Ecological Network Analysis for Umbria (Italy)

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RERU, Rete ecologica della Regione Umbria

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ABSTRACT

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This report gives the result of an analysis of the ecological network, designed for Regione Umbria. Indicator species relevant for conservation were selected. The model LARCH was used to assess whether these ecosystems still function as an ecological network. An ecological network was designed, on the basis of the analysis results.
Through the implementation of the ecological network good opportunities are created, especially for long-range species. Analysis results were however mostly indicative for forest ecosystems; other relevant ecosystem like (alpine) grasslands or steppe, or aquatic ecosystems should be studied in more detail with relevant species.
The approach used here, based on the Geobotanical map, can be applied elsewhere in Italy.

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

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Preface

The set-up of the landscape-ecological part of the RERU-project (Ecological Network for the Umbria Region) follows the outline, as given in the project plan and in the inception report of November 2003, which was discussed with the project responsible.

Alterra contributes to this project by an analysis of the landscape and its potential for wildlife (*task 15, Sceriario RERU* in the project plan), and, based on this, by a design for an ecological network to improve crucial connections for specified species and ecosystems (*task 16, design of actual RERU* in the project plan).

In this document we present the results of this landscape analysis and network design. We have modelled on the basis of parameters we have in our database, which were adjusted for this study. All parameters were sent to the Scientific Committee for prior approval – we subsequently received green light of the project responsible to proceed.

The Scientific Committee of the RERU project consists of:

- Prof. B. Ragni (fauna)
- Prof. E. Orsomando (vegetation)
- Prof. B. Romano (land use planning)
- Dott. G. Pungetti (coordination)
- Dr. B. Pedroli (landscape ecology)

We would like to thank the Scientific Committee, which has greatly helped to finish this study. Special thanks go to Project Leader Dott. Segatori of the Regione Umbria in Perugia, who was the direct contact person at the Regione. He was crucial in solving communication problems and was always focused on good results. Also the initiative and mediation of Gloria Pungetti, without whom this project would never have been started, is gratefully acknowledged. She was very helpful in editing the Italian summary of this report.

Finally we thank our ALTERRA colleague Harold Kuipers, who assisted in the modelling, and Rogier Klaver, who did in the framework of his MSc. studies a valuable reconnaissance study on the large carnivores of Umbria.

Riassunto (Italian summary)

Il progetto RERU e un programma della Regione dell'Umbria finalizzato ad arrivare a una rete ecologica più efficace e sostenibile per le specie target di vari tipi di ecosistema.

Alterra contribuisce al progetto con un'analisi del paseaggio e la sua capacità potenziale per sostenire una fauna naturale (*capitolo 15, Sceriario RERU* della specificazione metodologica), e, basato su questo, con un disegno di una rete ecologica per migliorare le connessioni fondamentali per le specie target scelte degli ecosistemi tipo (*capitolo 16, desegno della RERU attuale*). Il lavoro del gruppo ecologia del paesaggio per la RERU segue il piano del progetto come accordato dal responsabile del Progetto RERU.

In questa relazione finale si presentano i risultati dell'analisi del paesaggio e del disegno della rete eologica. Il modello LARCH usato per l'analisi é basato sui parametri disponibili da Alterra, adattati per Umbria secondo ladisponibilità di dati specifici. Questi parametri, da presentarsi al Comitato Scientifico del progetto per approvazione, sono invece continuati conl'analisi e il disegno della rete.

Le questioni da risolvere sono:
come dovrebbe essere disegnata una rete ecologica ottimale per le Regione dell'Umbria?
la situazione attuale, presenta delle limitazioni per le specie target?
gli habitat sono troppo sparsi o frammentati, e se questo éil caso, dove mancano le connessioni o *stepping stones* ?

La rete ecologica attuale è stata analizzata per determinare se gli habitat (o loro frammenti) sone abbastanza grandi per la persistenza delle specie. Questo éstato fatto con un'analisi delle esegenze delle specie target selezionate e la connettività del paesaggio col modello LARCH.
I tipi di habitat analizzati sono boschi, prati umidi, praterie. Le specie target selezionate comprendono qualche specie di mammiferi con home-range intermedio, e qualche specie d'ucelli. LARCH-SCAN éstato usato per determinare dove si trovano i corridoi funzionali. La carta geobotanica, preparata dal Professore E. Orsomando nel progetto RERU, éstata usata come punto di partenza per l'analisi LARCH.

Questa relazione presenta i risultati di questa analisi spaziale, e raccommandazioni basate su questi risultati. Per dettagli della metodologia usata ed una descrizione più dettagliata dei risultati si referisce all' allegato in Appendice (Ecological Network Analysis for Umbria).

Una tabella con le specie rilevanti per la Regione Umbria é stata presentata per essere analizzata col modello LARCH. Il Commitato Scientifico ha portato modificazioni alla tabella (Tabella 1). Nella tabella é indicata. (la posizione delle specie relative

L'habitat delle specie è stato valutato a livello di popolazione, a livello di rete ecologica, ed in termini della connettività del paesaggio.
A livello delle popolazioni si é analizzato se le popolazioni locale si possono svilluppare, cioé se dentro la *home range* di una specie l'habitat disponibile sia sufficiente o no per una popolazione locale, chiave o sostenibile (più grande della MVP, popolazione minimale persistente, vede App. par. 2.2).
A livello di rete ecologica si e analizzato se la metapopolazione é sostenibile a lungo.
Finalmente, la coesione spaziale permette un impressione della connettività del paesaggio per le specie.
Nei paragrafi seguenti i risultati aggregati sone dati per le specie scelte degli ecosistemi tipo presi in considerazione (vedi App. per una descrizione).

Basato sull'analisi della connettività e sull'analisi della persistenza delle popolazioni, si è stato effettuato un disegno per la rete ecologica dell'Umbria. Il disegno si focalizza sugli ecosistemi tipo come indicati nella Tabella 1.

Sulla carta della coesione spaziale nell'Umbria del Culbianco (fig.14) sono indicati glihabitat maggiori in rosso. A base di queste concentrazioni, i corridoi possono essere disegnati per l'ecosistema tipo **praterie**. Per questa specie l'analisi spaziale non ha un'esigenza particolare per i corridoi. Infatti, tutti glihabitat sono ben connessi (vede App. par 3.2.1).
Invece, se riguardiamo specie più esigenti, come per esempio il Ramarro, o specie di praterie come *Riccio*, *Tritone cristato meridionale, Rospo commune* o *Licena delle paludi* è molto probabile che il territorio sia (molto) frammentato! Una analisi più profonda é indispensabile pre arrivare a risultati più indicativi per la connettività delle praterie nell'Umbria.

Per l'ecosistema tipo **boschi** abbiamo evidenza più ampia, indicata dalle aree forestate. A base di questa carta è possibile desegnare una carta con l'indicazione di dove si trovano i posti più adatti per corridoi, date le migliori connessioni tra le aree centrali (Le aree verde scuro presentano popolazioni persistenti, la base della rete ecologica. Quelli sono conessi con areeche hanno charatteristiche migliori per la connettività (grigio). Anche qui vale che specie più piccole potrebbero essere più indicative pre frammentazioni. Le specie selezionate per il modello sono meno esigenti in questo senso, e hanno delle home range molto più larghe.
Generalmente la quantità dell'habitat disponbile è probabilmente grande. Per questa ragione un'analisi più detagliata potrebbe essere adeguata per analizzare gli effetti delle strade maggiori su popolazion di qualche specie di bosco.

Per gli ecosistemi umidi non era selezionata una specie che poteva essere presa come modello. Per questo il disegno della rete è molto preliminare, basato su interpretazione della rete dei fiumi, fossi e acque stagnanti (fig. 16). Specie per il modello sarebbono *Rospo commune*, *Tritone crestato meridionale*, *Damigella*, *Lontra*, eccetera. La carta finale della rete proposta è presenta nella .fig. 17.

La rete ecologica esistente nella Regione Umbria, vista come la configurazione degli habitat per varie specie target appare presentare grandi possibilità per le popolazioni sostenibili, specialmente per le specie di *home range* intermedia. Dopo ammiglioramento dei corridoi, come proposto in questa relazione, la situazione per le specie di home range limitate, potrebbe anche essere migliore.

E' stata analizzata una selezione diotto specie. Quelle specie sono indicatrici per un gran numero di altre specie. L'analisi spaziale con LARCH ha mostrato risultati molto adeguati. Però, per poter meglio quantificare e calibrare queste indicazioni, il disegno dovrebbe essere esaminato meglio con altre specie più adatte all'oggetto dell'analisi.

La rete ecologica disegnata dovrebbe essere attuata il più presto possibile. Questo si dovrebbe accompagnare a misure legislative per consolidare e proteggere la rete ecologica ed integrare la rete nella pianificazione territoriale della Regione.

Si raccomanda di svilluppare con cura i corridoi strategici indicati sulla carta della rete, per la quale occorre tempo.

La considerazione di modello di specie più suscettibili potrebbe ancora ammigliorare il disegno della rete.

In caso di costruzione stradale é essenziale un compenso di tutti gli effetti negativi sugli habitat. Autostrade e strade principale presentano barriere, specialmente per specie suscettibile per barriere come *Tritone crestato meridionale*, *Ramarro* e *Moscardino*.

Il disegno di una rete per specie particolari come fatto per esempio per il Piano di Navelli in Abruzzo (Van der Grift & Van der Sluis 2003), potrebbe stimolare la discussione e aumentare il supporto all'implementazione di corridoi ecologici.

I boschi sono abbondanti nella Regione Umbria. Specie con esigenze habitat intermedie o grandi possono prosperare sotto la condizione attuale. la frammentazione può presentarsi soltanto in caso di specie molto sensitive per barriere, o con una home range molto limitata (come il *Moschardino*).

La cura delle **praterie** nelle area centrali e corridoi dovrebbe concentrarsi su condizioni migliori per la flora a la fauna degli insetti perché da molto beneficio agli ucelli. Alcune misure possono essere un tipo di agricoltura meno intensivo o biologico.

