 1988) and in heathlands (Geijskes & van Tol 1983). Large numbers are found in oligotrophic water (Geijskes & van Tol 1983).

The females spend little time near the water (Geijskes & van Tol 1983). The species is a well-known migrant (Dumont & Hinnekind 1973 in Askew 1988, Wasscher & Velzen, 1999). The home-range is estimated to be 1000 m, dispersal distance might be 50 km (Dumont). http://www.brocross.com/dfly/species/quad.htm. The species is also analysed as a patch-species.
The selected habitat of the *Four-spotted chaser* consists of (Table 8):

Table 9: Relevant habitat types in the land use map for Four-spotted chaser

Habitat type	Importance
Inland water	++
Inland water; natural environment	++
Peatland ponds	+++
Ponds	++

2.5.2 Heathland

2.5.2.1 Stonechat

The *Stonechat* (*Saxicola torquata*) occurs in most of central and South-eastern Europe (Hagemeijer & Blair, 1997, pp. 528). It has suffered a strong decline in Britain, from 30-60000 breeding pairs to 8500-21500, due to changed grazing and burning management.
Densities in optimal areas of 15-25 bp/10 ha, so approximately 200 Breeding pairs/100 ha (Hagemeijer & Blair, 1997). There has been a marked decline of the *Stonechat*, due to agricultural intensification, but also climate has marked effects on the population size and its distribution.

Preferred habitat is uneven, often craggy landscapes with some gorse and coarse heather. Moist areas with dunes in the vicinity are also used.
In Cheshire the *Stonechat* only occurs in low numbers and low densities, recently at most only 5 breeding pairs. The species has shown a decline, partly as a result of severe winters and conversion of uncultivated lands. The *Stonechat* occurs only in coastal heathland. The sandstone hills and sand dunes of the Wirral (just outside Cheshire) are considered the best areas (Guest *et al.,* 1992).
Its habitat consists of extensively cultivated agricultural areas with varied grass cover, and especially the shrub-like habitats in between (Burton & Hayman 1976). Grassland with tall herbs and shrubs forms it prime habitat.

The home-range of the *Stonechat* is 200 m., the network distance 10000 m. Densities are estimated at some 7.5 RE/100 ha. in optimal habitat.
The selected habitat along the coast of the *Stonechat* consists of (Table 10):

Table 10: Relevant habitat types in the land use map for Stonechat

Habitat type	Importance
Cliff	++
Heath	++
Rough grassland; heath	+
Scrub; rough grassland	+

2.5.2.2 Small heath

The *Small heath* (*Coenonympha pamphilus*) occurs in low numbers on coastal heathland and the Pennine foothills (Shaw, 1999). The butterfly is absent from many localities in the Cheshire Plain, it has a patchy and fragmented distribution and is a scarce species. Over recent years the species has shown a decline, which has been reflected elsewhere in Britain. The reason for this decline is unknown (Shaw, 2001), but it probably might be attributed to replacement of native grassland by arable crops or improved grassland (pers. comm. B. Roberts).

Its habitat consists of unimproved, well-drained grasslands, with sparsely growing fine-leaved grasses, in the hills especially on short turf in areas grazed by sheep

(Shaw, 1999). The *Small heath* is also observed at old industrial areas around Northwich (Shaw, 2001).
According to the Millennium Atlas (Asher *et al.,* 2001) 'Mobility in this species has not been studied in detail. The *Small heath* is capable of moving some distance and individuals have been found several kilometres from known populations'. Whenever areas of suitable habitat are created relatively close to existing populations, they might be colonised by the *Small heath*.

The home-range of this species is estimated at 250 m. Network distance is estimated to be some 5000 m. Area requirements for a population is at least 1 ha, with species densities ranging from 4/ha up to 64/ha (Bink, 1992), on average estimated at 10/ha. Minimum required area is some 50 ha.

The selected habitat of the *Small heath* consists of (Table 11):

Table 11: Relevant habitat types in the land use map for Small heath

Habitat type	Importance
Cliff	+
Heath	++
Rough grassland; heath	+++
Scrub; rough grassland	+

2.5.2.3 Common lizard[1]

The *Common lizard* (*Lacerta vivipara*) occupies many different habitats, especially where there is some dense cover adjacent to open areas for basking in the sun. Good, structurally varied vegetation, with open patches allowing basking spots but at the same time providing physical cover from predators, is essential. *Common lizard*s often use woodpiles, fence posts and similar structures for basking.

From mid-October *Lacerta vivipara* will seek an appropriate place to hibernate. Walls, foundations, old railway sleepers, rock/wood piles, manure heaps and mammal burrows are all used. Preferred hibernation sites should be on high, south facing areas that stay dry right through until March when *Lacerta vivipara* comes out of hibernation.

Lacerta vivipara may migrate distances of more than a mile depending on the constraints of the available habitat. The home-range is some 250 m, network distance 1000 m. (pers. comm. Rob Bugter). Density is maximal 400/100 ha., minimal required area 25 ha.
The selected habitat of the *Common lizard* consists of (Table 12):

[1] Edited by: Gail Butterill & Richard Storey, Cheshire Wildlife Trust May 2002

Table 12: Relevant habitat types in the land use map for Common lizard

Habitat type	Importance
Heathland	+++
Heathland, mixed	+++
Coastal cliff tops	++
Peatlands	+++
Woodland Edge	++
Non coniferous trees – scattered	+
Coniferous trees – scattered	+
Non coniferous trees – scattered, mixed	+
Rough Grassland	++
Railway sidings	+
Road side verges	+

2.5.3 Wetlands/rivers

2.5.3.1 Water vole

The *Water vole* (*Arvicola terrestris*) breeds in most of Europe (Mitchell-Jones, 1999). It inhabits slow-flowing streams, ditches, dykes and rivers. Animals usually occur within 5 m. from the water, although they are occasionally caught away from the water (Woodroffe, 2000, Broekhuizen *et al.,* 1992). It is important that water levels do not fluctuate much (www: Wildlifetrust.org.uk/cornwall/species/wvoles). The banks should be well vegetated, to protect animals for predators. Ditches or canals should be preferably deep, so that they don't freeze down to the bottom or dry out. They may be 1-3 m wide, with steep and treeless banks (pers. comm. F. Niewold). Spatial analysis shows that a relatively high layering of the vegetation is preferred (Woodroffe, 2000).

Habitat fragmentation might pose a threat for this species (Wilcove *et al.,* 1986) and linking fragmented populations is recommended (English Nature, 1999). Roads can be considered a barrier. However, culverts underneath roads allow for migration of animals. For that reason barriers are not taken into account in the analysis.

For modelling purposes habitat within 25 m. from streams are selected.
Home-ranges of radio-tracked animals measured up to 240 m. were found. Depending on overall population density, season and habitat quality the length of territory ranges from 30m to 150m (for females) and from 60m to 300m for males. The dispersal distance might be 3200 m. The densities may differ much, from 2.5-6 RU per km sq up to 29 per km sq. (based on English research, pers. comm. F. Niewold)
A local distance of 250 m. is used, and a network distance of 3200 m. Optimal densities are 30 RU/km sq. Dispersal distance might be 3-5 km. (pers. comm. F. Niewold)
The selected habitat of the *Water vole* consists of (Table 13):

Table 13: Relevant habitat types in the land use map for the Water vole

Habitat type – adjoining streams	Importance
Inland water	+++
Inland water, natural environment	+++
Marsh reeds or salt marsh – edge	++
Marsh reeds or salt marsh, scrub – edge	++
Scrub, non-coniferous trees, marsh reeds –edge	++

2.5.3.2 Banded demoiselle

The *Banded demoiselle* (*Calopteryx splendens*) is locally common in suitable habitats. The flight period is May to August. The *Banded demoiselle* is found on rivers and streams of moderate to slow-flow with beds of silt and marginal vegetation, but also on canals and occasionally lakes with more or less muddy beds (Askew 1988, Gabb & Kitching, 1992). Most time is spent at rest on waterside vegetation.

Its favoured habitat is unmodified rivers, particularly when meandering through meadowland. This explains why the species is relatively rare, since man has modified many river habitats.

Adult dragonflies move up to hundreds of meters away from the water in meadows (Geijskes & van Tol 1983). Observations in Dutch dune areas at distances of at least 50 km from other wetlands demonstrate the large dispersal distance of this species (Wasscher & Velzen, 1998, http://www.brocross.com/dfly/species/splend.htm)

The home-range measures up to 800 m, network distance some 10000 m. Appr. 1000 m. of river bank length is required for a local population. Minimum required area is 100 m2. The species also requires plenty of tall bankside vegetation and patches of shade and light rather than completely open to the light. This reduces the suitability of pastureland if the edges of the stream are grazed or cut right back (Kitching, pers. com.). Therefore, natural vegetation adjoining rivers was selected as habitat.

The selected habitat of the *Banded demoiselle* consists of (Table 14):

Table 14: Relevant habitat types in the land use map for Banded demoiselle

Habitat type	Importance
Inland water, adjoining natural vegetation	++
Rivers, adjoining natural vegetation	+++

The results are the best attainable at this stage, due to lack of detailed information on rivers. Only the selection of suitable streams by hand might improve modelling results.

2.5.3.3 Sedge warbler

The *Sedge warbler* (*Acrocephalus schoenobaenus*) was formerly very common in the Cheshire plains, abundant in marshy land around meres, by marl pits, and along brooks and ditches (Guest *et al.,* 1992). The species has strongly declined as a result of improved drainage and dereliction (in particular of mill ponds). It is now mainly restricted to wet marshy strongholds such as flashes, canals, meres, sludge pools and the like. The species stronghold in the region is at Woolston (just outside Cheshire), with over 100 pairs during the past decades (ref birds). The species has vanished from farmland, although spring migrants are occasionally heard singing from the scrub around marl pits. The total Cheshire population is probably 500-650 pairs.
Densities of *Sedge warbler* might be highest in Eastern Europe, with 2000 breeding pairs/50 km. In the UK and the Netherlands densities are 1000 bp/50 km (Hagemeijer & Blair, 1997).
The species breeds up to 200 m. away from the water, in shrubs and grassland (pers. Comm. B. Martin).
Home-range of this species is limited with only 200 m., network distance is 10000 m. The selected habitat of the *Sedge warbler* consists of (Table 15):

Table 15: Relevant habitat types in the land use map for Sedge warbler

Habitat type	Importance
Inland water	++
Inland water – natural environment	++
Non-coniferous strees (scatt.); r. grassland	++
Rough grassland	+++
Rough grassland; scrub	+++

2.5.4 Woodland

2.5.4.1 Purple hairstreak

The *Purple hairstreak* (*Quercusia quercus*) occurs in well-wooded areas, but is also found on isolated Oaks along mature hedgerows. Most colonies are found on Pedunculate Oak (*Quercus robur*) but it is also found on Turkey Oak (*Q. cerris*). It has always been a scarce species in Cheshire, at one stage it was even considered to be extinct (Boyd 1946). Recent survey work has revealed many new breeding sites, and probably the species has often been overlooked during field surveys (Shaw, 2001).

The species is presently expanding its range in Cheshire, and moving along oaks in hedgerows. *Purple hairstreak* has spread during the last two decades in a southwesterly and northeasterly direction, which shows that the dispersal capacity is good in this landscape (pers. comm. B. Roberts). It is most common on the Wirral (which is not part of Cheshire county) and in the south west of Cheshire, but has now colonised many other areas of the county, even as far as the north east (Shaw, 2001).
Little is known about its sensitivity to barriers although it is known that the species seems bound to trees. It has been observed flying across small open fields, up to 200-300m away from the nearest Oak. (pers. comm. B. Roberts).

The Millennium Atlas of Butterflies in Britain and Ireland says 'The *Purple hairstreak* is not a highly mobile species but occasional dispersal and colonization have been observed. A mass migration was recorded following a population build up in the hot, dry summer of 1976' (Asher *et al.,* 2001).
The home-range is 250 m., the dispersal distance is estimated to be 2000 m. Area requirements for a population is at least 1 ha, with species densities ranging from 16/ha up to 260/ha (Bink, 1992). The species generally does not appear above 200 m. so an altitude cut-off was used to model the species' habitat.