A parte della conettività degli ambienti **umidi**, la qualità delle **acque** é molto importante. Pesticidi e fertilizzanti possono essere detrimentali per molte specie già in quantità molto bassi. Questo può affliggere popolazioni locali, e di consequenza

frammentare la popolazione che forma una MVP (popolazione minimale persistente).
Specie di ucelli di ambienti umidi meno esigenti beneficeranno già immediatemente della rete disegnata con un aumento di habitat. Per qualche specie più esigente come *Migliarino di palude, Damigella* e *lontra*, la qualità delle vegetazione a Phragmites é molto importante, e sono richieste.aree più larghe.
Un approccio integrale (per esempio concentrandosi su un bacino fluviale intero) può dare risultati positivi per specie esigenti come il *Arvicola d'acqua*.

Come indicato, la selezione delle specie target per un'analisi di rete ecoogica é un momento rilevante. A parte le specie importanti dal punto di vista della conservazione, devono essere studiate anche specie con home range più limitato e preferenza stretta per vari ecosistemi. tipo. Nel presente esersizio mancano ancora specie adatte per esempio particolarmente a praterie, ecosistemi di montagna e ambienti umidi/fiumi. In questo modo la rete ecologica potrebbe ancora ammigliorarsi.

The Altiplano Grande, example of Alpine grasslands at an altitude of 2000 meters (Picture by B. Pedroli)

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 Regione Umbria. Regione Umbria, the 'green heart' of Italy, lies in the center of the county.
It is a county of contrasting landscapes - wooded river valleys, rugged mountainous area and pastures - which in turn support a variety of wildlife habitats, some of which are of international importance.

The aim of the analysis is (1) to identify the functional ecological network at present for different ecosystems and wildlife populations and (2) to design an ecological network to improve the situation for the selected species and ecosystems. This is done through an assessment of the habitat requirements of species (selected by the Scientific Committee) and the connectivity of the landscape with LARCH. The species selected are in particular indicative for woodlands, and to a very limited extend wetlands and rivers and grasslands.
The selected species include some medium-range species, e.g. mammals, which are to some extent vulnerable for fragmentation. In addition, some bird species are included in the analysis.

The study in Umbria might form a good basis for further development of the ecological network. The ecological network drafted results in an improvement for all ecosystems. It is recommended to implement the ecological network as soon as possible.
Through the implementation good opportunities are created, especially for medium-range species. After improvement of corridors the situation for species with a short home-range might also improve.

Species most vulnerable, even after implementation of the ecological network, are the less mobile species, like small mammals, reptiles, amphibians, butterflies etc. 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.

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 (Van der Sluis *et al.* 2001a; 2003; Van der Grift & Van der Sluis 2003).

1.2 Study area: Regione Umbria

The surface area of Umbria is 8 456 sq.km (2.8% of Italy). The population counts some 831 000 inhabitants (1.2%), with a population density of 98 inhab./sq.km. The climate in Umbria is continental with very hot summers and quite cold winters. But in the western part of region the climate is milder.
The territory of Umbria is very favourable thanks to vast plain areas, plenty of water, rich vegetation, so it was inhabited since the Neolithic ages. The people were Etruscans, followed by Umbrians and Romans, which founded the first cities (Perugia, Orvieto, Spoleto, Todi, and Assisi), introduced the new agricultural practices and built the roads.

The landscape of Umbria consists mostly of mountains and hills, with an altitude between 40 m in the south and Mt. Vettore, 2478 m, situated in the East. The rivers crossing the territory of the region are: Tiber, Nera, and Velino. To the east of Terni is located an amazing water-fall "cascata delle Marmore". Here is also the greatest lake of Apennines - Trasimeno (128 sq.km.) but only 6m deep. Some 30 % of the territory is hilly, 70 % is considered mountainous.

Agriculture in Umbria is quite modest from the productive point of view; the main reason is the excessive division of the property, the absence of big companies with the modern means of cultivation and technics. The principal crops are: corn, vegetables, sugar beet, tabacco, olive and grape. Also the breeding of pigs and production of wood is of some economical significance. The mountain forests of Spoleto, Norcia, Cascia are famous for the growing there black truffle.

The areas were visited by ALTERRA in March-April 2003 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 Regione Umbria be designed?
- Is the present situation limiting for species?
- Are present habitats too far apart, or are they fragmented and if that is the case, where are linkages or stepping stones required?

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.

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, and grasslands. The situation is assessed for a number of relevant species for woodlands. The selected species include some medium-range mammals species, most of which are 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, by the Scientific Committee. The results are presented in Chapter 3, this is followed by discussion, recommendations and conclusions in Chapter 4. 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 persistence 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
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

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 1). 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 1: 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 persistent 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 Brown bear). 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 persistence of metapopulations in a fragmented environment.

LARCH provides information on the metapopulation structure and population persistence 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.

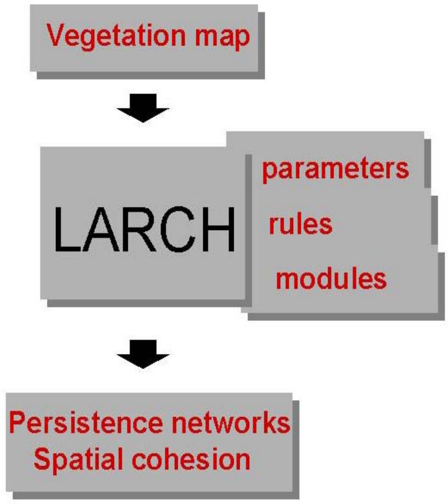


Figure 1: set-up of model LARCH

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.,* 2002, 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, 2003a, 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 persistent population. If that is the case, the network population is persistent 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, Van der Sluis *et al.* 2003). 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 persistence of the network population and spatial cohesion (fig. 2).

Habitat modelling
The Carta Geobotanica (fig. 2a – in example the map of Abruzzo) 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, 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 persistent population. A population is only large enough to cope with normal fluctuations in the population (see Box 1) 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).

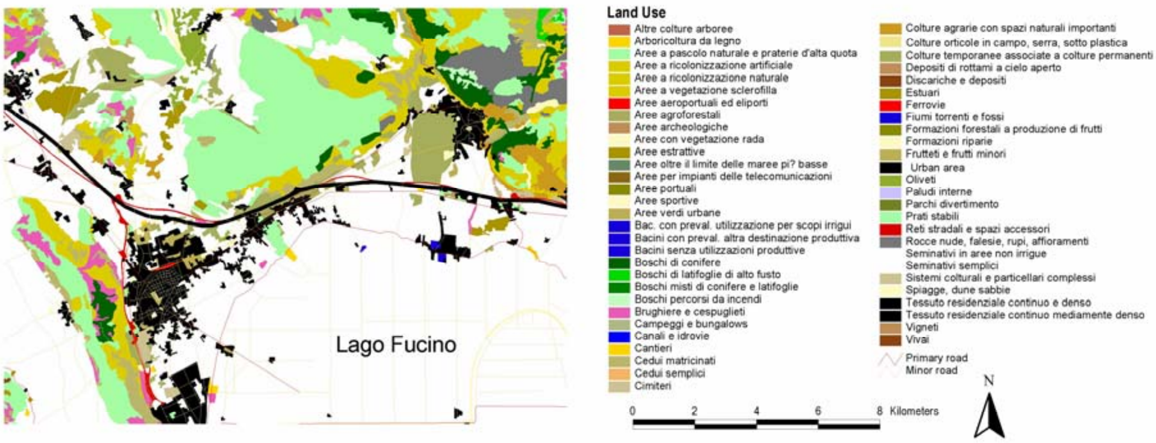


fig. 2A: Input for LARCH *is Land Use map (in this example from Abruzzo)*

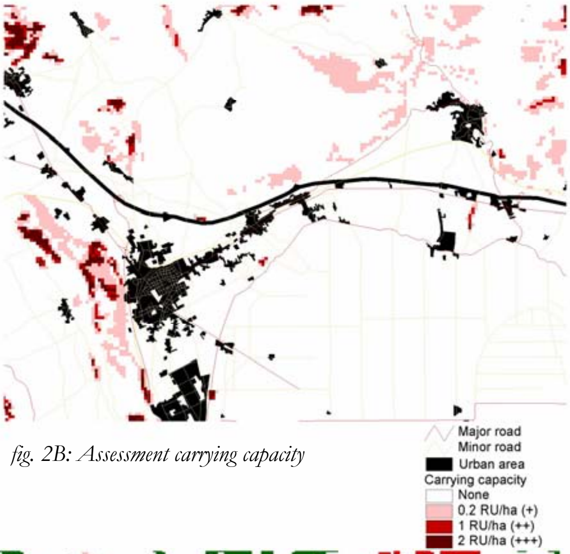


fig. 2B: Assessment carrying capacity

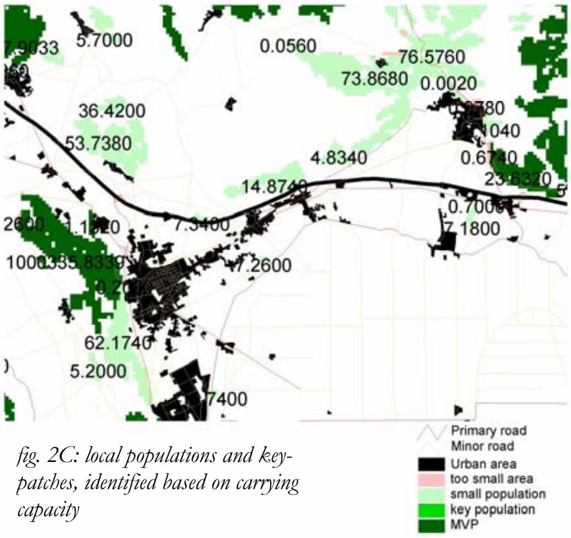


fig. 2C: local populations and key-patches, identified based on carrying capacity

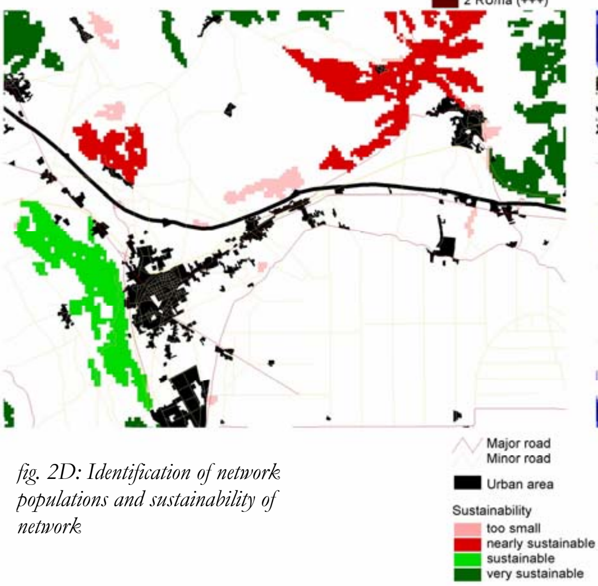


fig. 2D: Identification of network populations and sustainability of network

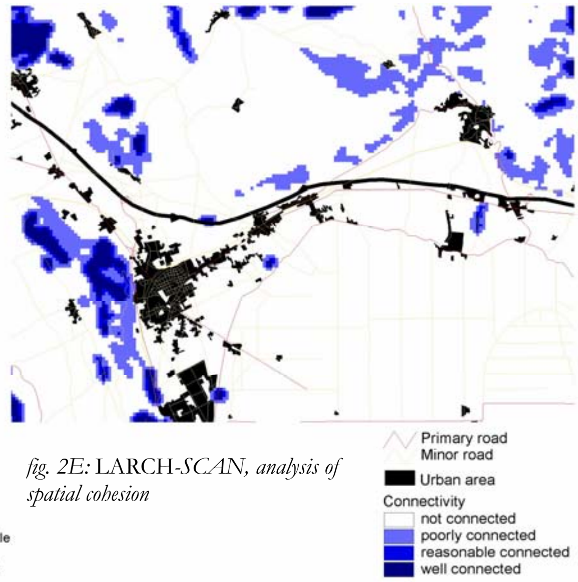


fig. 2E: LARCH-*SCAN, analysis of spatial cohesion*

Figure 2: LARCH analysis procedure: fig. 2A to 2D indicate the steps taken in LARCH to come to a persistence 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 persistent 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 persistence of the network
In the final step the persistence of the network is determined: the persistence (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 persistence 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 1), 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

The geobotanical map, prepared by Orsomando in the framework of the RERU project, was used as a basis for the LARCH analysis. The map was based on the earlier version from 1998 (Orsomando *et al.*), and updated based on aerial photo interpretation, field work and map analysis.
The distribution of land use types is presented in Table 1.

The area was briefly checked during a three-day field visit in Regione Umbria in April 2004.

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

Habitat (map)	Habitat (english)	Area (ha)	%
Boschi e pinete di sclerofille sempreverdi mediterranee	evergreen Pine forest	38965	4.6
Boschi di caducifoglie planiziali, collinari e submontane	Broadleaved for. of plain, hills, and submontane	278760	33.0
Boschi di caducifoglie montane	Broadleaved montane forest	14144	1.7
Boschi e boscaglie di caducifoglie ripariali	Riparian forest	6563	0.8
Brughiere planiziali e basso-collinari	Shrubland of plains and lower hills	26	0.0
Arbusteti collinari e montani	Shrubland of hills and mountains	4226	0.5
Siepi	Hedges	2330	0.3
Praterie primarie	Secondary grassland	828	0.1
Praterie secondarie submediterranee, collinari, montane	Secondary mediterranean grassland	73042	8.6
Popolamenti idrofitici	Aquatic groups	16100	1.9
Popolamenti terofitici, praterie umide e torbose e elofitica	Annual vegetation, wet and peaty grassland, aquatic	1512	0.2
Aggruppamenti casmofitici	Vegetation of rocky surfaces	1585	0.2
Rimboschimenti	Reforestation	11402	1.3
Seminativi semplici e incolti	Sowed fields	278649	32.9
Seminativi arborati	Tree plantations	23370	2.8
Oliveti	Oliveyard	38286	4.5
Vigneti	Vineyard	10432	1.2
Frutteti	Orchard	243	0.0
Pioppeti	Poplar plantation	242	0.0
Aree urbanizzate	Urban area	42835	5.1
Aree con vegetazione scarsa o nulla	Vegetation rare or absent	1728	0.2
Zone obliterate	Disturbed zones	646	0.1
Sum Area		**845913**	

2.4 Spatial profiles

A table was prepared with relevant species for Regione Umbria, to be analysed with LARCH. The Scientific Committee adopted this table with some amendments (Table 2).

The species selected differ in their habitat requirements and dispersal range. Some species have a very limited range, of some five kilometres, whereas some large mammals might have a range of 50 km or more. Similarly for habitat requirements for a key population: *Reed warbler* will persist with a small area, of a few hectares, whereas a *Wolf* requires extended areas for foraging. In Table 3 the position of the species is indicated.

Table 2: Species selection and ecosystems

Nome italiano	***English name***	***Scientific name***	boschi	praterie /rocce	umidi
Culbianco	Northern wheatear	Oenanthe oenanthe		X	
Picchio muratore	Nuthatch	Sitta europaea	X		
Tasso	Badger	Meles meles	X		
Lupo	Wolf	Canis lupus	X	X	
Lepre bruna	Hare	Lepus europaeus			
Istrice	Porcupine	Hystrix cristata	X		
Gatto selvatico europeo	Wild cat	Felis silvestris	X		
Capriolo	Roe deer	Capreolus capreolus	X		
Cannareccione	Great reed warbler	Acrocephalus Arundinaceus			X

Data on distribution of wildlife species was used to improve the modelling results, in particular the Atlante dei mammiferi dell' Umbria (Ragni 2002) for the selected mammal species.

Table 3: Dispersal distance and habitat requirements for Species profiles, and attribution to ecosystems: ***Woodland, Rivers & Streams, Grassland & steppe***

Ka \ Nd	<1	1-3	3-7	7-15	15-35	>35
0-0.1						
0.1-1			**Reed warbler**	**Nuthatch**	**Northern wheatear**	
1-5						
5-10					**European hare**	
10-50			**Porcupine**		**Roe deer**	
50-150					**Badger**	
150-1000						**Wild cat**
> 1000						**Wolf**

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

Castellucio, at 1452 m one of the highest permanent villages in Italy (B. Pedroli)

3 Results spatial analysis

3.1 Introduction

Chapter 3 presents the general results of the analysis. 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, for definitions of terms 1.4). 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.

Per species two maps are presented. The first map, left, shows the populations.
It classifies areas in:
- home-ranges too small
- small populations
- key populations
- Minimum Viable Populations (MVPs).

The right map shows the persistence of these networks, i.e. the populations that possibly exchange and form together a metapopulation. For these networks is indicated whether they are too small, nearly sustainable, sustainable and very sustainable.

With LARCH-SCAN the spatial cohesion was defined for the landscape (see par. on methods). This was done for those species for which it was relevant. Species which have a range of 20 km. or more are not indicative anymore. First of all, because habitat present always will be connected, provided that it is distributed across the area. Second, because all habitat outside the region analysed is not taken into account, so this makes results in that case meaningless.

For this study it meant that for five species the spatial cohesion was analysed:
- Nuthatch
- Northern Wheatear
- Hare
- Porcupine
- Wild cat

Two points should be kept in mind, when interpreting the LARCH 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 species results are organised per main ecosystem. As can be noted, not for all ecosystems indicators were selected. This will have implications for the general applicability of model results.
The figures with results of the LARCH analysis are included at the end of Chapter 3.

3.2 Predicted situation in wildlife populations

3.2.1 Grassland & Steppe

3.2.1.1 Northern wheatear, Culbianco

Populations
The territories in the east of the Region and North of Perugia are large, extended and we find mainly Minimal Viable Populations (MVPs) here (Figure 3). In the west, some larger key-populations are found, whereas otherwise small and fragmented habitat is present.

Networks
The ecological network population for this species is persistent; due to its larger distribution range local populations form together a network. In the central agricultural zone only fragmented suitable habitat is present, as a result of more intensive land use.

Connectivity
For the Northern Wheatear core areas are in the Apennines, the area of Piano Grande and the area near Gubbio (Figure 11).
At this scale, for this mobile species which is not vulnerable for traffic, the landscape is well connected.

Discussion
We find that for the Northern wheatear potential habitat is situated in the eastern and more elevated part of Umbria. This is related to its dependence on open grassland, which is more found in the mountainous regions.
No species distribution maps were available to improve modelling results.

Table 4: Results LARCH analysis Northern wheatear: + = reasonable, ++ = good, +++ = very good

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

3.2.2 Woodland

3.2.2.1 Nuthatch, Picchio muratore

Populations
Except for the agricultural areas, all over Umbria persistent populations may be present (Table 4). This is due to the presence of forested areas, and the home range of the species (800 m) which results in a (potential) large number of territories

Networks
Since local populations are already of the size of MVPs, the networks are very persistent.

Connectivity
For the Nuthatch sufficient habitat is available, with core areas in the Appenines, in particular between Norcia and Ternia (Figure 11). Other core areas are west of Marsciano and in the North of Umbria. These are rather well connected for this species, which is not vulnerable for roads or other barriers.

Discussion
The nuthatch requires specifically old forests. To improve modelling results, the habitat selection should be refined, and it should be indicated which of the present vegetation types is indeed old, suitable forest.

Table 5: Results LARCH analysis Nuthatch: + = reasonable, ++ = good, +++ = very good

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

3.2.2.2 Badger, Tasso

Populations
The territories in Umbria are large, extended and we find mainly Minimal Viable Populations (MVPs) here (Figure 5). In the west, small and fragmented habitat is present. Due to its homerange of 2 km also smaller, forested areas may be inhabitated by local populations.

Networks
The situation for this species is persistent, due to its larger distribution range local populations form together networks.
Fragmentation does occur; some smaller areas enclosed by roads (in the most urbanised regions) have no persistent networks. This is due to the vulnerability of the species to traffic.

Discussion
Not all of the area is suitable for the burrows of badgers. The modelling of badgers usually requires a map, defining the burrows present, or at least the areas suitable for burrows. With such a map modelling can be improved.

Table 6: Results LARCH analysis Badger: + = reasonable, ++ = good, +++ = very good

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

3.2.2.3 Wolf, Lupo

Populations
In the habitat selection procedure the very small areas (less than 100 ha) are excluded, because larger extended forests are required. Since the wolf requires large territories, only smaller, local populations are possible (Figure 6).