The selected habitat of the *Purple hairstreak* consists of (Table 16):

Table 16: Relevant habitat types in the land use map for Purple hairstreak

Habitat type	Importance
Non-coniferous trees	++
Non-coniferous trees – mixed	+
Non-coniferous trees (scattered)	++
Non-coniferous trees (scattered) - mixed	+
Scrub, non-coniferous trees	+
Ancient woodland	+++

2.5.4.2 Dormouse[2]

In Britain the *Dormouse* (*Muscardinus avellanarius*) occurs in diverse, species rich woodlands often associated with coppiced hazel understorey. Dormice have a preference for woodlands with an open canopy and a dense, varied shrub layer. The *Dormouse* occurs only in one area in the Wych valley, South West Cheshire, where it was re-introduced in 1996. During the year different areas are utilised as different food sources become available, but all habitat should occur within approx. 1 ha. (Foppen & Nieuwenhuizen, 1997, Foppen, 1999). Food sources include nectar, pollen, fruit, nuts, seeds and insects (Bright & Morris, 1996). Climatic conditions are probably of great importance for this species (Foppen, 1999). The network distance might range from 250 to 1500 m, dependent on the landscape resistance. In landscapes with a large number of hedgerows (e.g. in Cheshire) it might therefore approach the maximum distance of 1500 m. (Foppen & Nieuwenhuizen, 1997).

The species is very vulnerable to fragmentation: all roads are considered barriers. According to some authors the species only moves through trees and shrubs (http://www.wildlifetrust.org.uk/cheshire/dmbap.htm#Dormouse%20BAP%20Header).
The home-range of the species is less than 100 m., home-range size between 0.3-1.0 ha., dependent on the area (Foppen, 1999). Bright and Morris (1996) reported home range sizes with a mean of 0.68ha (males) and 0.22ha (females). Maximum distance travelled from nest site in one night averaged 143m with a maximum of 393m (Bright and Morris, 1996).
Dispersal distance is 1500 m. Densities are rather low, 1 to 10 animals per ha. (Bergers & Nieuwenhuizen, 1995), densities of nests being 2-3 per 100 m. of forest edge.

2 Amended by Sue Tatman and Gail Butterill, Cheshire Wildlife Trust, May 2002

The selected habitat of the *Dormouse* consists of (Table 17):

Table 17: Relevant habitat types in the land use map for Dormouse

Habitat type	Importance
Non-coniferous trees	++
Non-coniferous trees; mixed	++
Scrub, non-coniferous trees	+
Ancient woodland	+++

2.5.4.3 Nuthatch

The *Nuthatch* (*Sitta europea*) occurs in mature broad-leaved woodland. Broad-leaved treelines in conifer forest are also frequented. At the turn of the century the species was mainly confined to south-west Cheshire. During recent decades the species has spread to many parts of the county, and they are now observed in more than half the tetrads (Guest *et al.,* 1992). Adult birds are sedentary, but juveniles move over larger distances. Observations around a garden in Moreton on the Wirral (just outside Cheshire) showed a dispersal distance of 14 km. (Guest *et al.,* 1992). The species was shown to use hedgerows and small woodland for its movements through the landscape (Schotman, 2002, Verboom *et al.,* 1991).

The local distance for *Nuthatch* can range from 250-800 m., network distance ranges from 5000-15000 m. For modelling purposes 300 and 5000 m. are used. The minimum required area for a key-population is 50 ha.
The selected habitat of the *Nuthatch* consists of (Table 18):

Table 18: Relevant habitat types in the land use map for Nuthatch

Habitat type	Importance
Non-coniferous trees	++
Non-coniferous trees – scattered	++
Non-coniferous trees – mixed	++
Coniferous trees	+
Ancient woodland	+++

2.5.5 Grassland

2.5.5.1 Great crested newt

The *Great crested newt* (*Triturus cristatus*) occurs in grasslands, but might be considered as an intermediate species since it is partly dependent on wetlands for reproduction, as well as terrestrial habitat, such as moist woods and hedgerows for hibernation and foraging (MacGregor, 1995, Kupfer & Kneitz, 2000, Van der Sluis *et al.,* 1999). It is particularly a species that lives in metapopulations, networks of ponds that contribute to the population's success (Langton *et al.,* 2001).

The decline of the species is attributed to destruction of reproduction areas, intensive agriculture and urbanisation of rural areas. Also predation by fish is a detrimental factor (Caputo *et al.,* 1993).
The *Great crested newt* is mostly found in aquatic habitat. The species occurs in ponds, small lakes, wells, disused extraction sites, preferably with rich submerged aquatic vegetation. Its terrestrial habitat consists of meadows and woodlands, located near the reproduction areas. Some of the observations occur in anthropogenic habitats, such as gardens, parks etcetera (Oldham & Swan, 1993, Van der Sluis *et al.,* 1999).

For modelling purposes it is assumed that terrestrial habitat (grassland and woods) is usually present around its main reproduction habitat, that is, ponds. Main roads form barriers for most Triturus species (Van der Sluis & Vos, 1999).
For *Triturus cristatus* in the Netherlands maximum dispersal distances were measured up to 1490 m (Van der Sluis *et al.,* 1999), and in UK dispersal distances were observed up to 1.1. km (Swan & Oldham, 1993). The home-range used is 250 m. (although at times the actual home-range might be more). Network distance used is 1000 m (Langton *et al.,* 2001).
The selected habitat for the *Great crested newt* consists of (Table 19):

Table 19: Relevant habitat types in the land use map for Great crested newt

Habitat type	Importance
Ponds	+++
Marsh reeds	++
Marsh reeds, scrub	++
Scrub, marsh reeds	++
Natural Grassland – plains area	++
Grassland	++

2.5.5.2 Barn owl[3]

The *Barn owl* (*Tyto alba*) even early in the twentieth century was said to be rare in Cheshire and in decline due to hunting, changing land use practices, pesticides and destruction or lack of nesting sites. Modernisation of farm buildings might be a cause for decline as well (Burton and Hayman 1976). The *Barn owl* is occasionally found as a road casualty, due to its hunting behaviour along roadside verges.

In the 1930's there were 240 pairs in Cheshire. There was a serious decline in numbers, but presently the species shows a recovery. By 2000 this was up to 20 pairs but the bird is still considered to be scarce (pers. comm. C. Green, CWT). The number of *Barn owl*s has increased due to implementation of conservation measures such as habitat improvement and the provision of nesting boxes.
The species is rare in the uplands of the county, i.e. the Peak District. In modelling *Barn owl* habitat the upper part of the Pennines were excluded for that reason.

Habitat for the *Barn owl* consists of small-scale agricultural landscapes, areas of rough grassland, with occasional trees and scrub. They nest in cavities in trees, old houses,

[3] Edited by Chris Green, Cheshire Wildlife Trust, May 2002

farm buildings or church towers. In the past dovecotes are also reported as important. Habitat is selected around nesting sites in the open countryside.
(Young ringed owls were recovered more then 10 miles away from their nest sites, one as far as 42 miles. The Network distance can be at least 50 km.). The home range of the *Barn owl* is estimated at 1km radius, requiring 50 ha. of rank grassland. *Barn owl*s can have a home range of 3-5 km, depending on the available habitat (Hawk and Owl Trust, 1996).
The selected habitat of the *Barn owl* consists of (Table 20):

Table 20: Relevant habitat types in the land use map for Barn owl

Habitat type	Importance
Buildings	+++
Rough grassland (Plains)	+++
Rough grassland; trees or scrub	++
Scrub; rough grassland	+
Roadside verges	++

2.5.5.3 Common blue

The *Common blue* (*Polyommatus icarus*) is a widespread resident butterfly, although its distribution at lowland sites has become more patchy due to loss of habitat caused by modern farming methods. It is in decline, even in protected sites (pers. Comm. B. Roberts). In the Pennines the populations seem stable. Acid grasslands, as well as higher altitude (above 300 m), result here in lower numbers, whereas the species doesn't occur above 500 m. Paths, roadside verges and railways also form important habitat, in particular when species rich grassland is present.

Common blue breeds in a range of habitats, including wastelands and derelict industrial areas (Shaw, 2001). Dune and coastal areas are also used. The butterfly is restricted to where its foodplants are found, especially Common Bird's-foot Trefoil (*Lotus corniculatus*): the species particularly occurs on calcareous soils (Shaw, 1999). The *Common blue* quickly colonises new suitable habitats and has been recorded as doing so at a Northwich former industrial site since 2000.

The Millennium Atlas (Asher *et al.,* 2001) says 'Comparatively little is known about their mobility, but some dispersal takes place and newly formed habitat is readily colonised in most parts of its range. Adults of the first generation may be more mobile than those of the second' (Asher *et al.,* 2001). In addition '...this species remains widespread enough to find its way to areas of land that are suitable for breeding within a few kilometres of an existing population'.

The home-range and network distance is estimated to be 250 m. and (at least) 3000 m. respectively. Area requirements for a population is at least 1 ha, with species densities ranging from 4/ha up to 260/ha (Bink, 1992), although the species is known to survive in as little as 0.5-1.0 ha of suitable habitat (Asher *et al.,* 2001). Minimum required area is some 10 ha.
The selected habitat of the *Common blue* consists of (Table 21):

Table 21: Relevant habitat types in the land use map for Common blue

Habitat type	Importance
Path	++
Roadside	+++
Rail	+
Rough grassland	+++
Rough grassland; other	++
Scrub; rough grassland	+
Non-coniferous trees (scatt.); r. grassland	++
Heath; rough grass	+

3 Results spatial analysis

3.1 Introduction

Chapter 3 presents the general results of the spatial analysis with LARCH. In the discussion of the results, the species habitat is evaluated at population level, at network level, and in terms of the connectivity of the landscape (see also 2.2). At population level an assessment is made as to whether or not local populations are formed, i.e. whether within home-range of a species available habitat is sufficient for either a local- key-, or sustainable population (exceeding the size of an MVP; see par. 2.2.1). At network level an assessment is made as to whether or not the metapopulation is sustainable in the long term. Finally, spatial cohesion gives an impression of the connectivity of the landscape for a species.

As mentioned in par. 1.3, the ecological network needs to be assessed to diagnose the current situation for biodiversity. If a new situation is compared with the present situation, a kind of 'scenario', it is possible to assess the improvement in regard of the present situation (Peterson *et al.,* 2003). A scenario was developed, detailing targets for different ambition levels (Van Rooij *et al.,* 2003a). The targets and required measures for specific ecosystems formulated in that study form the basis for comparison (fig. 34 and annex 4 in Van Rooij *et al.,* 2003a). In this report they are described in some more detail at the beginning paragraph of each ecosystem.

Two points should be kept in mind, when interpreting these results:

(1) First of all, LARCH assesses the potential situation, i.e. the situation in which habitat is considered optimal. An area assessed as suitable might not always correspond with the actual presence of a target species in that area. In reality, the situation might be much more complex as ever can be predicted with models.

(2) Second, to be able to give useful advice on the quality of the proposed network, we look at more species at a given time, and try to extract a 'general' result for the modelled species for this specific ecosystem. The species are therefore to be seen as 'indicative' for a number of species, it is an ecoprofile, a group of species with similar characteristics. This result is of much more importance than the result for one single species.

The figures with results of the LARCH analysis are included at the end of Chapter 3.

3.2 Predicted changes in wildlife populations

3.2.1 Meres and mosses

3.2.1.1 Proposed scenario

The three species analysed for meres and mosses ecosystems are *Black darter, Green hairstreak* and *Four spotted chaser*. The *Green hairstreak* (butterfly species) has a limited dispersal range, the dragonfly species, however, can be very mobile.

In Delamere 80 ha of mosses are to be restored by re-wetting old peatlands. In Peckforton 135 ha, 50 ha for Gowy marshes, and 110 ha in the east of Cheshire (Annex 4, Van Rooij *et al.,* 2003a).
In the LARCH analysis, species were analysed using the Peatland map. In the scenario map LARCH results as well as additional information was used, so that a more realistic scenario could be drafted. The basis therefore differs, and for the meres and mosses species no scenario could be analysed.

3.2.1.2 Black darter

The results for the *Black darter* are shown in figure 4. A key population is possible in the south. Elsewhere, there are only small local populations (Table 22). Since the habitat requirements are not large and the dispersal capacity is large (a good connectivity), these small populations taken together can form a sustainable population.

No scenario was analysed, since the modelling approach differs too much from the scenario design.

Table 22: Results LARCH *analysis Black darter: + = reasonable, ++ = good, +++ = very good*

	Present
Population assessment	+
Network assessment	++
Connectivity	+++

3.2.1.3 Green hairstreak

The results for the *Green hairstreak* are shown in figure 5. A MVP is possible in the Pennines and around Delamere: a key population is found further south around Peckforton. This results in a viable situation for this species (Table 23). Despite the short home range of this species, habitat is sufficient in many areas due to its limited habitat requirements. Delamere and the Pennines are well connected: Peckforton is reasonably well connected.

No scenario was analysed, since the modelling approach differs too much from the scenario design.

Table 23: Results LARCH *analysis Green hairstreak: + = reasonable, ++ = good, +++ = very good*

	Present
Population assessment	++
Network assessment	+++
Connectivity	+

3.2.1.4 Four-spotted chaser

The results for the *Four-spotted chaser* are shown in figure 6. The *Four-spotted chaser* uses a wider range of habitats than the other target species for this ecosystem. Habitat is therefore sufficient for one MVP, spread over Cheshire (Table 24). The large dispersal range results in a well-connected landscape for this species. The population is highly sustainable, due to the large number of habitat patches.

No scenario was analysed, since the modelling approach differs too much from the scenario design.

Table 24: Results analysis Four-spotted chaser: + = reasonable, ++ = good, +++ = very good

	Present
Population assessment	++
Network assessment	+++
Connectivity	+++

3.2.2 Heathland

3.2.2.1 Proposed scenario

The three species analysed for grassland ecosystems are *Stonechat, Small heath* and *Common lizard*. The latter two species have a limited dispersal range, whereas the *Stonechat* is more mobile.

The proposed scenario results in a net increase of some 370 ha of heathland, including:

- increasing heathland around Delamere Forest (120 ha)
- increasing heathland around Peckforton (more than 100 ha)
- creating two stepping stones east of Congleton (50 ha each, heather or rough grassland) including also mitigating measures for 11 roads
- increasing heathland by some 35 ha in the east of the county

3.2.2.2 Stonechat

The results for the *Stonechat* are shown in figure 7. The species would only form local populations, based on the scattered distribution of heathlands. In reality the species occurs mainly in dune areas along the coast, and Wirral. Part of the Wirral is missing

in the habitat maps, and is therefore not reflected in the results. Based on heathland situated near the coast, at most 5 pairs might be possible.
The network wouldn't be viable under current conditions (Table 25). Connectivity is also limited, due to lack of habitat.

Table 25: Results LARCH *analysis Stonechat: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	-	-
Network assessment	+	+
Connectivity	-	-

The scenario will not improve the situation, since the area where measures are taken are not focussed on the dune areas.

3.2.2.3 Small heath

The results for the *Small heath* are shown in figure 8. The only stable population is present in the Pennines. For the remainder of Cheshire there would be small local populations (Table 26). (NB: for part of the Wirral, outside Cheshire, no habitat information was available). Due to the dispersal capacity (up to 5000 m), these areas might occasionally be occupied by small numbers of butterflies.
The connectivity is limited, with the focal point obviously in the Pennines and around Delamere, Peckforton and the Wirral.

Table 26: Results LARCH *analysis Small heath: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	+	++
Network assessment	+++	+++
Connectivity	+	++

As a result of the proposed scenario a large area, sufficient for an MVP, is established Northeast of Peckforton. This also improves spatial cohesion, but overall network viability is, and remains, very viable.

3.2.2.4 Common lizard

The results for the *Common lizard* are shown in figure 9. The habitat patches can only maintain small local populations, and the species is not viable under present conditions (Table 27). Habitat is fragmented by roads. If roads are not taken into account, viable populations are possible around Delamere Forest and Peckforton.

Table 27: Results LARCH *analysis Common lizard: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	0	+
Network assessment	0	+
Connectivity	-	+

In the proposed scenario a corridor is to be realised between Peckforton and Primrose Hill wood, just south of Delamere. The area, partly linked to existing habitat, is sufficient for a MVP.
The areas along this corridor are reasonably well connected, otherwise all habitat is still very fragmented.

3.2.3 Wetlands / rivers

3.2.3.1 Proposed scenario

For wetland / river ecosystems the *Water vole, Banded demoiselle* and the *Sedge warbler* have been selected. They display different characteristics in regard of dispersal ranges. The *Banded demoiselle* and *Sedge warbler* have a dispersal distance of approximately 30 up to 50 km, whereas the *Water vole* has a dispersal distance of only some 1000 m.
It should be taken into account that some parts of the Wirral (outside Cheshire County) were not included in the OS MasterMap map, which forms the basis for this study, and therefore some important floodplains are not included in the analysis.

Under the proposed scenario, three river ecosystems are improved: river Dee, river Gowy, and the floodplain in the north, connecting these two areas. Improvement will focus on the development of more natural riverbanks and floodplains, for all rivers (development of some 400 ha wetland and improvement of 80 km river bank is proposed. In total some 1200 ha. is developed.

3.2.3.2 Water vole

The results for the *Water vole* are shown in figure 10. Some key-populations are potentially present, on the River Dee and Comber Mere. Many small patches form a local population.
The network analysis shows that all small populations and small patches link to a larger network, and that the entire network could potentially be very viable (Table 28). This analysis is undertaken under the assumption that roads form barriers for the *Water vole*, but in many cases rivers or ditches might freely flow beneath roads so fragmentation might be less than anticipated. The connectivity of the landscape is poor in general.

Table 28: Results LARCH *analysis Water vole: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	+	++
Network assessment	+++	+++
Connectivity	-	+

The proposed scenario shows two major MVPs, along the river Dee and Gowy, and depending on the saline impact and location of measures, one MVP towards Ince Marshes. In the east no measures are planned, so no improvement is seen. The network remains very viable. In the west the connectivity improves greatly, but for most of the County the situation remains rather fragmented as long as no particular measures are planned.

3.2.3.3 Banded demoiselle

The results for the *Banded demoiselle* are shown in figure 11. In the central and eastern parts of Cheshire are mainly MVPs, in the west mainly key populations. Over 150 local populations together constitute in potential a large viable network (Table 29). The center of the population lies in the east, where there are main rivers and canals like the Weaver, Trent & Mersey Canal and Macclesfield Canal. The connectivity for this species is very good, since it is very viable. Its limited presence is attributed to lack of suitable riverside habitat, i.e. slow flowing rivers with adjoining natural vegetation.

Table 29: Results LARCH *analysis Banded demoiselle: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	++	+++
Network assessment	+++	+++
Connectivity	+++	+++

The scenario does improve the situation for the western part of the county, where habitat is enlarged, up to the level of potential MVPs. For the network as a whole the situation remains very viable, and the connectivity is still very good.

3.2.3.4 Sedge warbler

The results for the *Sedge warbler* are shown in figure 12. An MVP is possible in the Wirral (just outside Cheshire), a key population at the Ince Banks. Only a few areas are large enough for local populations. Many areas are too small: habitat seems to be limiting for this species (Table 30). Due to the large dispersal distance of *Sedge warbler*, however, the scattered local populations link up to form a viable network. The spatial cohesion of the landscape is reasonable, only good in the western and south-western parts of Cheshire (fig. 13).

Table 30: Results LARCH *analysis Sedge warbler: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	+	++
Network assessment	++	++
Connectivity	+	+++

The proposed scenario results in a large MVP, which is created in wetlands along the rivers. Still many smaller areas are probably too small for a local population. The total population can potentially double. The viability increases, but all in all it remains viable. Connectivity improves significantly in the western part of the county, and reasonably elsewhere.

3.2.4 Woodland

3.2.4.1 Proposed scenario

Two of the selected species for woodland ecosystems (Table 5): *Purple hairstreak* and *Nuthatch*) are versatile species, capable of utilising a wide range of habitats, and can expand in areas with little woodland. The Dormouse, by contrast, is a critical species that uses particularly old woodlands.

The low ambition for the woodland scenario is to realise a total of almost 400 ha of new woodland (fig. 2). This means in practice (Van Rooij, 2003a):

- the realisation of some 70 ha of woodland North of Delamere, being a key-patch and a corridor
- the realisation of wildlife corridors by hedgerows (25 ha) south-western part of Cheshire
- extending Delamere Forest with more than 115 ha
- extending woodland in the Peckforton area by some 60 ha
- the realisation of a corridor from Peckforton southwards (over 30 ha including solving barriers, 8 roads)
- the enlargement of woodlands South of Peckforton by 90 ha.

The additional areas are based on existing areas versus what is required for the species.

3.2.4.2 Purple hairstreak

The results for *Purple hairstreak* are shown in figure 14. Under present conditions the species can form MVPs in many parts of the county, but also several key populations are formed (Table 31). The population is viable, which is partly a result of the low habitat requirements of this butterfly.

The connectivity is limited, which is a result of the low dispersal distance of the species (fig. 15). This might well be an underestimate, however, since the species is likely to use hedges and woodrows for migration, which were not mapped in the OS MasterMap.

Table 31: Results LARCH *analysis Purple hairstreak: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	++	+++
Network assessment	+++	+++
Connectivity	+	++

Based on the scenario the population assessment shows an increase in population size, in particular based on woodland enlargement in west Cheshire. The viability of the network improves slightly, but it was, ánd remains, very viable.
The connectivity improves in the western part as well, and more or less a north-west axis is formed, linked to the east.

3.2.4.3 Dormouse

The results for the *Dormouse* are shown in figure 16. If no barriers are considered, many woodland areas might be suitable. However, due to fragmentation by roads, woodland areas are too small: the species requires larger, old growth woodlands. Under present conditions only one area, Beckett's wood and Blackmoor wood (around Aston) might be considered large enough for a key-population (Table 32). In this instance the area measures in total some 340 ha. In this area, adjoining the Weaver Navigation, few roads are present, and smaller old woodlands are present and almost adjoining one another.
There might be an underestimate here since more areas might be connected, because hedgerows are not shown on the OS MasterMap.
The connectivity for this species is poor throughout the county, due to its low mobility and vulnerability to roads.

Table 32: Results LARCH *analysis Dormouse: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	+	+++
Network assessment	0	++
Connectivity	-	++

As a result of the scenario, populations exceeding the size of an MVP are possible around Delamere forest and further south, and in the East of the county. For small, less mobile species like the *Dormouse* the situation has improved.
Viable networks are realised both in the west (from Delamere towards Peckforton and Bickerton and south to Wrexham county).
The connectivity improves, the habitat is well connected in those areas where large forest areas are established. However, due to the low mobility of the species, connectivity between different populations is still very low.

The *Dormouse* requires habitat of high quality, species rich, wit sufficient food plants. For new areas developed as forest definitely time is required to have a suitable vegetation development, with high species diversity.

3.2.4.4 Nuthatch

The results for the *Nuthatch* are shown in figure 17. The species can potentially live in most wooded parts of the county, and ample habitat is available (Tabel 33). Due to its larger home-range, the species can be considered very viable.
Due to the larger dispersal distance, connectivity is currently good. (fig. 18).

Table 33: Results LARCH *analysis Nuthatch: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	++	++
Network assessment	+++	+++
Connectivity	+++	+++

The proposed scenario results in habitat expansion, and thus a slightly larger population. The viability does not change much. Connectivity improves in the west of Cheshire, also forming a north-south axis. The fact that the species is recently expanding its range into Cheshire suggests that the connectivity of the landscape for a small woodland bird with a intermediate home-range might be adequate.

3.2.5 Grassland

3.2.5.1 Proposed scenario

The three species analysed for grassland ecosystems are *Great crested newt, Barn owl* and *Common blue*. The *Great crested newt* and *Common blue* have limited dispersal ranges, whereas the *Barn owl* can be very mobile.

In the proposed scenario for Cheshire 900 ha of species-rich or rough grassland is created, in particular for a sustainable network for the *Barn owl*. These areas are adjoining existing grassland habitat. A narrow corridor is created in the west of Cheshire.

3.2.5.2 Great crested newt

The results for the *Great crested newt* are shown in figure 19. In several parts of Cheshire large viable pond networks already exist, due to the high number and density of ponds present (Table 35). In fact, the situation might be better in some areas then is shown by these results, since only the open, non-vegetated ponds were used for the analysis. Still there are isolated ponds, not forming part of the network, so fragmentation does locally occur. Due to a different modelling method (an approach based on patches, not on area) it is not possible to calculate the connectivity of the landscape.