Networks
The species is not really vulnerable to traffic, so all populations together may form a network. The Umbrian population of wolf is nearly sustainable. However, as long as a good connectivity is guaranteed with surrounding regions, the situation is probably very persistent.

Discussion
Altitude may be of importance for occurrence of the species, but this hasn't been used in present modelling. Wolf is not only indicator species for forests, but also for grasslands and steppe.

Table 7: Results LARCH analysis Wolf: + = reasonable, ++ = good, +++ = very good

	Present
Population assessment	+
Network assessment	+
Connectivity	+++

3.2.2.4 Hare, lepre bruno

Populations
The hare is vulnerable traffic. Mainly the provincial roads will have impact. As a result, some fragmented areas may only support small populations (Figure 7). Some areas on the border of Umbria show this as well, they seem isolated, which may not be true if we take habitat in surrounding regions into account.

Networks
At network level only the Autostrada form barriers. However, the habitat requirements for this species is rather general and the species is rather common, so it results in a very persistent situation.

Connectivity
The Hare is a species which is very well distributed all over the territory, the habitat selection is wide (many types of habitat, both forested and grasslands, are chosen), and is widely available. Based on this, all of the habitat area is well connected for the hare (Figure 12).

Table 8: Results LARCH analysis Hare: + = reasonable, ++ = good, +++ = very good

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

3.2.2.5 Porcupine, Istrice

Populations
The porcupine is vulnerable for barriers. Mainly the provincial roads and Autostrada will have an impact. As a result, some fragmented areas may only have small populations (Figure 8). This occurs in areas on the border of Umbria, which may not be correct if we take surrounding habitat into account.
Some smaller areas surrounded by roads, e.g. around Lago di Trasimeno may also be suitable for small local populations only.

Networks
At network level only the Autostrada is a barrier. However, there is sufficient habitat for this species available and the species is rather common, so it results in a very persistent situation.

Connectivity
The porcupine is even more common than the other species like the hare, although the range of the species is less. Almost all of the territory is well connected, except for some of the larger valleys in the center of Umbria (Figure 12).

Discussion
Possibly also altitude may affect distribution; for that reason the results for the higher parts of the Appenines may be incorrect. It is assumed that water (rivers) do not form a barrier for the Porcupine.

Table 9: Results LARCH analysis Porcupine: + = reasonable, ++ = good, +++ = very good

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

3.2.2.6 Wild cat, Gatto silvatico

Populations
The Wild cat is vulnerable for fragmentation. Mainly the provincial roads and Autostrada will have impact on local populations.
The Wild cat lives in low densities. As a result, many fragmented areas harbor in potential only small populations (Figure 9).

Networks
At network level only the Autostrada forms a barrier, they may cross provincial roads.
There is sufficient habitat for this species available, so in potential there is a persistent network.

Connectivity
The Wild cat is well connected in all aspects (Figure 13), due to the larger dispersal range, and relatively small habitat requirements (territories). This does not mean however that there are no fragmentation effects for this species.

Discussion
If the field observations done in the RERU project are made available, and a better evaluation of habitat and density parameters is done by the species expert, it is possible to improve the modelling results.

Table 10: Results LARCH analysis Wild cat: + = reasonable, ++ = good, +++ = very good

	Present
Population assessment	+
Network assessment	++
Connectivity	++

3.2.2.7 Roe deer, Capriolo

Populations
The Roe deer is not so vulnerable for fragmentation, only the Autostrada forms a barrier. The Roe deer has a wide habitat selection, and due to the presence of forested areas it could live in most of the territory of Umbria (Figure 10).

Networks
There is sufficient habitat for this species, so in potential the territory is large enough for a persistent network.

Discussion
Habitat selection may be improved, to improve model results.

Table 11: Results LARCH analysis Roe deer: + = reasonable, ++ = good, +++ = very good

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

3.2.3 Wetlands / rivers

3.2.3.1 Reed warbler, Cannareccione

As was indicated in the parameters for this species, information is required on the presence of reeds (Phragmites australis). Since this data is lacking in the geobotanical map, no indication can be given on the suitability of aquatic habitat. No spatial analysis could be done, for that reason.

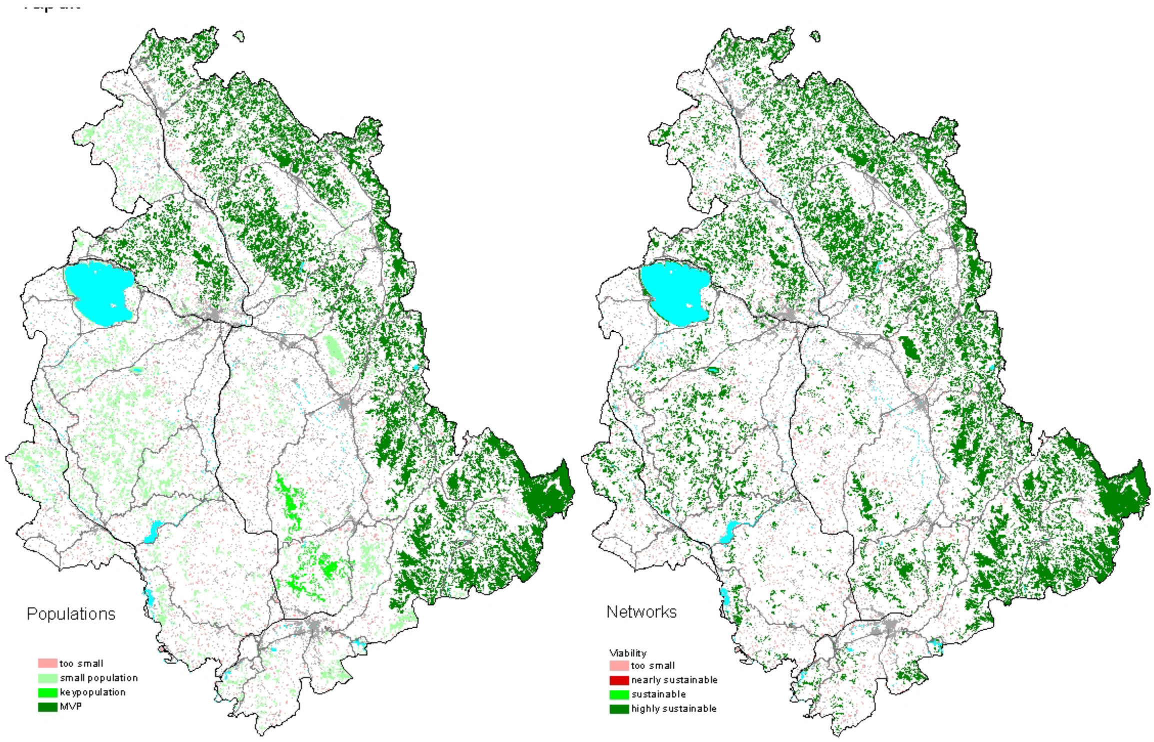


Figure 3: LARCH analysis results for the Northern wheatear (see text for discussion)

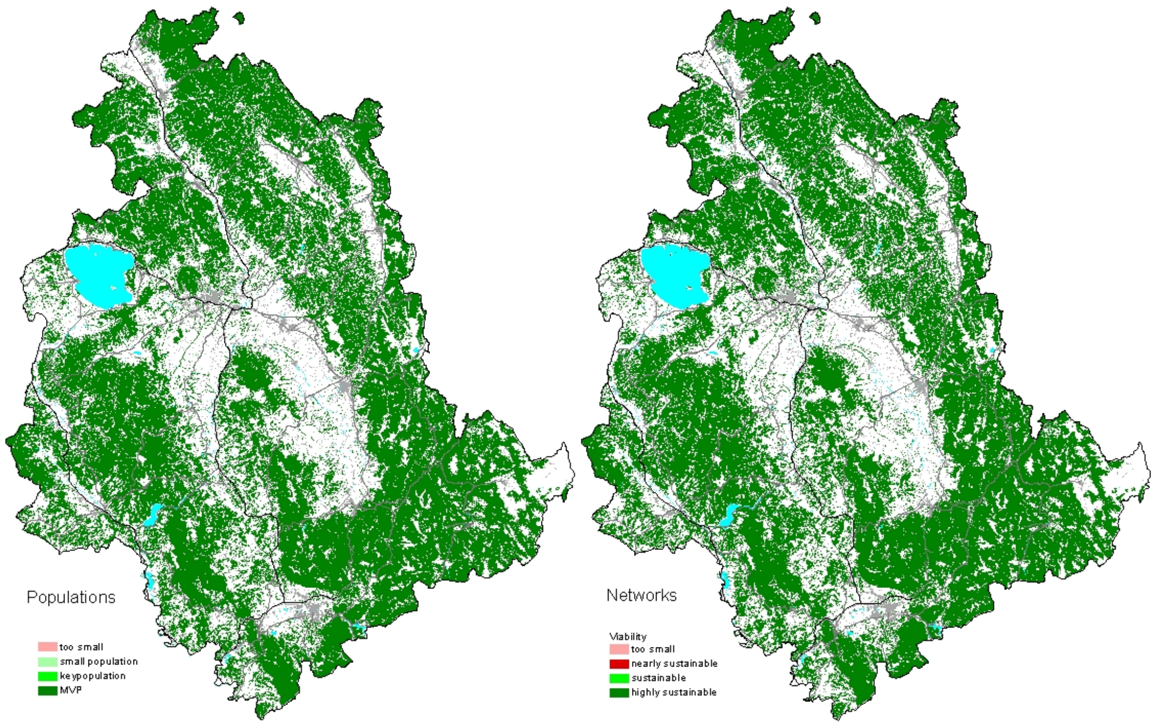


Figure 4: LARCH analysis results for the Nuthatch (see text for discussion)