Table 34: Results LARCH *analysis Great crested newt: + = reasonable, ++ = good, +++ = very good*

	Present
Population assessment	++
Network assessment	++

The proposed scenario will improve the situation in the West of the County. However, since the *Great crested newt* is also dependent on water for its reproduction and woodland for terrestrial habitat, it is very difficult to assess the change for this species.
To improve the situation for *Great crested newt* further, restoration of unsuitable ponds, or creation of new ponds could be considered.

3.2.5.3 Barn owl

The results for the *Barn owl* are shown in figure 20. The present situation shows one large MVP, and all habitat forms part of the larger network due to the large dispersal distance of this species (Table 35). In potential over 40 pairs could be expected, if the quality of habitat is good. Roadside verges form clear structures in its habitat network. However, the associated risk is that owls are hit by vehicles, resulting in road casualties. The population as such is viable, due to the large dispersal distance, and the probable exchange with populations in adjoining counties. The connectivity of the landscape is reasonable, which is due to the large dispersal distance of 50 km.

Table 35: Results LARCH *analysis Barn owl: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	+	++
Network assessment	+++	+++
Connectivity	++	+++

With the designed scenario the population might increase up to 60 pairs, i.e. some 30 %. Also in this scenario the population is large enough for an MVP and the network is viable. The connectivity increases slightly.

3.2.5.4 Common blue

The results for the *Common blue* are shown in figure 21. Several MVPs are potentially present, in Delamere Forest and Peckforton (along the sandstone ridge). In addition, larger roadside verges along the Motorway and main roads link habitats, resulting in areas the size of an MVP. Several key populations are present as well as many small populations (Table 36). In particular the MVPs and key areas are sustainable. Most of the populations in the county are, however, not sustainable. Since the dispersal distance is limited, most of the areas in Cheshire do not form part of a larger network. The connectivity is reasonably good, except for the southern part of Cheshire.

Table 36: Results LARCH *analysis Common blue: + = reasonable, ++ = good, +++ = very good*

	Present	Scenario
Population assessment	+	++
Network assessment	+	+
Connectivity	++	++

The proposed scenario results in west Cheshire in key populations that increase up to the size of an MVP, whereas new key populations are also established. The overall viability increases slightly. The connectivity shows only a slight improvement where the proposed new corridor has been realised. Overall the area remains fragmented for *Common blue.*

3.2.6 Summary LARCH-analysis

In general all of the analysed species show a marked increase in population viability and size in the scenario compared with the current situation, and most show an increase in spatial cohesion. Only grassland shows a limited increase in population viability of the selected species (Table 37).
One should keep in mind though that the potential situation is better then the actual situation.

Table 37: Summary of the results for the spatial analysis ○ = no change; ↑= slight improvement; ⬆ = some improvement; ⬆⬆ = significant improvement; n.a. = no scenario analysed

Change occurring under scenario Species	*Change LARCH population assessment*	*Change LARCH-SCAN – Spatial cohesion*
Meres and mosses	n.a.	n.a.
Heathland:		
Stonechat	○	○
Small heath	⬆	⬆
Common lizard	⬆	⬆
Wetlands/Rivers:		
Water vole	⬆⬆	⬆
Banded demoiselle	⬆	○
Sedge warbler	⬆	⬆⬆
Woodland:		
Purple hairstreak	⬆	⬆
Dormouse	⬆⬆	⬆⬆
Nuthatch	↑	↑
Grassland:		
Great crested newt	n.a.	n.a.
Barn owl	⬆	⬆
Common blue	⬆	↑

The scenario has a relatively large impact on woodland ecosystems. The total area of broad-leaved forest is at present appr 10223 ha. Under the scenario there is an increase of total woodland habitat by 3.9% up to 10623 ha.

For wetlands the areas available seem already quite substantial, spatial cohesion is in general good. Measurements to be considered could be creation or enlargement of some core areas. The *Sedge warbler* and the *Water vole* both benefit considerable from the increase of wetlands.

The grassland ecosystems do improve under the scenario. The *Great crested newt* is viable at present, but the species might benefit from the improvement of ponds, in particular when work is focussed on those areas where populations are not viable.
The *Barn owl* does improve, however, this is based on foraging areas. It is known that breeding areas (mainly old buildings, or sometimes nest boxes) might be a limiting factor. So with improvement of grassland habitat, other measures for nesting places should go hand in hand in these areas.

Under current conditions and the development scenario the ecological network is poor for the *Stonechat*. However, management of land and intensity of land use is critical for the *Stonechat*. Management of productive land could be adapted, with measures beneficial for those species e.g. set aside policies, land-stewardship payments for abandoning fertiliser and pesticide use. This would effectively increase available habitat, and improve the quality.
Here at the northern boundary of its distribution aarea, the species is only found on the coast, the dune area. Measures for heather will therefore probably only bear effect if they are done near the coast.

The meres and mosses have only a very limited aerial extent. The degraded old peatlands will differ in potential for restoration. The selected darter species do have a large dispersal distance, so they might easily benefit from increase in habitat. The success of these measures mainly depends on how critical the selected species are.

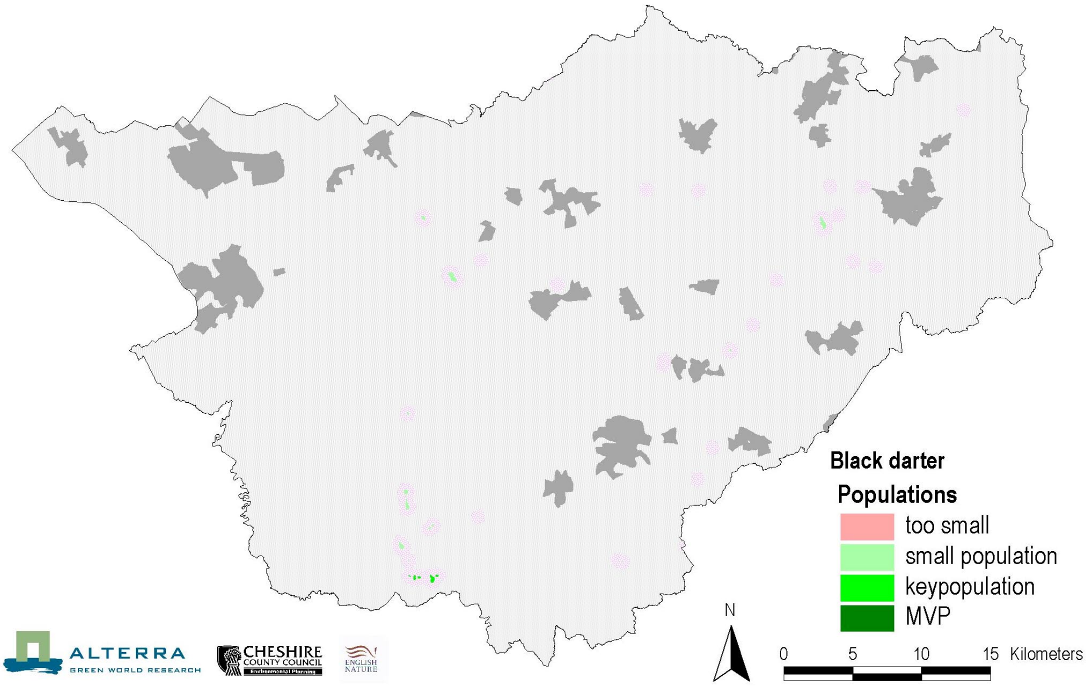


*Figure 4 :*LARCH *analysis for the Black darter, colour is based on available habitat and carrying capacity*

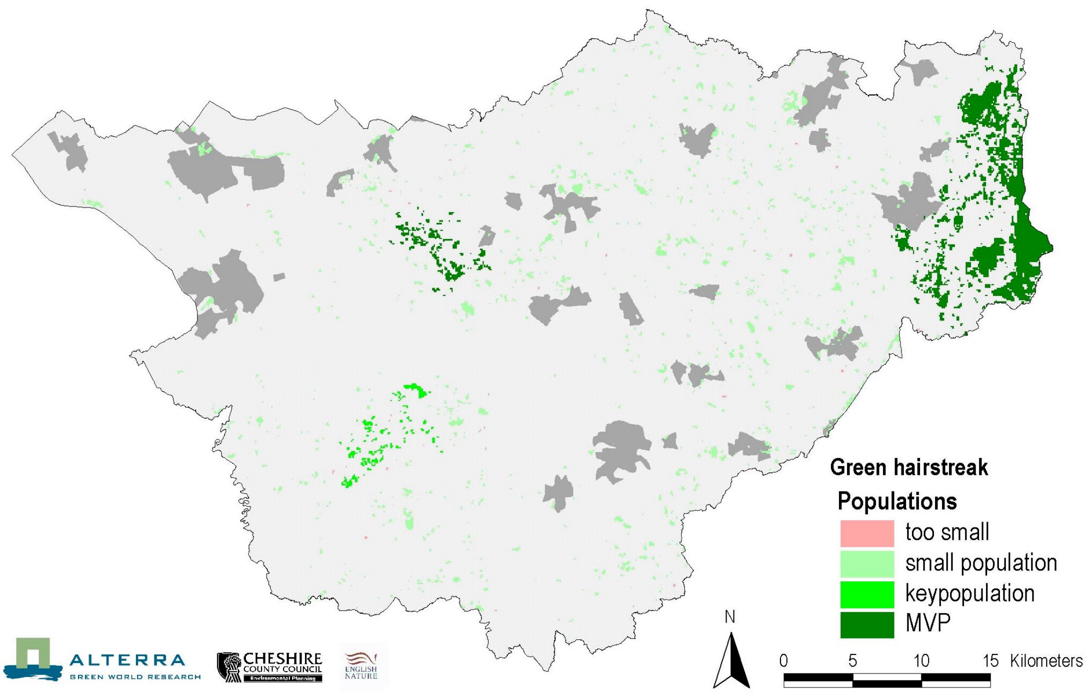


Figure 5: LARCH analysis for the Green hairstreak, colour is based on available habitat and carrying capacity

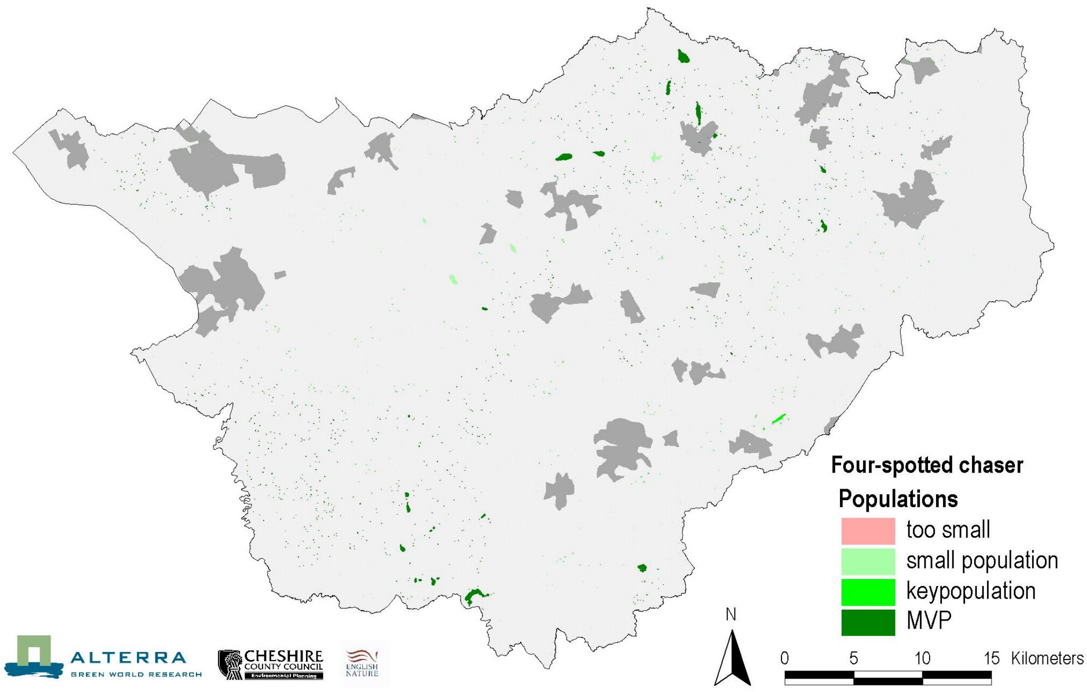


Figure 6: LARCH *analysis for the Four-spotted chaser, colour is based on available habitat and carrying capacity*

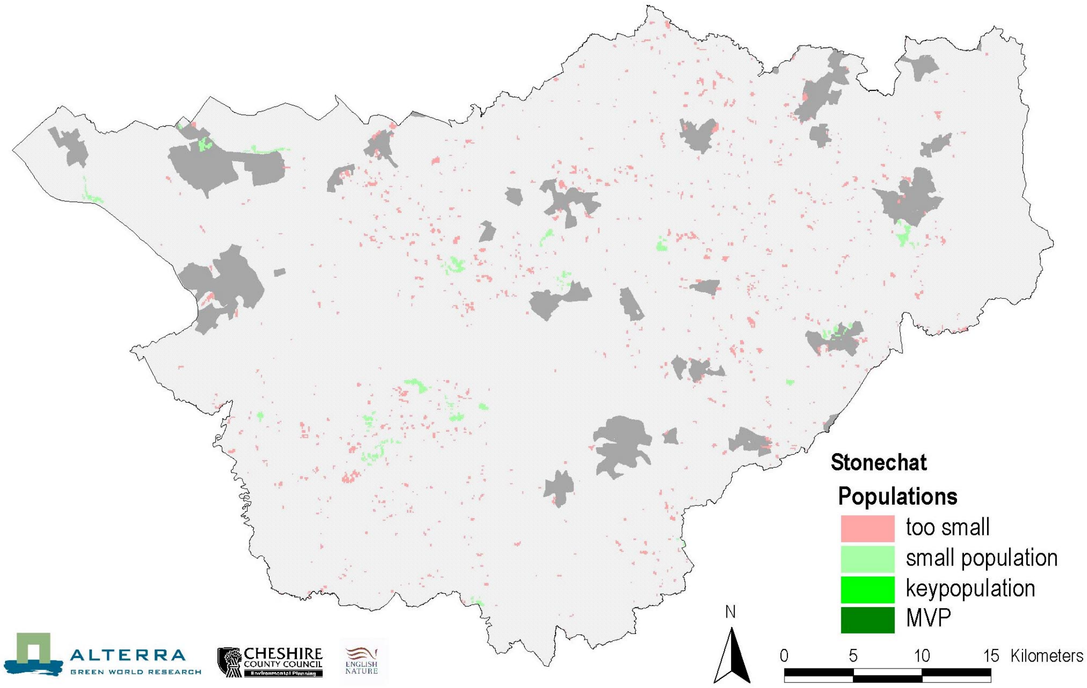


Figure 7: LARCH *analysis for the Stonechat, colour is based on available habitat and carrying capacity*

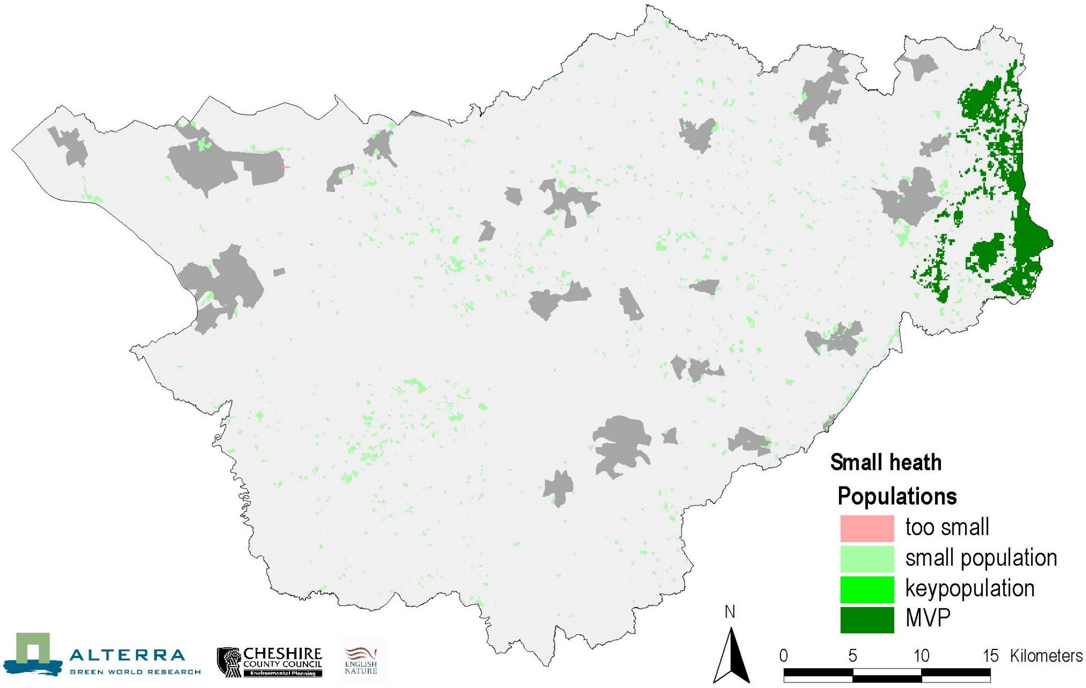


Figure 8: LARCH *analysis for the Small heath, colour is based on available habitat and carrying capacity*

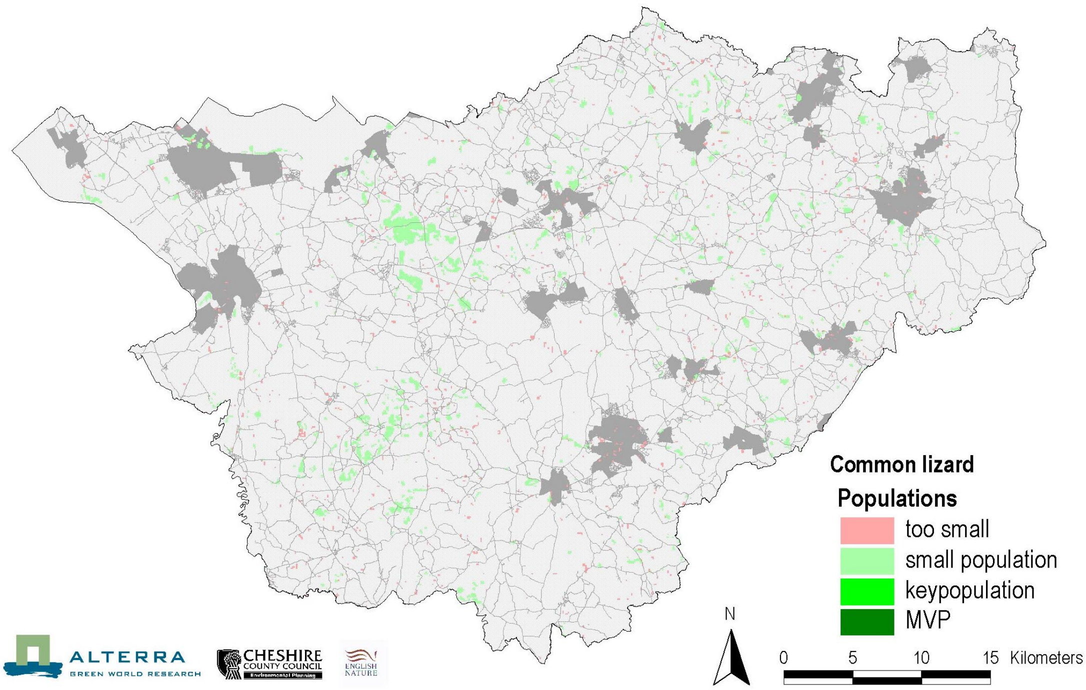


Figure 9: LARCH *analysis for the Common lizard, colour is based on available habitat and carrying capacity*

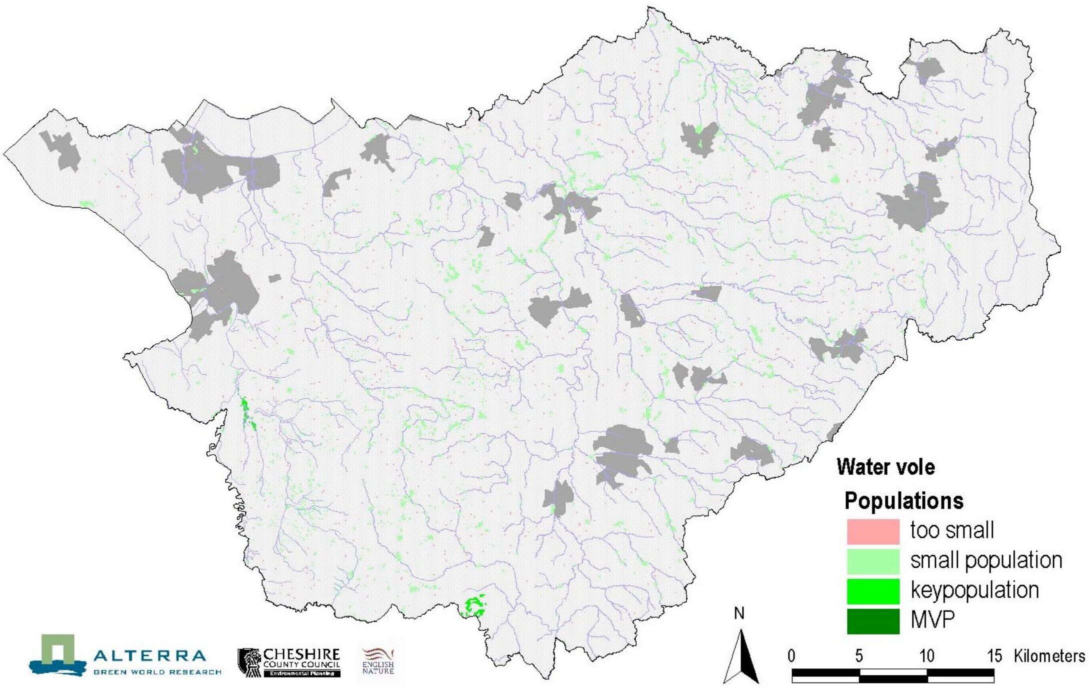


Figure 10: LARCH analysis for the Water vole, colour is based on available habitat and carrying capacity

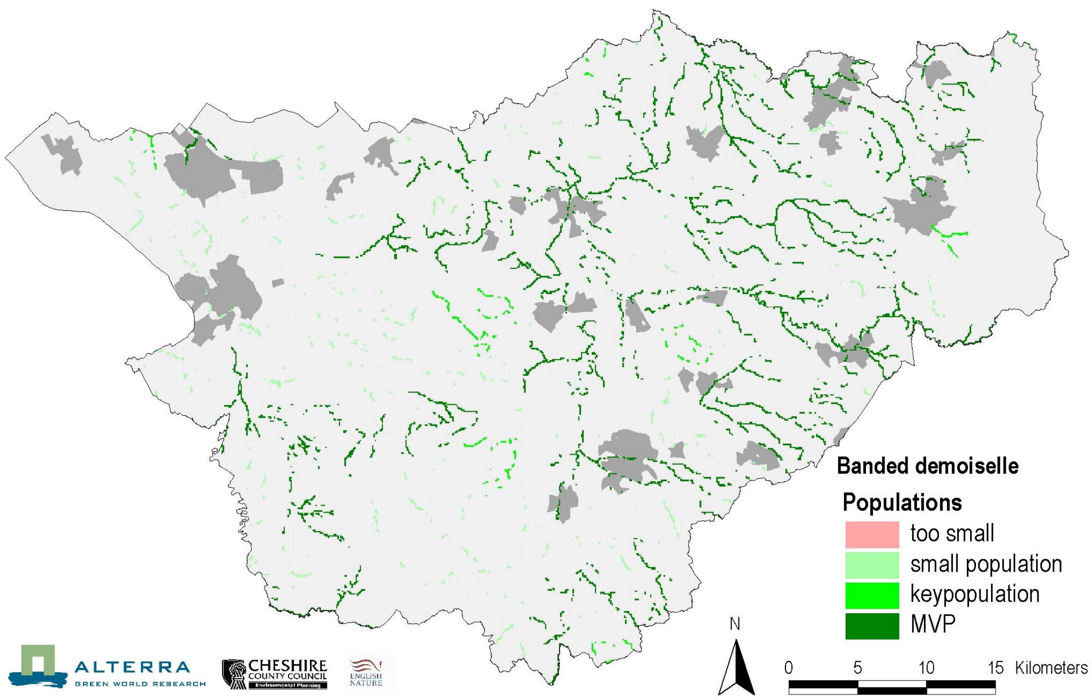


Figure 11: LARCH *analysis for the Banded demoiselle, colour is based on available habitat and carrying capacity*