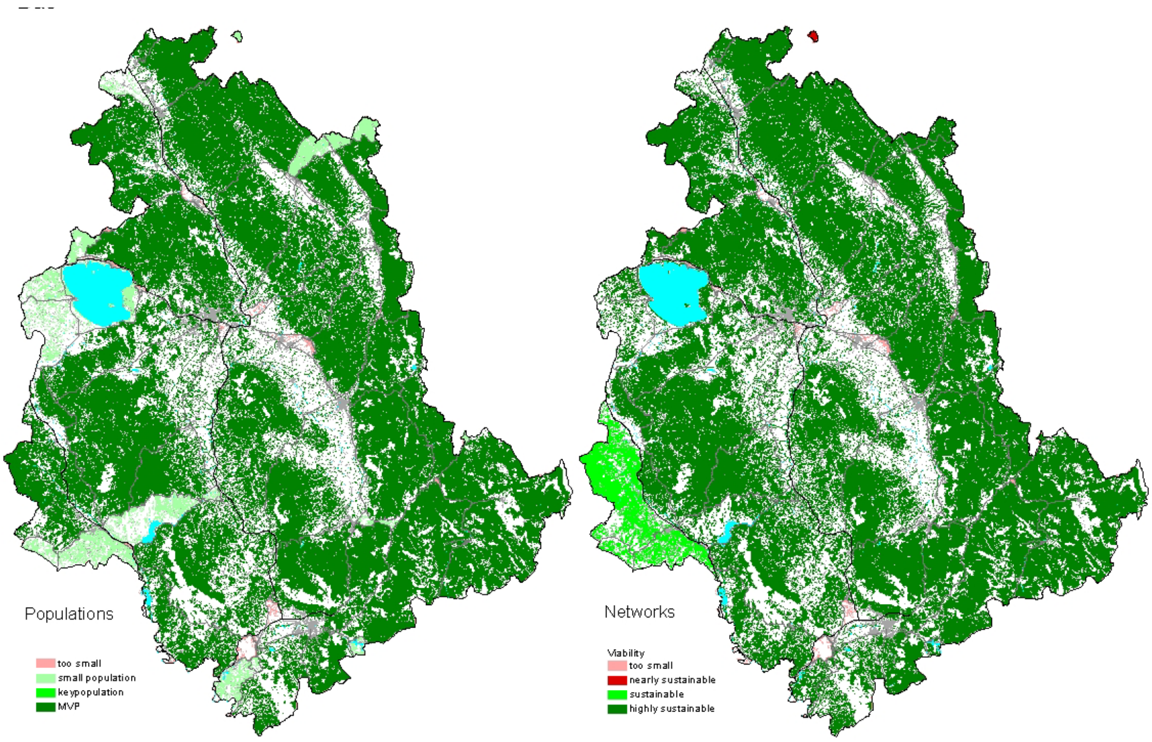


Figure 5: LARCH analysis results for the Badger (see text for discussion)

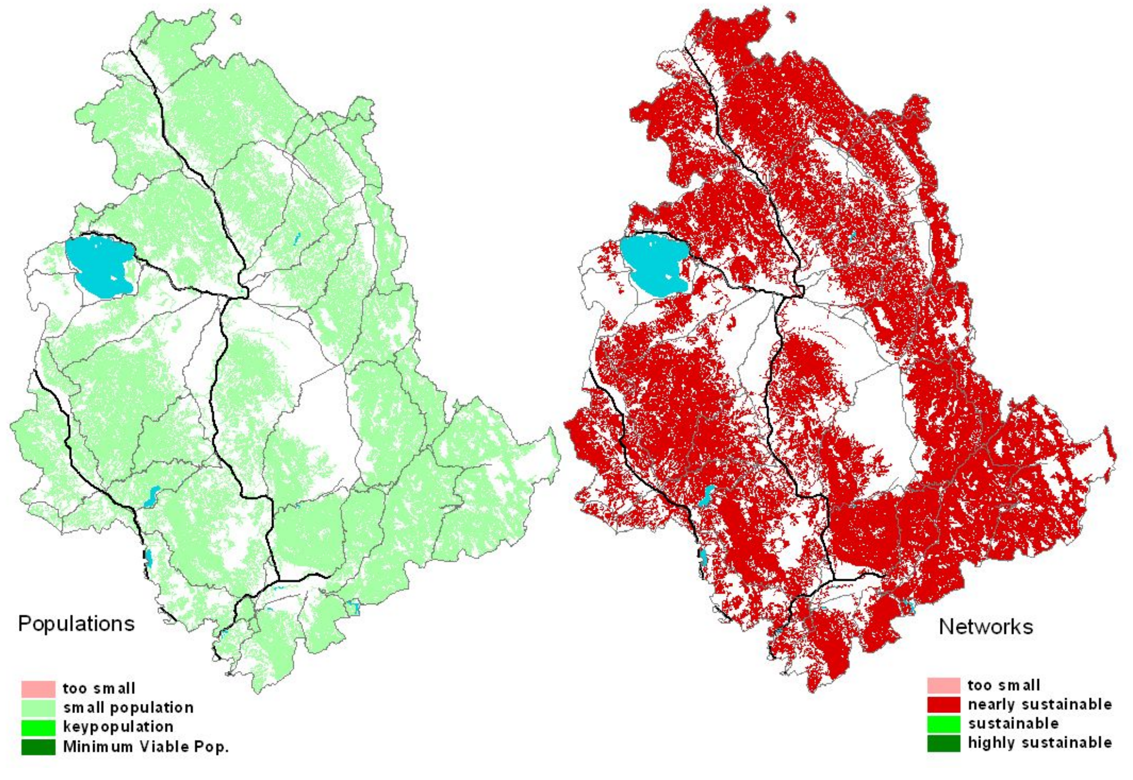


Figure 6: LARCH analysis results for the Wolf (see text for discussion)

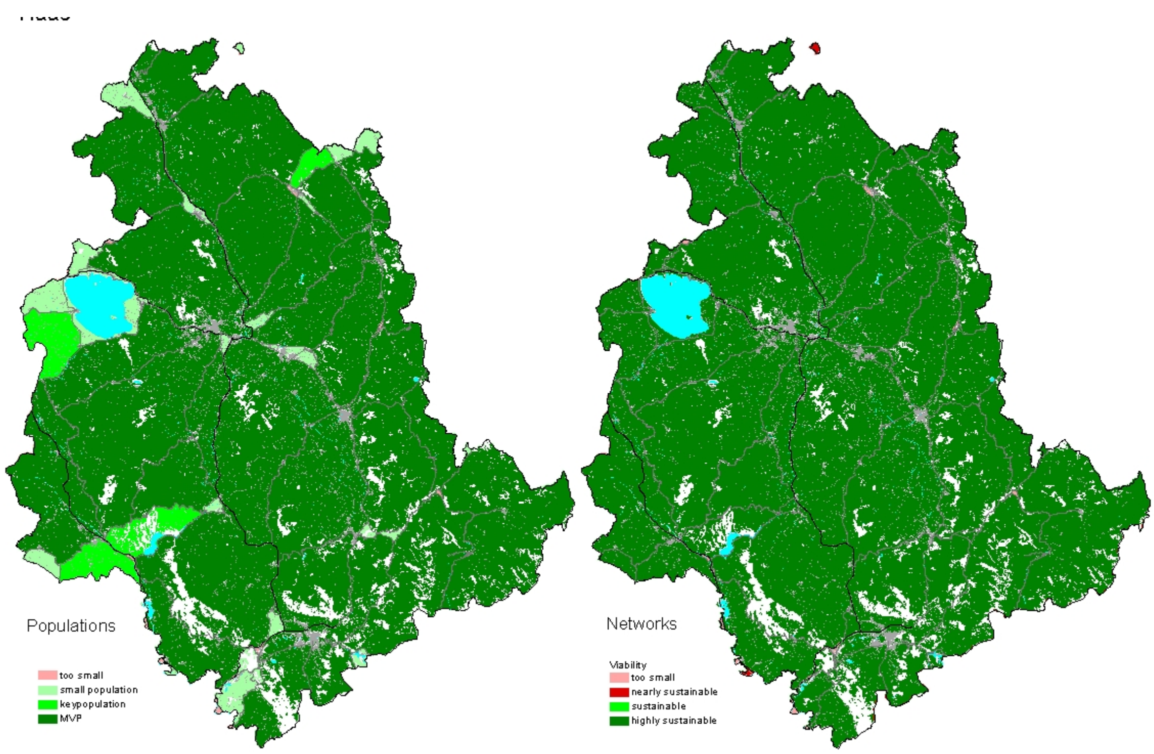


Figure 7: LARCH analysis results for the Hare (see text for discussion)

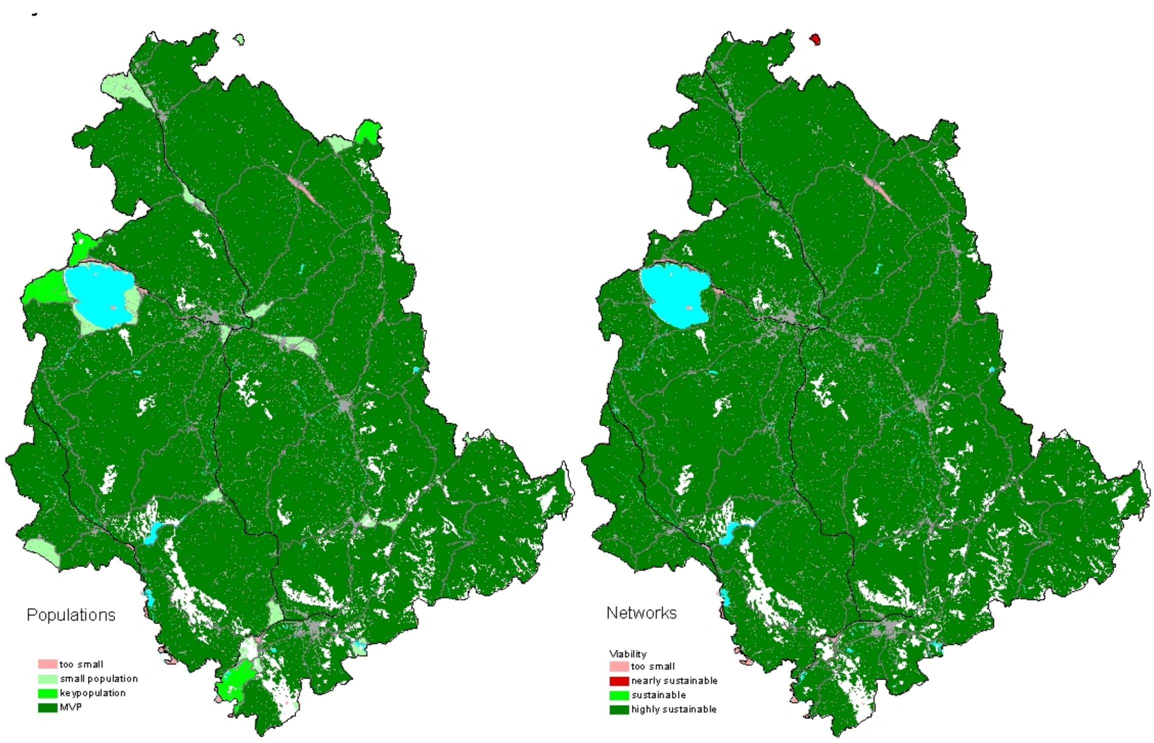


Figure 8: LARCH analysis results for the Porcupine (see text for discussion)