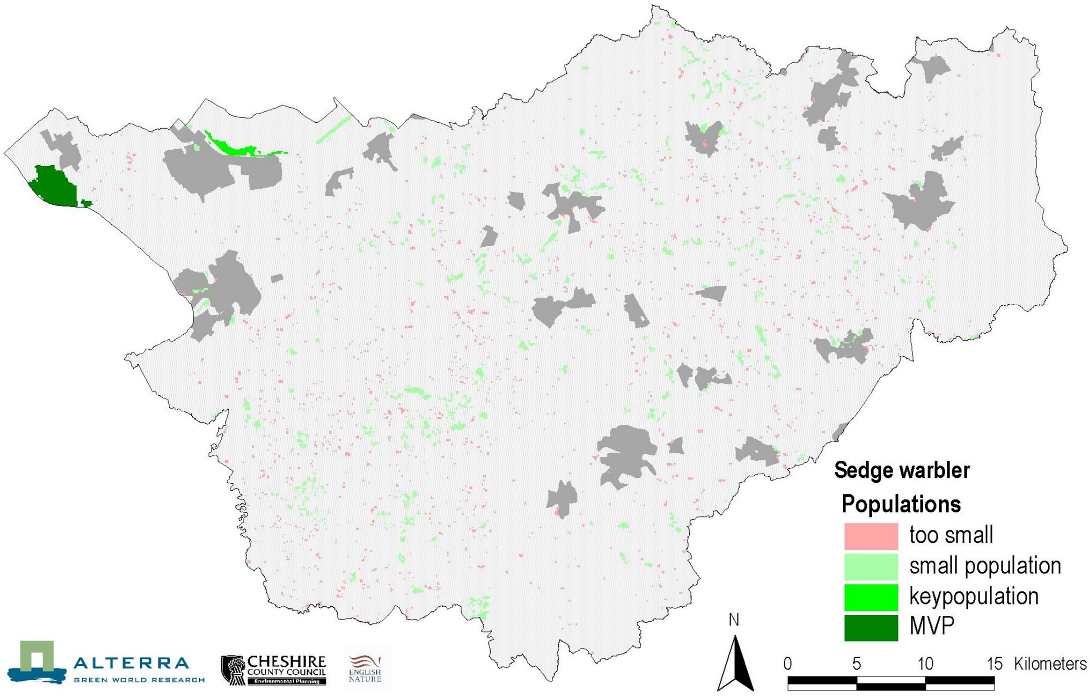


Figure 12: LARCH *analysis for the Sedge warbler, colour is based on available habitat and carrying capacity*

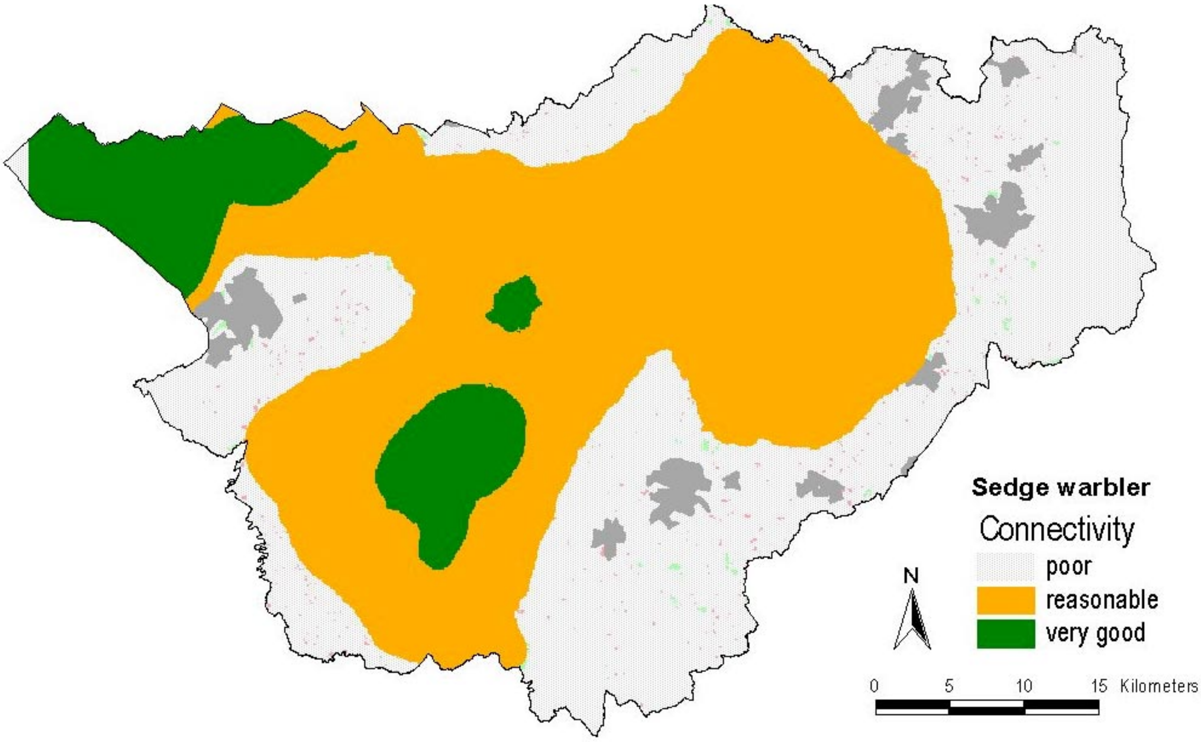


Figure 13: LARCH *spatial cohesion for the Sedge warbler, colour is based on available habitat and carrying capacity*

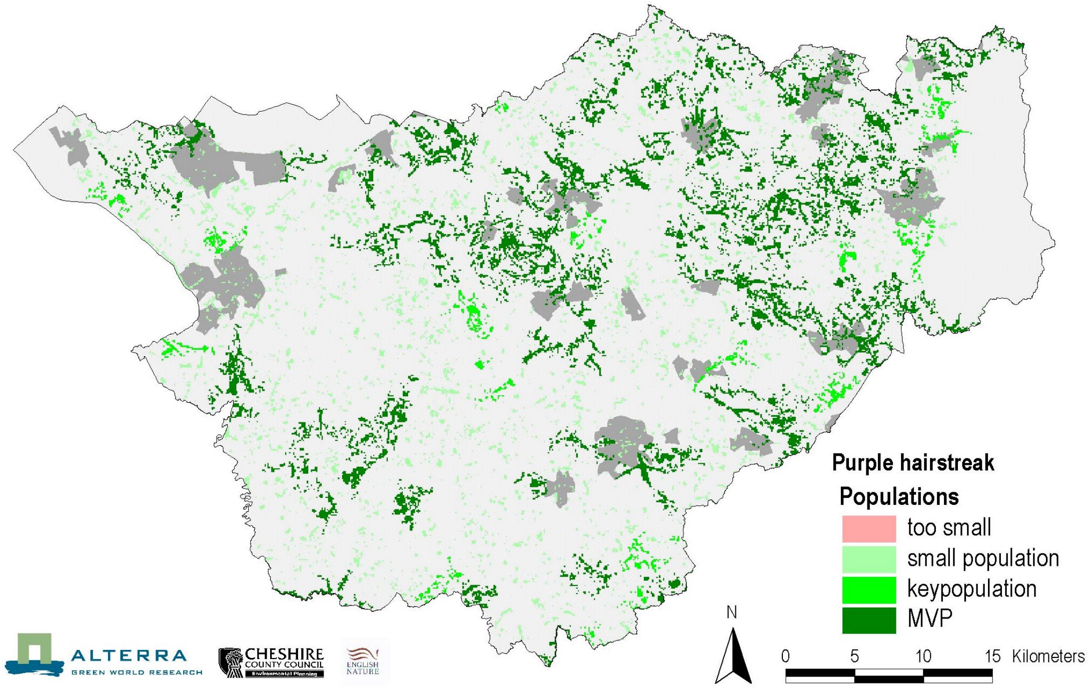


Figure 14: LARCH *analysis for the Purple hairstreak, colour based on available habitat and carrying capacity*

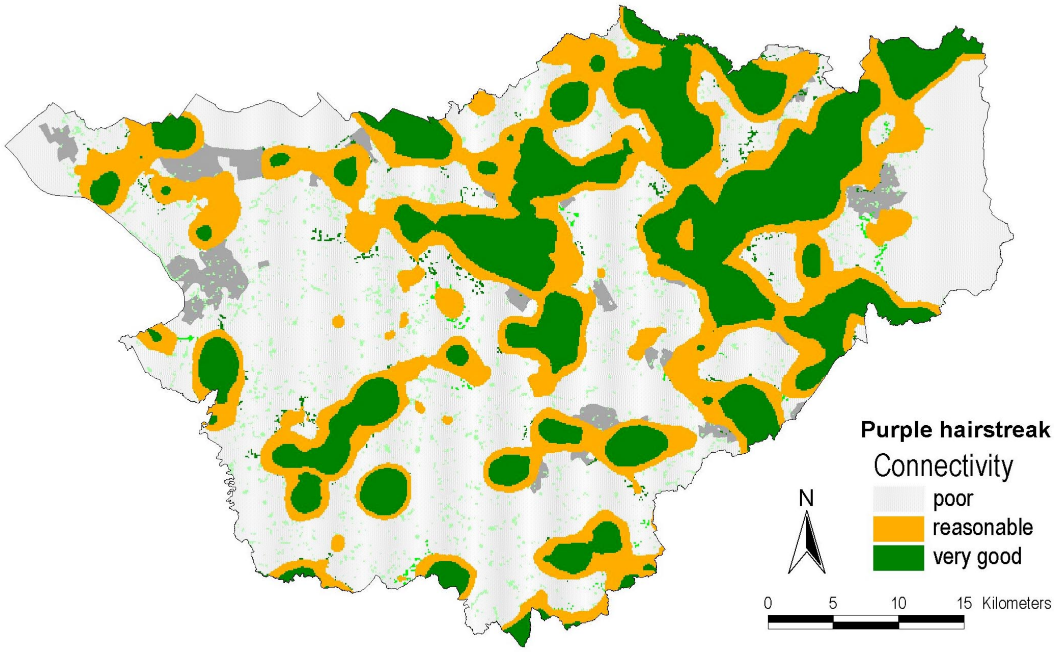


Figure 15: LARCH *spatial cohesion for the Purple hairstreak, colour based on available habitat and carrying capacity*

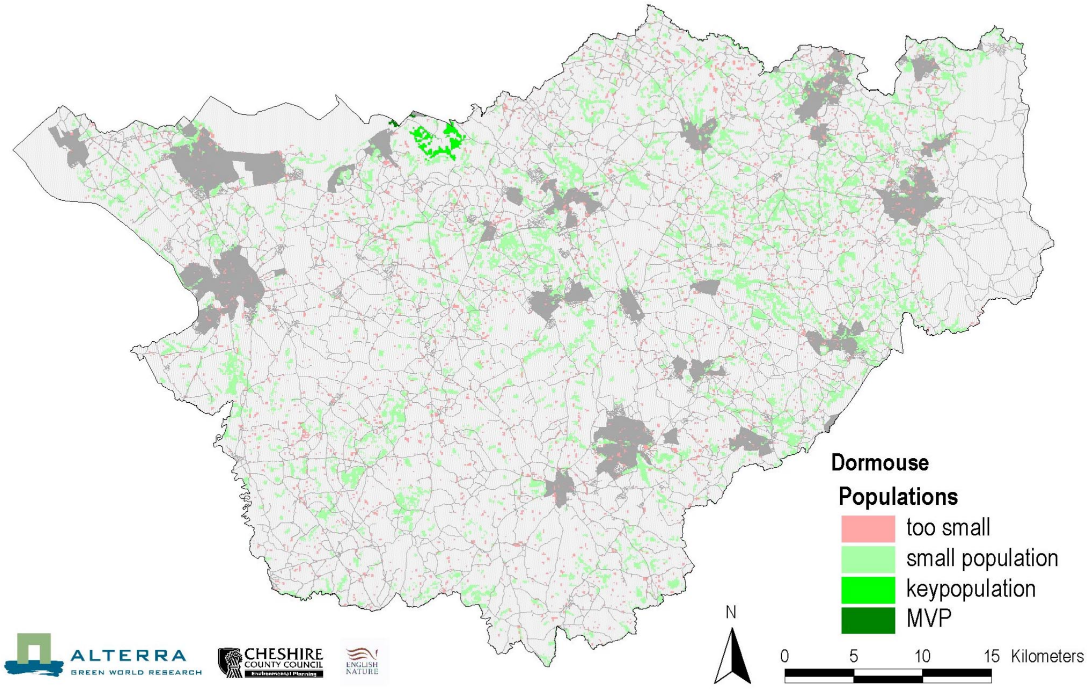


Figure 16: LARCH *analysis for the Dormouse, colour is based on available habitat and carrying capacity*

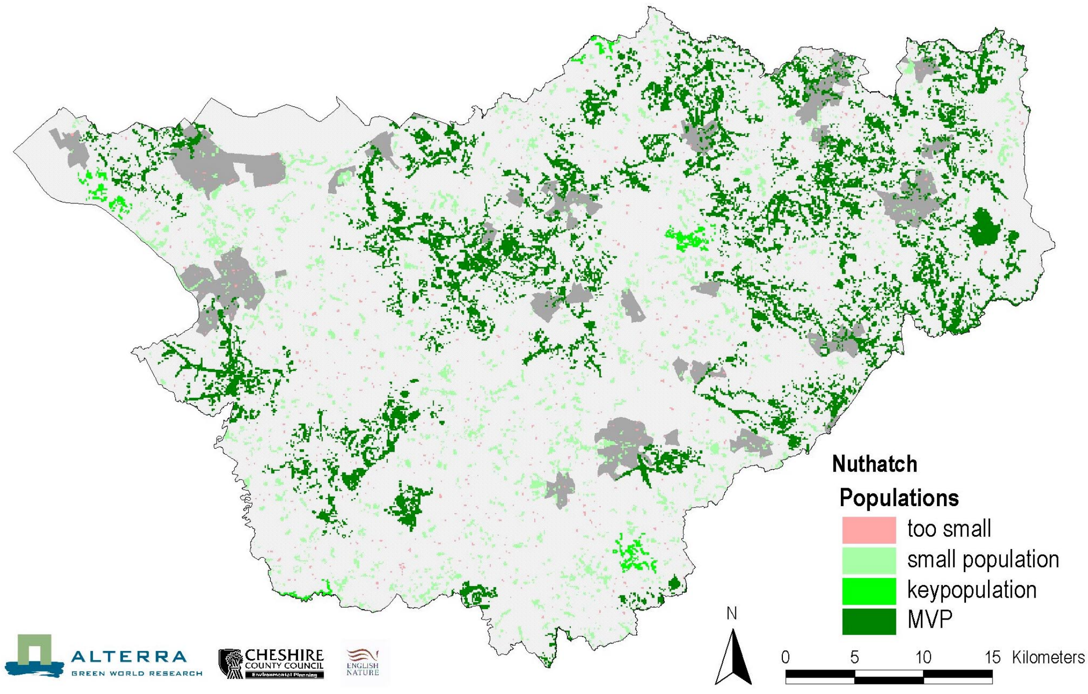


Figure 17: LARCH *analysis for the Nuthatch, colour is based on available habitat and carrying capacity*

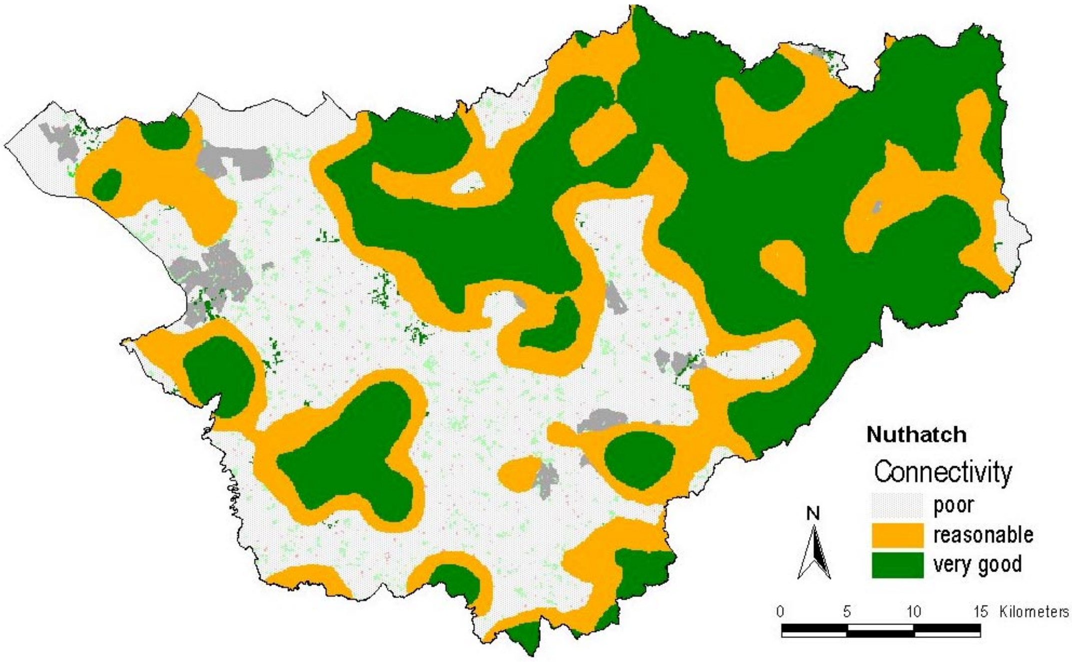


Figure 18: LARCH *spatial cohesion for the Nuthatch, colour is based on available habitat and carrying capacity*

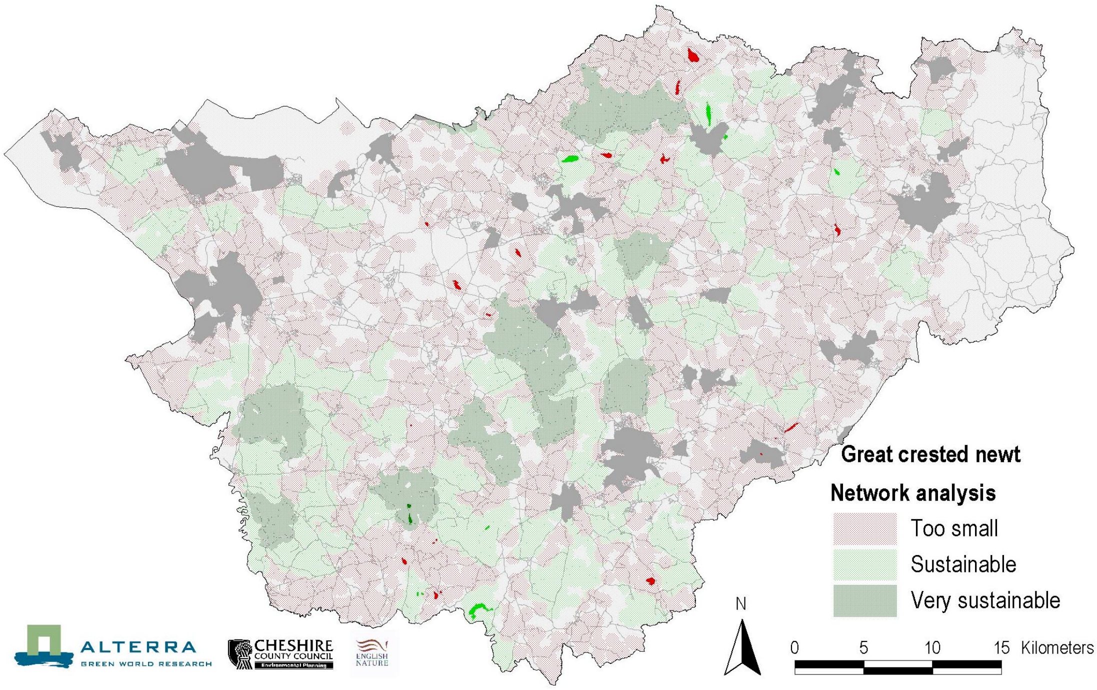


Figure 19: LARCH *analysis for the Great crested newt, colour is based on available habitat and carrying capacity*

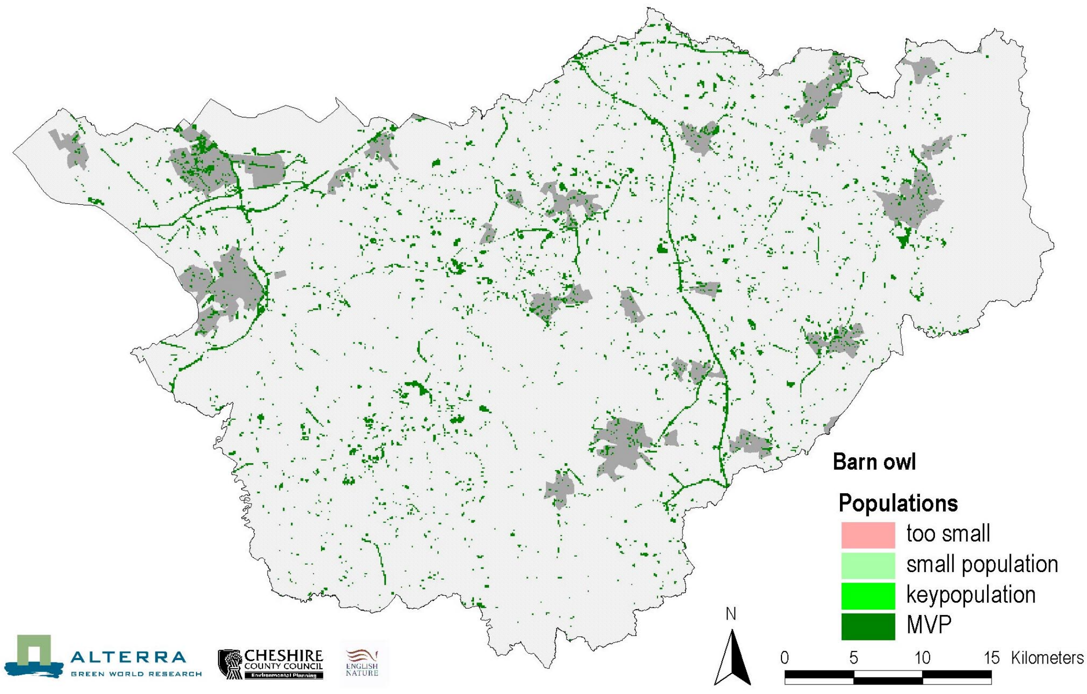


Figure 20: LARCH *analysis for the Barn owl, colour is based on available habitat and carrying capacity*

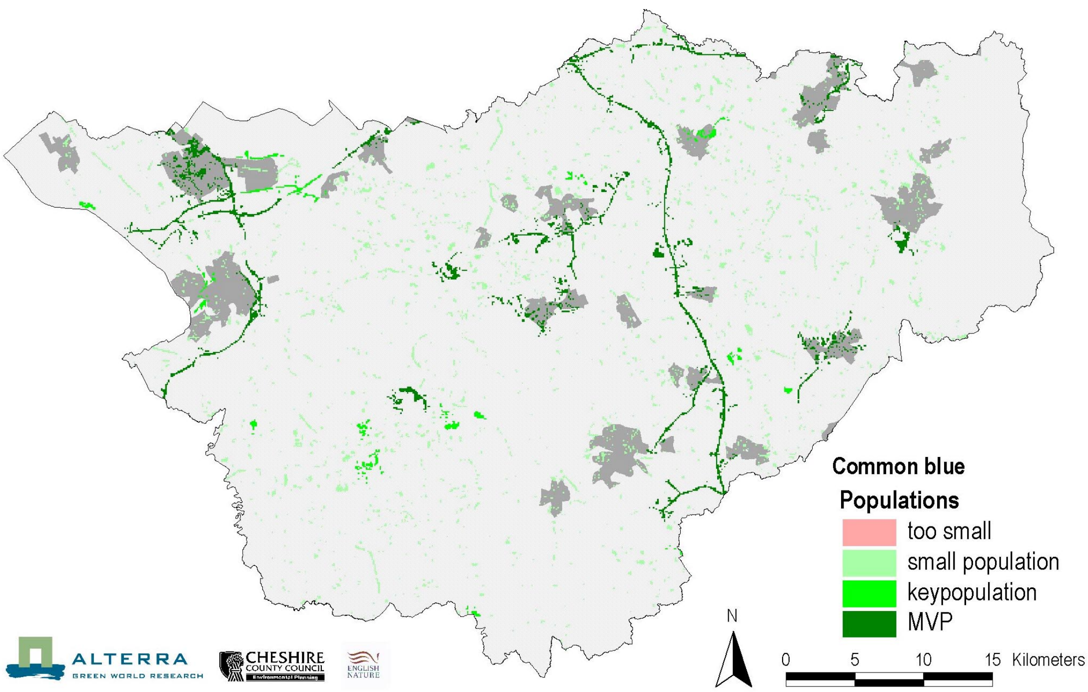


Figure 21: LARCH *analysis for the Common blue, colour is based on available habitat and carrying capacity*