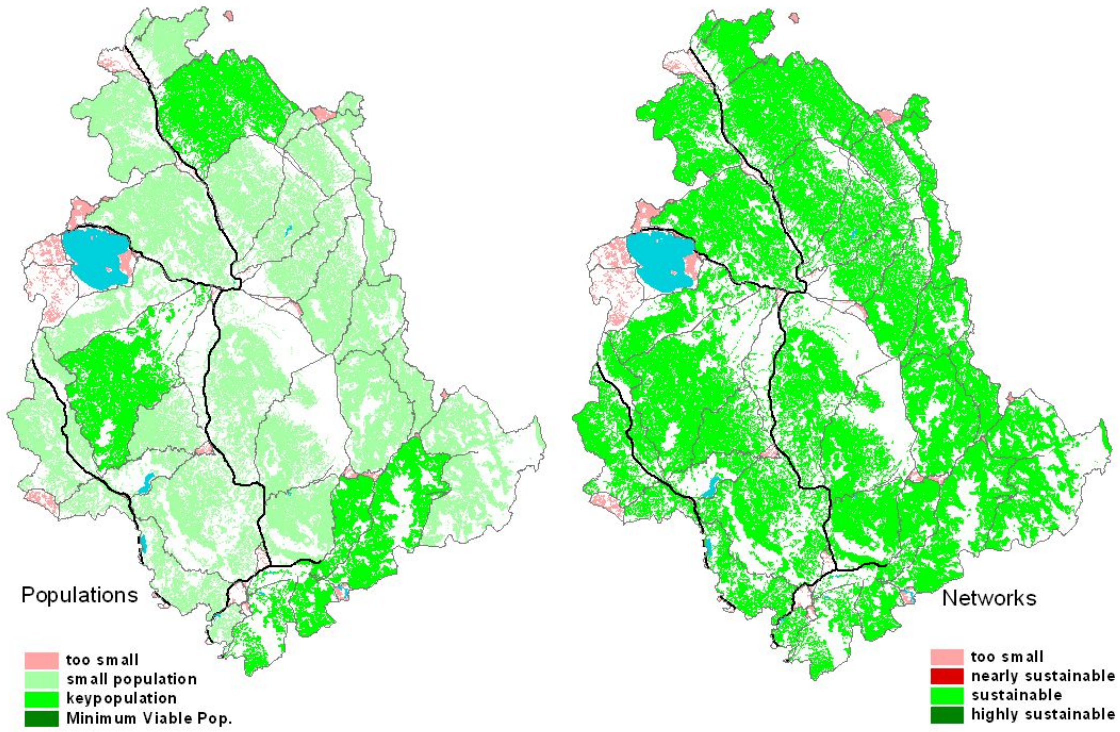


Figure 9: LARCH analysis results for the Wild cat (see text for discussion)

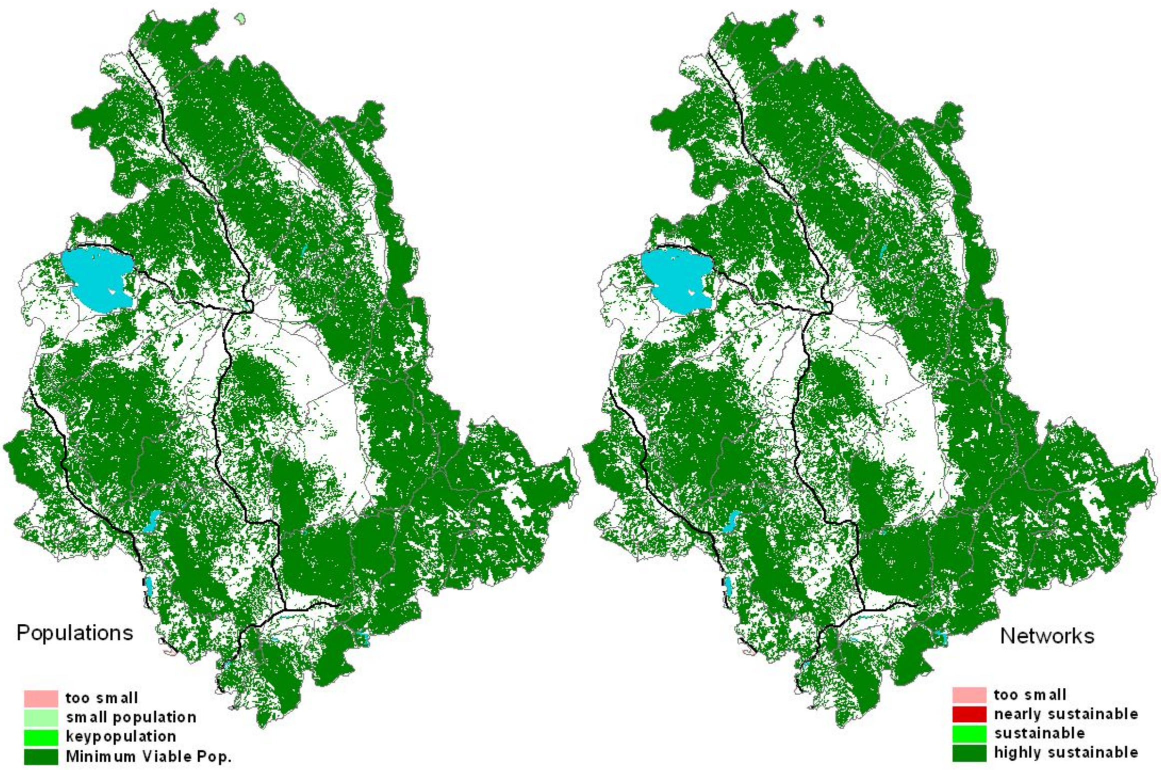


Figure 10: LARCH analysis results for the Roe deer (see text for discussion)

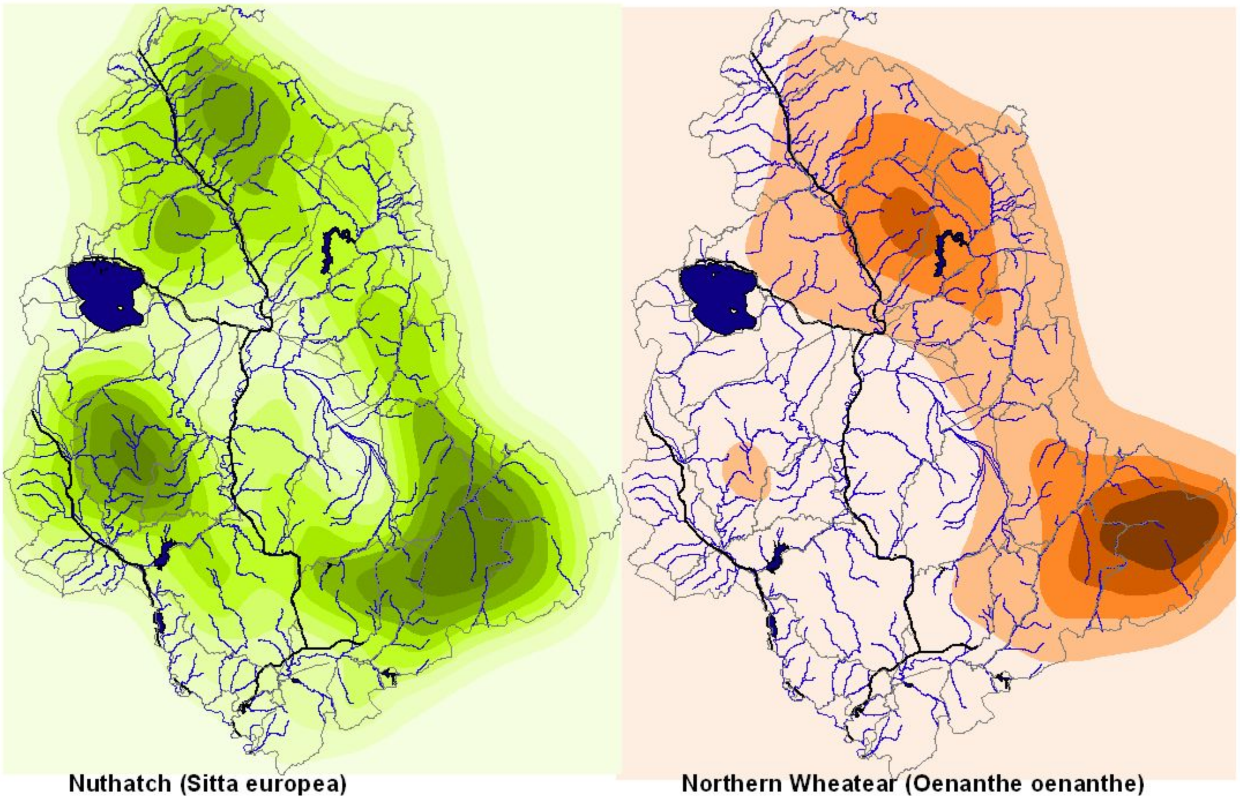


Figure 11: Spatial Cohesion as assessed with LARCH-SCAN, for Nuthatch and Northern Wheatear