Picture 5: Plain area of Cheshire, with some hedgerows (drawing: R.G.H. Bunce)

Picture 6: Plain area, scenario with an increase in small woods (drawing: R.G.H. Bunce)

4 Discussion

4.1 General discussion of the methods used

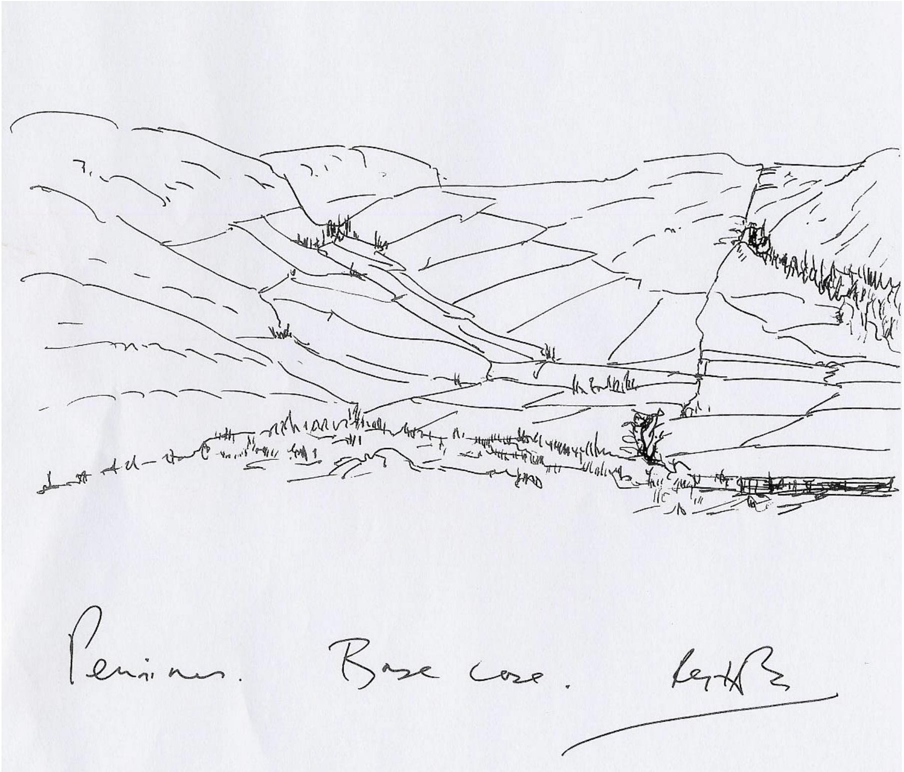
The Ordnance Survey MasterMap for Cheshire has been used as the basis for this analysis. The OS MasterMap in general is of good quality, the detailed topographical classification is useful for habitat mapping, although in some cases compounded typology might lead to some errors. Meres and mosses, as well as heathland are mapped in limited detail. For these ecosystems, as well as for ancient woodlands, additional maps could sometimes be used to improve habitat modelling.

Only a limited area of the OS MasterMap surrounding Cheshire County was available for analysis, habitat information in adjoining counties, in particular, the uplands in the Pennines, and coastal habitats on the Wirral (just outside Cheshire) were lacking. This affects especially the *Stonechat*, the species with limited suitable habitat, or species with a larger dispersal distance like the *Barn owl*. For other species this is not considered to be a serious problem.

The main shortcoming in the base map is considered to be the lack of information on hedgerows that can contribute very substantially for the ecological network of some species. This was accounted for to some extent, by using in the modelling the maximum home ranges and dispersal ranges of species.

Roadside verges are important connecting habitat that function as corridors at landscape scale. However, habitat quality might often be insufficient (pollution, disturbance) and it bears considerable risks of traffic victims

For some species habitat modelling is done by combining different maps and different habitat types. For example for the *Water vole* or *Banded demoiselle*, specific habitat is selected near water. The quality or degree of naturalness of river banks is very important here, and map information might be insufficient to do a more reliable habitat modelling. In addition, a species like the *Banded demoiselle* is also very dependent on water quality and water flow, for which no information is available.
The same goes for a species like the *Great crested newt*: it is a grassland species but requires also terrestrial habitat (small woodlots, forest edges) and reproduction sites (ponds, marl pits, marshland). Intensity of cultivation is an important factor as well. Here was modelled with the Pond map from the Pond Life project, which is the best information available, other habitat types were not taken into account, since it is hard to quantify relationships.



Picture 7: Pennines, present situation (drawing: R.G.H. Bunce)

Picture 8: Pennines, scenario with increase in lineas features (drawing: R.G.H. Bunce)

5 Conclusion & Recommendations

5.1 Conclusions

The study in Cheshire presents ideas and might form a good basis for further development of the ecological network. The scenario drafted (van Rooij *et al.,* 2003a) which is tested in this study, results in an improvement for all ecosystems. It should be seen as a minimum scenario, which can be realised - there should be aimed for more, the high ambition level!

Through the implementation of the scenario very good opportunities are created, especially for long-range species. After improvement of corridors the situation for species with a short home-range might also improve.

Measures for the meres and mosses and heathland are most difficult to realise, due to a limited potential of the area. The aims in current conservation policies are too low to improve significantly the situation for species with higher demands. For these ecosystems habitat is most limiting, and therefore it is essential that measures are taken to increase habitat and improve connectivity of the landscape for those species.

The spatial analysis with LARCH has yielded useful results. For quantification and calibration of the results, the scenario should still be tested better though.

Species most vulnerable, even after implementation of the scenario, are the less mobile species, such as *Water vole, Common lizard, Green hairstreak* and *Common blue*. Specific de-fragmentation measures are important for those species.

The approach used here, based on an analysis with OS MasterMap, can be applied elsewhere in the UK. In fact, as long as the same maps are used, and the same target species are selected, the same ecoprofiles that were developed in this study can be applied, which will allow for easier and faster analysis results.
In the case that species differ in ecological requirements (species on the border of their distribution area), or in different geographical regions (e.g. Northern Scotland), adjustments of these ecoprofiles might be necessary.

Specific strategic corridors required for woodland, grassland and wetlands networks seem to overlap quite well; this would justify development of multiple use corridors, i.e. of combined habitat types (Van Rooij *et al.,* 2003a).

A selection of 15 species has been analysed. These species are indicator for a larger trait of species. Also for critical species like the reed bunting or the otter, the increase in habitat might result in an important improvement in population viability.

5.2 Recommendations

General recommendations:

- The habitat requirements for most selected species are high. With the realisation of the proposed minimum scenario, almost all of the species will move out of the danger zone. In particular the conditions for wetland/river and woodland species will improve. This shows that with strategic choices in nature restoration and development of the ecological network sustainable populations might be realised.

- Two scenario's were designed, a scenario with a so called 'minimum ambition level', as well as a 'high ambition level'. It is recommended to implement the latter scenario to improve the situation all species.

- The scenario should be implemented as soon as possible. The implementation should go hand in hand with the legislative measures to consolidate and protect the ecological network and integrate the ecological network in the planning framework of Cheshire County Council.

- It is recommended to implement the strategic corridors as planned at present. Priority should be given to the corridor function of the river Dee, the peatland and grassland- and heathland corridors.

- When road works are considered, compensation of all negative impacts of road building and habitat destruction are essential. Motorways and main roads form barriers, especially for barrier-sensitive species like the *Great crested newt, Common lizard* and *Dormouse.* It is recommended to realise those corridors which are most beneficial for the development of the ecological network across the Motorway south of Chester.

5.3 Recommendations regarding specific ecosystems:

Woodland areas are limited in Cheshire. Only species with limited habitat requirements will thrive under present conditions, that is, in the case that they are not sensitive for barriers or if they have a medium or large dispersal range (like the *Nuthatch*). Species that are sensitive to barriers, suffer in this area from severe fragmentation.

The water quality is very important. E.g. intensive-farming practices can be very detrimental. Local 'disasters', with pesticides or herbicides might eliminate a local population, which on its turn might fragment the population that forms a MVP.

Roadside verges are important connecting habitat that function as corridors at landscape scale. However, habitat quality might often be insufficient (pollution, disturbance) and it bears considerable risks of traffic victims

The quantity of grassland is not so much limiting. Management should be directed towards creating optimal conditions for the flora and insect fauna. This will benefit much of the bird populations studied in this analysis. One of the measures, might be improvement of extensive agricultural management. Extensive grazing of wet open areas around marshlands could restore favourable conditions for species like the *Water vole,* and preserve grassland habitat.

Smaller marshland bird species with less habitat requirements benefit already from the designed scenario. The increase with 1200 ha and, additionally, improved river banks, is an improvement for these species.
For some critical species like the reed bunting or the otter, the quality of reedland is also of importance, and larger, old reedland areas are required. Management should be aimed at increasing reedland and improving the quality of the vegetation.

Connectivity of wetland habitat for *Banded demoiselle* seems to be sufficient after realisation of the scenario: not many local populations are isolated and not included in a larger population network. However, this depends much on the presence of natural vegetation along the river, as well as stream velocity.

An integral approach (i.e. focusing on an entire river basin or sub-basin will yield most results for a species like the *Water vole*

5.4 Recommendations for further research

Data on the distribution of target species and to monitor population and distribution trends should be collected, to be able to adjust regional environmental policies and launch further conservation plans.

Landscape ecological data is required for assessing more accurately landscape ecological relationships. This data includes dispersal ranges, home ranges, and specific information on habitat and habitat use by species. Further research undertaken in this field by, for example, universities should be stimulated.

Further study is required on the *Water vole*. The ecological parameters found in the literature or from fieldwork show a large variation and a (landscape) ecological study would for sure benefit spatial modelling of this species, and in the long term protection and conservation of the species.

Picture 9: view over part of Delamere forest

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Picture 10: Four-spotted chaser (Foto: T. van der Sluis)

Picture 11: ancient woodland with Bluebelle

Appendix 1 Ecological profiles available for analysis with LARCH

Dispersal capacity Area requirement	0-3 km	3-7 km	7-15 km	15-35 km	> 35 km
0.5 ha	Brown argus Alcon blue Purple hairstreak Green hairstreak Silver-studded blue Ringlet Idas blue Cranberry blue False heath fritillary				
50 ha	Wall brown Ilex hairstreak Grayling Tree grayling White admiral Silver-spotted skipper Cranberry fritillary Sand lizard	Brown squirrel * Root vole * Water vole	Nuthatch Sedge warbler	Woodlark Whitethroat Black-tailed godwit	
300 ha	Adder Niobe fritillary Dark green fritillary	Map butterfly *	Bluethroat Yellowhammer Redstart Marsh tit Great spotted woodpecker Lesser spotted woodpecker Savi's warbler Skylark	Common buzzard Common bullfinch Great reed warbler European nightjar Roedeer * Redshank Fox * Golden oriole Eurasian curlew Turtle dove	Marsh harrier Little grebe Wood warbler Eurasian woodcock Northern shoveler Common teal
750 ha			Middle spotted woodpecker Stonechat	Comma Green woodpecker Large tortoiseshell Bittern Mourning cloak	Bearded tit Garganey Black woodpecker
3,000 ha				Pine marten Badger * Tawny pipit Northern goshawk Northern raven Northern wheatear Western honey buzzard	Hen harrier Hobby Red deer Common quail * Wild boar
20,000 ha				Black grouse	Wryneck Otter

* NB: habitat description lacking

Selection partly based on Pouwels *et al.,* (2002b), selected and translated by Theo Van der Sluis.