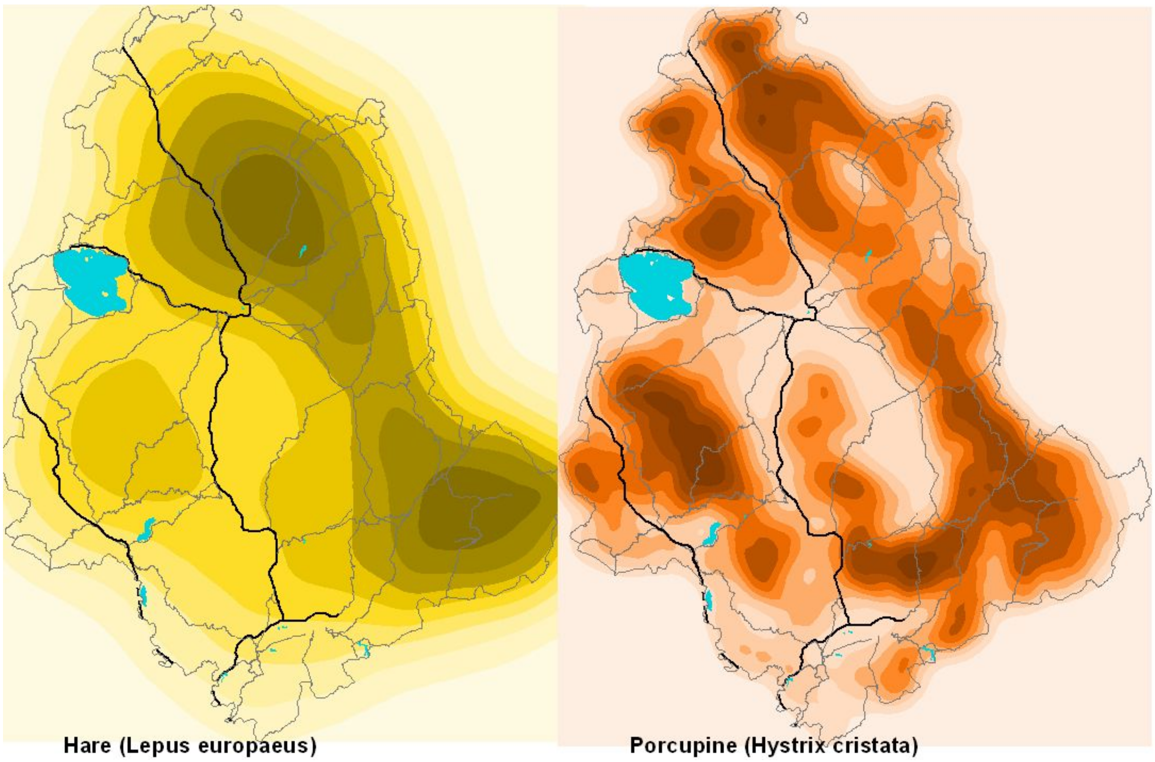


Figure 12: Spatial cohesion as assessed with LARCH-SCAN, for Hare and Porcupine

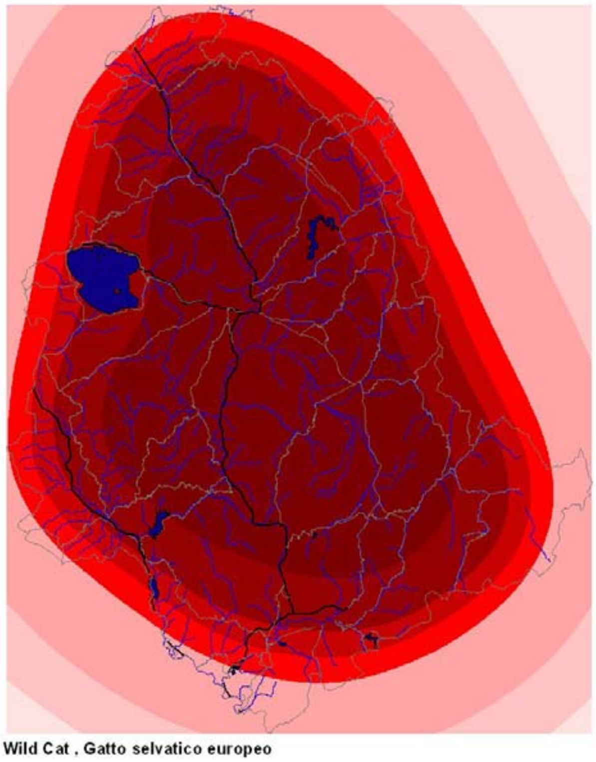


Figure 13: Spatial cohesion as assessed with LARCH-SCAN, for the Wild cat

High mountain zone and forests of the Appenines (picture: Theo van der Sluis)

4 Ecological Network design

Based on the connectivity analysis, as well as the population persistence analysis, a proposal has been prepared for the ecological network of Umbria.

The design of the ecological network should be based on the most important ecosystems; the priority ecosystems for Umbria are indicated in Table 2

Below is the map (Figure 14) of the spatial cohesion of Umbria with major habitat for the Northern Wheatear. Based on these concentrations the corridors can be drafted for **grassland / steppe ecosystems**.
If we base ourselves on the spatial analysis of this species, there is no particular requirement for corridors. All habitats are in fact well connected (par 3.2.1.1).
However, if we would look at more demanding species, like e.g. the *Green lizard,* (Ramarro), or grassland species like *Hedgehog* (Riccio), *Italian crested newt* (Tritone cristato meridionale) or *Common toad* (Rospo commune) it is most probable that the territory would be (very) fragmented!
Further analysis would be required to come to a better assessment for some of these species.

For **forest ecosystems** we have several analyses, which indicate where the main forest areas are. On the basis of these analyses it is possible to draft a map with the most suitable locations for corridors, on the locations where connections between core areas are best (Figure 15). The darker green areas are persistent populations, which form the basis for the ecological network. These are connected via areas that have best connectivity properties (grey colour, below).
Also here counts that some smaller forest species, like mice, might be much more indicative for fragmentation. The selected species for modelling are in that respect less demanding, and have a much wider range.
In general the quantity of available habitats is probably large, so further analyses would be useful in particular to assess the fragmentation effects of major roads on some wildlife populations. For the persistence of populations it probably would not have much effect.

For the **aquatic ecosystems** none of the species modelled is very suitable. The network design is therefore only indicative, and based on main rivers and wetlands (Figure 16).
Species that might be analysed are again *Common toad* (Rospo commune) *Italian crested new*t (Tritone crestato meridionale), *Banded demoiselle* (Damigella), *Otter* (Lontra) etc.

All ecological networks integrated are presented finally in Figure 17.

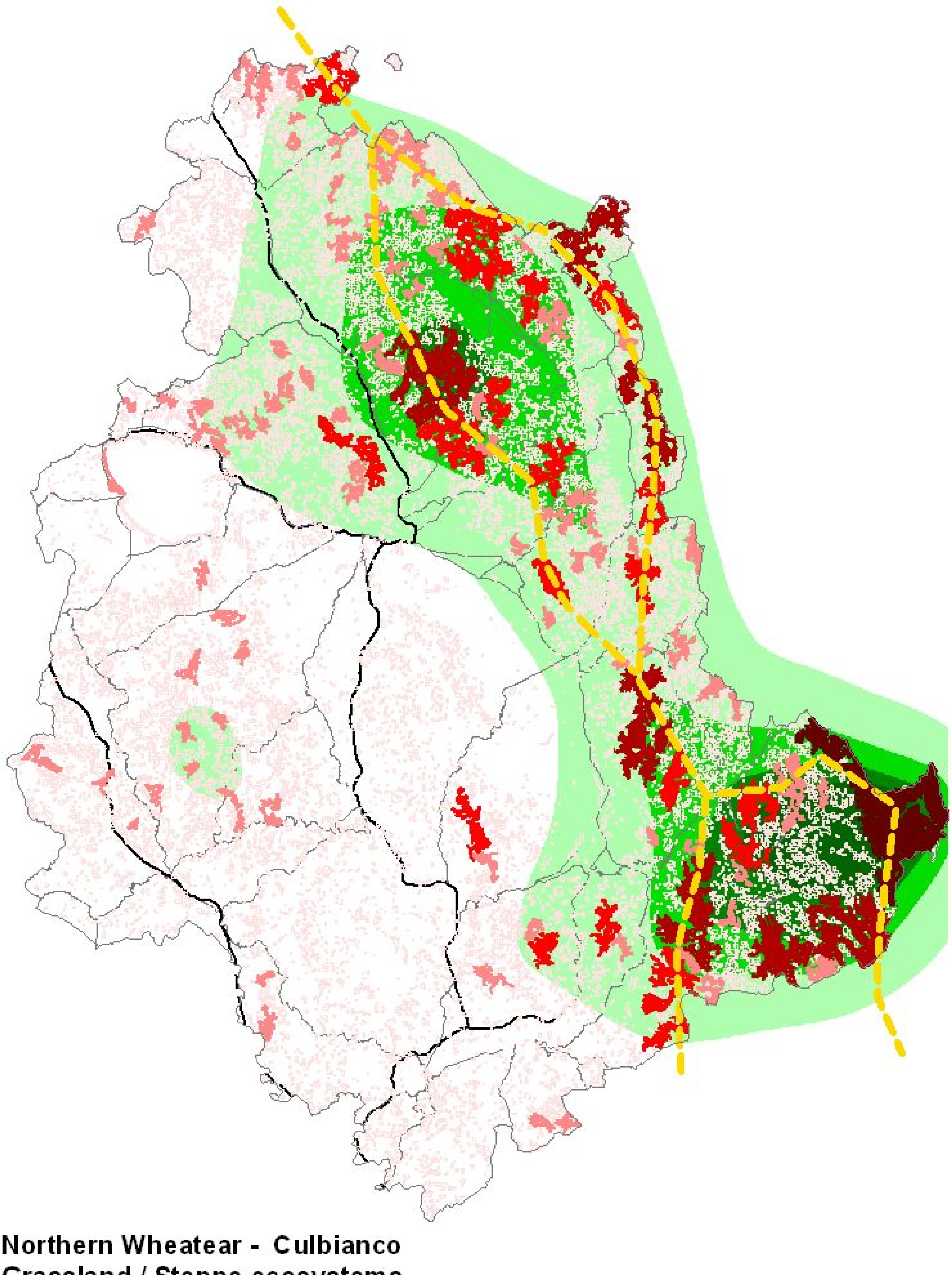
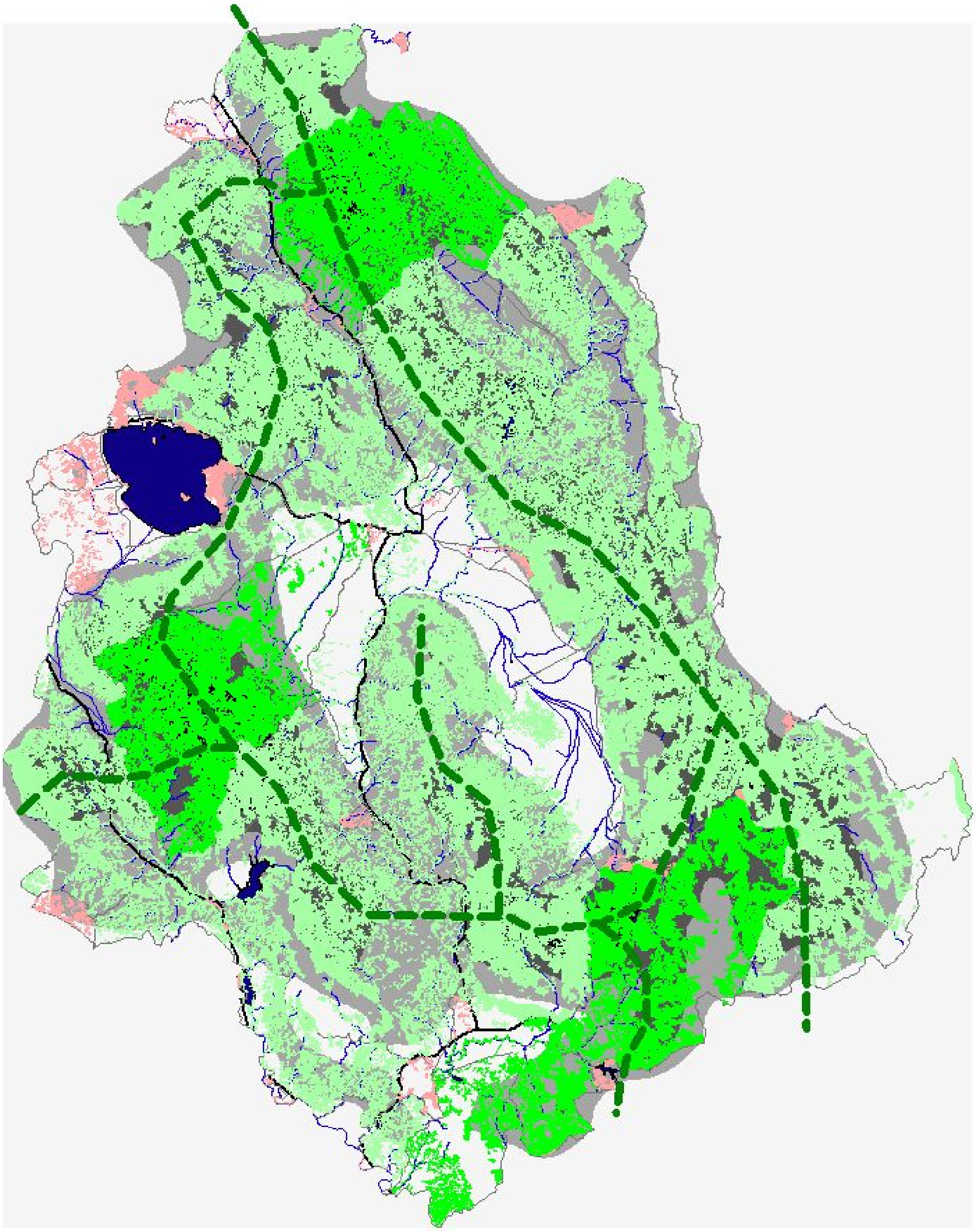


Figure 14: designed ecological network for Grassland/steppe ecosystems, based on LARCH analysis



Wild cat & Porcupine
Forest ecosystems

Figure 15: designed ecological network for Woodland ecosystems, based on LARCH analysis

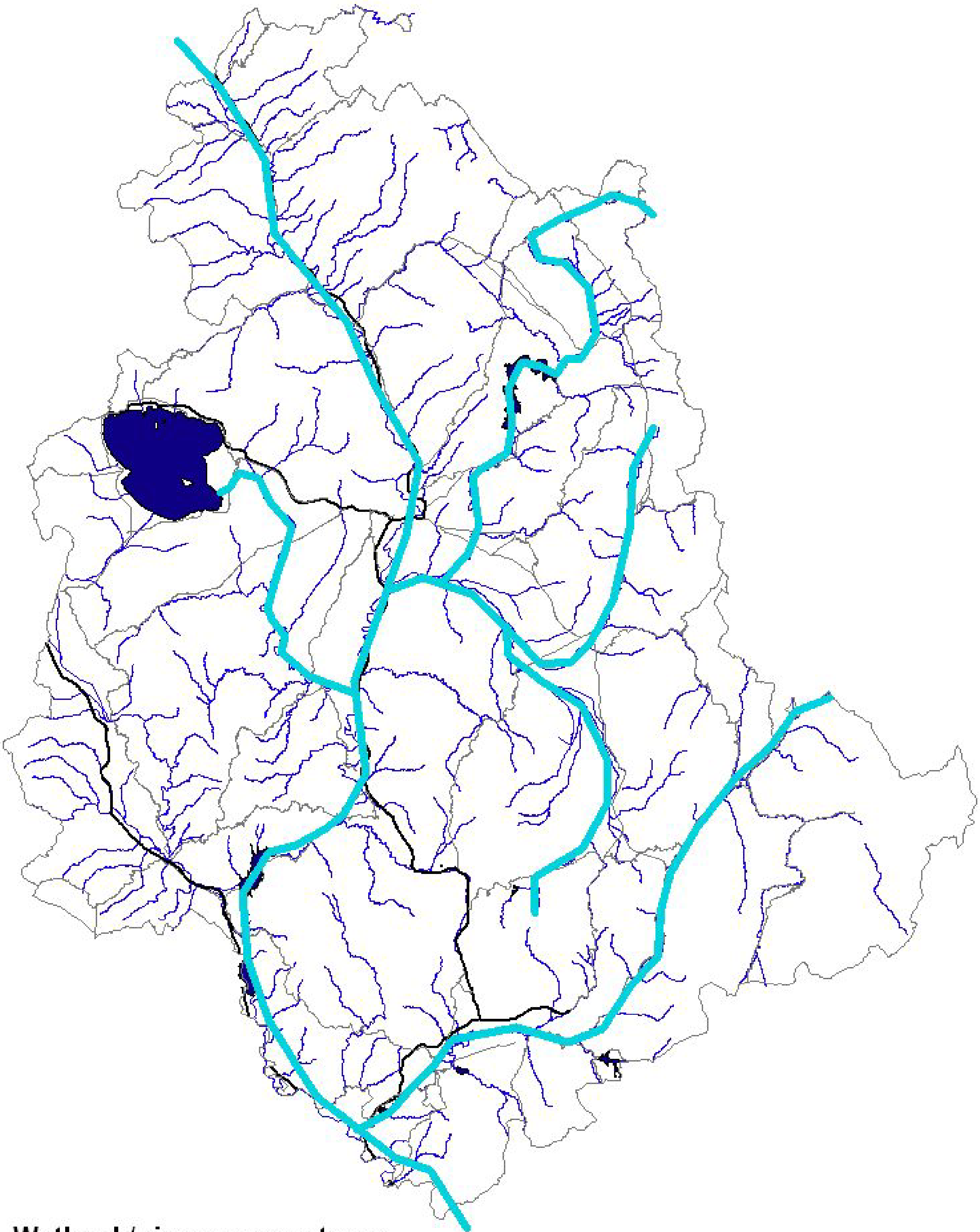


Figure 16: designed ecological network for Rivers/wetland ecosystems, based on LARCH analysis

Figure 17: Designed ecological network for Regione Umbria, for the three selected ecosystems

Wolves in winter (Picture by P. Kaczensky)

5 Conclusion and recommendations

The existing ecological network in Umbria, understood as the configuration and pattern of habitats of various indicator species, appears to offer very good opportunities, especially for medium-range species. After improvement of corridors the situation for species with a short home-range might also improve.

A selection of 8 species has been analysed. These species are indicator for a larger trait of 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.

If corridors required for woodland, grassland and wetlands networks do overlap, development of multiple use corridors, i.e. of combined habitat types, would be better and may be easier to realise, at lower costs (Van Rooij *et al.,* 2003a, 2003b).

Since no species were analysed which have only a short dispersal range, and are vulnerable for barriers, it would improve the work much if further analyses were done on such a group of species.

5.1 Recommendations

General recommendations:

- The designed ecological network 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 Regione Umbria.

- Modelling of more vulnerable species would improve the design of the ecological network

- 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 *Italian crested newt, Green lizard* and *Dormouse*.

- Species specific design, as was done for e.g. Piano di Navelli in Abruzzo (Van der Grift & Van der Sluis 2003) could stimulate discussion and increase support for implementation of ecological corridors. Also funding could be secured through more practical design guidelines.

5.2 Recommendations regarding specific ecosystems:

Woodland areas are abundant in Regione Umbria. Species with medium or even large habitat requirements will thrive under present conditions. In the case that species are sensitive for barriers or if they have a short dispersal range (like the *Dormouse*) fragmentation may occur.

The management of **grassland** should be directed towards creating better conditions for the flora and insect fauna. This will benefit much of the bird populations. One of the measures might be extensive agricultural management, environmental farming in combination with agro-tourism.

Marshland bird species with less habitat requirements benefit probably from the current network. An increase of habitat and, additionally, improved river banks, may benefit populations of large marshland birds like the *Bittern*.
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. The water quality is very important for the *Otter* or *Kingfisher*. 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.
An integral approach (i.e. focusing on an entire river basin or sub-basin) will yield most results for a vulnerable species like the *Water vole*.

5.3 Recommendations for further research

Data on the distribution of target species should be collected and distribution trends should be monitored, 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.

As indicated in par. 2.4 the species selection is very relevant for conservation. However, for assessment of fragmentation, species with smaller home ranges should be analysed. In particular for grasslands, mountain ecosystems and wetlands/rivers suitable indicator species are lacking.
Based on such an analysis the network design could be further refined.

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